Environment and Natural Resources Trust Fund

Research Addendum for Peer Review

Project Manager Name: Lee E. Frelich

Project Manager Email address: freli001@umn.edu

Project Title: Climate change and resilience in boreal forests

Project number: 135-F1+2+5

The research addendum should provide concise but also comprehensive information so that peer reviewers have the appropriate level of information to provide helpful comments. Each project should include the following information:

1. **Abstract** - Summarize the research and its essential qualities including a clear statement on the purpose of the research.

Forests of the Border Lakes Ecological Subsection of northeastern Minnesota are at the southern margin of the boreal forest, and although they cover a small portion of the state, they contain many boreal species that constitute a significant proportion of the state's biodiversity. The boreal tree species—currently the foundation of the ecosystem—are likely to decline with continued warming of the climate, and be replaced by temperate species. Therefore, the main purposes of the research are to: (1) assess the status of temperate tree species in the southern margin of the boreal forest (e.g. sugar maple, red maple, American basswood, northern red oak, bur oak, white pine, yellow birch), whether these species are currently expanding in response to warming that has already occurred, and whether sufficient seed sources are present to allow them to expand and fill the niche currently occupied by boreal species; (2) examine the distribution and potential expansion of invasive plant species (e.g. buckthorn, Canada thistle, garlic mustard) that may expand and compete with native species in a rapidly changing environment; and (3) examine the potential for cold temperature refuges on the landscape to continue to harbor boreal species in a future warmer climate. Extensive field surveys along transects that cross the landscape will be conducted to collect information for (1) and (2) above, and 100 hobos will be placed on the landscape to measure temperature variation (e.g. compare bogs with uplands and south slopes with north slopes) on an hourly basis for two years (for (3) above). This information will be used to prepare adaptation and management options for commercial and Boundary Waters Canoe Area Wilderness forests. Finally, via presentations and workshops, we will inform forest managers regarding future scenarios for forest health and resilience, and options for adaptation to climate change. The audience will include wilderness users and managers of the Boundary Waters Canoe Areas Wilderness, and managers of commercial forests, such as staff of the Superior National Forest, Minnesota DNR, County and Tribal forestry divisions.

2. **Background** - Provide the basic information and other relevant work that are the context for this research.

Northern Minnesota has already experienced a relatively large magnitude of climatic warming, and is projected to experience a larger magnitude of future warming than the global average; it is typical for mid-continental regions to experience larger changes in climate than the rest of the world (Frelich and Reich 2009, note that references cited are given below under description of Project Manager Frelich). Because the forests of the Border Lakes Subsection are at the southernmost extent of the boreal forest biome, where they are juxtaposed with the northernmost extent of the temperate forest biome, they are more susceptible to change than other forests in the interior of a biome. Thus, the forests in the Border Lakes Ecological Subsection study area are both more susceptible to changing climate, and are likely to experience a large magnitude of climate change (Frelich and Reich 2010). Projected climates by the middle of the 21st Century are not expected to support boreal forest (Galatowitsch et al 2009).

The existing boreal forests support a large number of boreal plant and animal species that could be lost to Minnesota if the forests disappear; in essence Minnesota could go from a three biome state (grassland, temperate forest and boreal forest) to a two biome state (grassland and temperate forest) if a warmer climate will no longer support the boreal forest (Frelich and Reich 2010). Such a scenario would lead to large changes for users of the Boundary Waters Canoe Area Wilderness and would be economically important for the tourism and timber industries. Therefore, we need a better understanding of potential responses to a warming climate.

The boreal forests of the Border Lakes Ecological Subsection are dominated by jack pine, black spruce, balsam fir, white spruce, white cedar, aspen and paper birch, with some red and white pine. Temperate tree species which reach their northern range limit in or near the study area include sugar maple, red maple, red oak, American basswood, yellow birch and bur oak (Frelich and Reich 2009). Currently there are some small outposts of these temperate species within the southern part of the boreal forest, but we know little about their frequency or potential to spread to fill the niche vacated by the retreating boreal forest in a warmer climate. A common phenomenon in ecological systems, is for invasive plant species to expand rapidly when a system is undergoing some type of disturbance or transition. A number of invasive species could compete with native temperate species at the time of transition from boreal to temperate forest; however, we have little systematic information about their distribution and potential to spread in the remote forests of the Boundary Waters Canoe Area Wilderness and surrounding commercial forests (Frelich and Reich 2009).

3. **Hypothesis** - State the premise or propositions set forth to explain and achieve the described outcome of the research.

The overarching hypothesis is that a relatively large magnitude of change is expected during climate warming at the boreal-temperate forest interface in the Border Lakes of northern Minnesota.

Subhypotheses are: (1) that native temperate and exotic plant species will both advance at the expense of boreal species, and (2) that local cold temperature refuges may exist that could allow boreal species to persist after temperate species occupy most of the landscape.

Three main questions that will be answered are:

1. Are sufficient seed source populations already present for temperate species such as red maple, sugar maple, American basswood, bur oak, yellow birch and white pine to potentially fill in the niche vacated by boreal tree species, and are those temperate species populations already expanding?
2. Will invasive plant species (e.g. buckthorn, Canada thistle) be able to jump in and take advantage of the warming climate and changing forest situation, possibly spreading faster than native species?
3. Will boreal species like black spruce, balsam fir and jack pine be able to persist under a future warmer climate in areas with locally cooler climates (thermal refuges) such as bogs and north-facing hillsides?

4. Methodology - Describe the methodology to be employed to carry out the proposed research. Including descriptions of the sample design(s), if applicable.

The landscape will be systematically surveyed by placing transects in numerous locations (Rich et al 2007) in such a way as to obtain a representative sample of the entire landscape. Lengths of transects will be limited by the locations of lakes, but these could be from 1 to several miles in length. A graduate student will walk along each transect and record all instances where temperate tree species or invasive species occur. For these occurrences GPS coordinates will be recorded, and each population of the temperate species or invasive species will be characterized, including the context of the surrounding vegetation and landscape. For temperate tree species, sizes and densities of mature trees will be measured, as well the density and extent of surrounding seedlings via subtransects that radiate out in the four cardinal directions from the point at which the population is encountered along the main transect. A similar sampling scheme will be used to characterize the local abundance and extent of invasive plant species that are encountered.

We will characterize air temperature variation across the landscape using Hobos (small units developed for the space industry that automatically measure temperature at specified intervals and store the data) to measure temperature on an hourly basis at 100 points for two years. To get a representative sample of the landscape, we will choose N, S, E, and W slopes, flat upland locations, hilltops, bogs, and other wetlands, and have several replicate temperature records for each landform. The data are stored within the Hobo unit until downloaded to a computer; we will download data twice a year. The results of this will enable us to model temperature variation across the landscape, depending on local landform, using digital elevation models, so that we can produce a map of likely cold temperature refuges throughout the entire landscape. We will seek advice from climatologists at the University of Minnesota with regard to placement of Hobos and data analyses. If some areas are present on the landscape that are colder than the landscape average temperature, and the magnitude of the

difference is more than the degree of warming projected for a given future scenario (probably at least 2-4 degrees C), then there is evidence that boreal species may persist in some locations. We will use downscaled Global Circulation Model warming scenarios for the mid 21st Century from Galatowitsch et al (2009) for estimates of future climates.

5. **Results and Deliverables** - Describe in detail the expected outcomes of each of the results and deliverables.

Results 1 and 2. Map and analyses of the distribution of temperate tree species within the boreal forest, and Maps and analyses of the distribution of invasive plant species. While it is not possible to find every occurrence of temperate species and invasive species on the landscape, we can get a representative sample of their frequency of occurrence (how many occurrences intercepted per mile of transect line) as well as the types of sites on which each occur. This sampling scheme will detect temperate species, especially understory seedlings, at a much finer scale than existing Forest Inventory and Analysis data or remote sensing, and will provide a more detailed description of the relationship to landscape factors and seed sources. Given the frequency of temperate tree species and probable rates of spread deduced from the distribution of seedlings around the adult trees, and seed dispersal distances and growth rates from the scientific literature, we should be able to estimate how fast temperate species may possibly fill the landscape niche vacated by retreating boreal species. A similar assessment will estimate whether invasive species have the potential to spread as fast as temperate species, thus indicating to managers the level of effort that would be needed if a decision is made to limit their advance across the landscape.

Result 3. Map and analyses of potential cold temperature refuges where boreal species might persist in a warmer climate. This map will allow us to examine the potential refuge areas to assess the extent to which boreal tree cover may persist under various future warming scenarios. The map will also be useful for other biologists (e.g. natural heritage, Nature Conservancy, National Forest Service staff) to assess which boreal-forest dependent plant an animal species are present within potential refuge areas. Such species may persist in a warmer climate, while those present only in other areas may not. A number of endangered species such as the Lynx may or may not have sufficient future habitat under various future warming scenarios.

Result 4. Presentations, workshops, and publications. See details under dissemination and use below.

6. **Timetable** - Layout the proposed times for completing the proposed research including proposed dates for individual results and deliverables.

Transects to estimate frequency of temperate tree species and invasive plant species will be established on maps prior to the July 1, 2011 start date of the project, so that field work can begin immediately on July 1, 2011. Transects will be surveyed in the field from July-September 2011 and May-September 2012. Analyses of the transect data will take place from September 2012 through December 2013.

Hobos to measure temperature will be placed in the field during July and August 2011, and remain in the field until the end of the field season in 2013, so that we will have two field seasons of temperature data. Downloading of data will occur in spring 2012, fall 2012, spring 2013, and fall 2013. Preliminary analysis and mapping of the temperature data from the first year will be done during winter 2012-2013, and analyses including both years will proceed immediately upon finishing data collection in October of 2013.

Presentations and workshops will be prepared during fall 2013, in parallel with analyses of the transect data, so that they can be presented during January-June 2014. Publications will be prepared from January-June 2014.

7. **Budget** - Update the budget sheet from the original proposal based on the amount of funding recommended. Additional details can be added to the budget sheet to more fully describe the budget (The budget sheet is expandable so that additional information can be provided). Additional narrative on the budget can also be provided to more fully explain how the funds will be spent. The "Other Funding" section of the budget sheet should also be updated and include sufficient detail so that the source and amount of contribution is clear.

Budget explanation and justification (See also the accompanying excel file with budget worksheet).
This project will involve extensive field work to document the expansion of native tree species at the northern edge of their range in the Boundary Waters and surrounding forests. We visualize this as a Ph.D. project. Therefore, we have included 2.5 years of Research Assistant funding (standard 50% RA, total $90,671) and funding for a field and lab assistant (undergraduate hourly, fringe benefits for the summer period only, total $20,653). PI Frelich would supervise the entire project, advise the student, visit the filed sites, help analyze the data, and co-author several papers as well as prepare and present several workshops in northern Minnesota, therefore 30% of his salary is included for 2.5 years (total $67,216).

Equipment needed includes Hobos to measure temperature for 2 years on an hourly basis. 100 of these miniature units will be needed (plus a few extras in case of failure), at a cost of about $42 each and GPS equipment to locate study plots in remote areas (total $5,200).

Significant expenses related to dissemination of results and materials for workshops are necessary to carry out the project, therefore we are budgeting $2,760 for these expenses.

Travel for 2 months each summer to northern Minnesota would be necessary for the graduate student and undergraduate assistant, as well as occasional visits by the project manager Frelich. Frelich would also travel around northern MN towards the end of the project to present workshops (total $13,500).

2011-2012 Detailed Project Budget

IV. TOTAL TRUST FUND REQUEST BUDGET 3 years

BUDGET ITEM *(See list of Eligible & Non-Eligible Costs, p. 13)*	**AMOUNT**
Personnel: Frelich, project manager, advise graduate students, supervise undergraduate students, analyze data, write papers and co-write papers with graduate student, present workshops on climate adaptation (0.3 FTE for 3.0 years, $50454 salary, $16762 benefits, on soft money).	$ 67,216
Personnel: Graduate student, collect and analyze field data, write papers (0.5 FTE for 2.5 years, $49131 salary, $41540 benefits).	$ 90,671
Personnel: Undergraduate assistant, help collect field data during summer, assist with analysis in the lab during academic year (0.4 FTE for 2.5 years, $20,000 salary, $653 benefits).	$ 20,653
Equipment/Tools/Supplies: 100 Hobo units to record temperatures on an hourly basis at remote field sites, approximately $42 each, and two GPS units for navigation in remote areas.	$ 5,200
Travel: Summer field work for graduate student and undergraduate assistant, including lodging (camp grounds and university field station facilities will be used as much as possible to reduce costs), car rental and mileage for 4 months (2 months for each of 2 summers). Also included is mileage for visits while field work is in progress by project manager Frelich, mileage for travel by Frelich and Reich to present workshops. All travel will be in state.	$ 13,500
Additional Budget Items: Materials for workshops and public education, including duplication and dissemination of results.	$ 2,760
TOTAL ENVIRONMENT & NATURAL RESOURCES TRUST FUND $ REQUEST	$ 200,000

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ Being Applied to Project During Project Period:	NA	
Other State $ Being Applied to Project During Project Period:	NA	
In-kind Services During Project Period:	NA	
Remaining $ from Current ENRTF Appropriation (if applicable):	NA	
Funding History: This project is a logical contiuation of the following LCCMR project funded in 2009 (Peter Reich manager): Projecting Environmental Trajectories for Energy-Water-Habitat Planning.	$ 180,000	funded

8. **Credentials** - Provide brief background of the principal investigators and cooperators who will carry out the proposed research and selected publications (targeted/abbreviated resumes are acceptable).

Lee E. Frelich—project manager

Lee E. Frelich is Director of the University of Minnesota Center for Hardwood Ecology. He received a Ph.D. in Forest Ecology from the University of Wisconsin-Madison in 1986. Frelich teaches courses in Forest Fire Ecology and Landscape Ecology on St.Paul Campus. He has advised 20 graduate students, and is a senior member of the Conservation Biology, Natural Resource Science and Management, Ecology, and Invasive Species Graduate Programs. Frelich has published numerous papers on forest ecology and has been listed among the top 1% of all scientists in the world in the Science Citation Index, Ecology and Environment Category. He has appeared in the news media 250 times including *The New York Times*, *Newsweek*, *National Geographic*, and many TV and radio stations. Current research interests include fire and wind in boreal forests, long-term dynamics of old-growth hemlock and maple forests, invasive earthworms in forests, and global warming.

Contact information
University of Minnesota, Department of Forest Resources
1530 Cleveland Ave. N. St.Paul, MN 55108
E-mail: freli001@umn.edu
Phone: office, 612-624-3671, cell, 612-991-1359

Grants
Approximately $5,000,000 in grants since 1991, including major grants from National Science Foundation, USDA Forest Service, Joint Fire Science Program, MN Department of Natural Resources, and University of Minnesota.

Publications
Total of 87 publications (59 in peer reviewed journals, 7 books/book chapters, and 21 other). Publications appear in 28 peer-reviewed journals with 60 coauthors from six countries. Top 1% of scientists in the world list, Science Citation Index, Essential Science Indicators, *Ecology and Environment* category (2007, 2008, 2009).

Selected publications relevant to the Border Lakes study area in which this LCCMR project will take place:

Frelich, L.E. and P.B. Reich. 2010. Will environmental changes reinforce the impact of global warming on the prairie-forest border of central North America? *Frontiers in Ecology and Environment* 8: 371-378. DOI: 10.1890/080191.

Frelich, L.E. and P.B. Reich. 2009. Wilderness conservation in an era of global warming and invasive species: a case study from Minnesota's Boundary Waters Canoe Area Wilderness. *Natural Areas Journal* 29: 385-393.

Galatowitsch, S., Frelich, L.E., and L. Phillips-Mao. 2009. Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America**.** *Biological Conservation* 142: 2012-2022.

Rich, R.L., L.E. Frelich, and P.B. Reich. 2007. Wind-throw mortality in the southern boreal forest: effects of species, diameter and stand age. *Journal of Ecology*, 95: 1261-1273.
Frelich, L.E., C. M. Hale, S. Scheu, A.Holdsworth, L.Heneghan, P.J. Bohlen, and P.B. Reich. 2006. Earthworm invasion into previously earthworm-free temperate and boreal forests. *Biological invasions* 8: 1235-1245.
Weyenberg, S.A, L.E. Frelich, and P.B. Reich. 2004. Logging versus fire: how does disturbance type influence the abundance of eastern white pine (*Pinus strobus*) regeneration? *Silva Fennica* 38:179-194.
Mehta, S., L. E. Frelich, M. T. Jones, and J. Manolis. 2004 . Examining the effects of alternative management strategies on landscape-scale forest patterns in northeastern Minnesota using LANDIS. *Ecological Modelling* 180: 73-87.
Reich, P.B., P.Bakken, D.Carlson, L.E. Frelich, S.K. Friedman, and D. Grigal. 2001. Influence of logging and fire on boreal forest biodiversity and productivity. *Ecology* 82: 2731-2748.
Tester, J., A. Starfield, and L.E. Frelich. 1996. Modeling for ecosystem management in Minnesota pine forests. *Biological Conservation* 80: 313-324.
Frelich, L.E. and P.B. Reich. 1995. Spatial patterns and succession in a Minnesota southern-boreal forest. *Ecological Monographs* 65:325-346.

Peter B. Reich, Cooperator

Education

Ph.D. (1983) Department of Natural Resources
Cornell University, Ithaca, New York
Major in environmental biology and plant ecology

M.S. (1977) School of Forestry, Fisheries and Wildlife
University of Missouri, Columbia, Missouri
Major in forest ecology

B.A. (1974) Goddard College, Plainfield, Vermont
Majors in creative writing and physics

Positions held, University of Minnesota:

Professor and F.B. Hubachek, Sr. Chair (1991- present),
Distinguished McKnight University Professor (2003- present)
Regents Professor (2007- present)
Resident Fellow, Institute on the Environment Institute on the Environment

Graduate Faculty appointments: Ecology, Evolution and Behavior; Natural resource Science and Management, Plant Biological Sciences; and Conservation Biology Programs; University of Minnesota, St. Paul, MN

Mentoring

>25 graduate students and 30 additional scientists from 20 countries.

Grants

>20 million dollars in grants as PI or Co-PI since 1991, including several major grants from Department of Energy, National Science Foundation, and USDA Forest Service.

Publications:
320 peer reviewed publications, including 300 papers in journals and 20 book chapters. Institute for Scientific Information, Science Citation Index, top 20 most cited scientists in the world (out of 500,000) in the Ecology and Environment category. Publications relevant to this project coauthored with project manager Frelich are listed above.

9. Dissemination and Use – Describe how the findings of the research will be disseminated and describe the expected audience and potential use.

There will be two separate outreach efforts within Minnesota, one for users and managers of the BWCAW and a second for managers of surrounding commercial forests. A powerpoint presentation and a more detailed half-day workshop will be prepared for each of these two audiences. We will present these in northern Minnesota (Grand Marais, Ely) for the public and for agency personnel from the Minnesota Department of Natural Resources, Superior National Forest, and tribal and county forests. Three publications for peer-reviewed science journals will also be prepared, and will correspond roughly to the three questions listed above to be answered during the study.

7/26/2010