Revised Research Addendum for Peer Review

Project Manager: **Peter B. Reich (preich@umn.edu)**

Healthy Forests to Resist Invasion

Project number: **112-D**

Submitted by:
Peter B. Reich
Dept. of Forest Resources, University of Minnesota

Ann Pierce
Minnesota Department of Natural Resources

And

Kathleen Knight
USDA Forest Service, Northern Research Station

I. Abstract

In Minnesota, invasive plants cause considerable ecological and economic damage, and their control is difficult to achieve in a long-term cost-effective manner. Although not immune from invasion, healthy forests may be somewhat resistant to invasion; therefore management aimed at maintaining, restoring, or enhancing key forest characteristics might be a useful strategy for slowing forest invasion. This type of preemptive tool could help maintain diverse forest systems and might be cheaper and more effective in some instances than trying to remove invaders after they are present. Consequently, our goal is to better understand whether forest characteristics, especially those amenable to management, can be effective deterrents to plant invasion. We will establish 80 forest study sites and assess invasive plant species and a set of key indicators relevant to invasion, including disturbance history; degree of tree canopy cover; native plant diversity; levels of light and soil resources; and other site characteristics. We will determine the links between forest attributes and plant invasion, attempt to discern cause and effect, and based on this information develop guidelines for forest management to resist invasion. These will be provided to resource managers and the public. Information learned in the study can aid in the development of land management prescriptions that incorporate the current invasive status of the plant community and the health and integrity of the ecosystem, which will serve as an indicator of vulnerability to invasion. This information is critical to maintaining a resilient forest system in the face of future climate change coupled with invasive species spread.

II. Background

The rationale for our project is the need to better understand whether forest characteristics, many of which are amenable to management, can be effective deterrents to plant invasion. In the following section we will summarize the current extent of invasive species problems in Minnesota forests, describe our proposed research plan, and end with a vision for where our project might lead.

In Minnesota, as elsewhere, invasive plant species cause considerable ecological and economic damage (Pimentel *et al*. 2004; Invasive Species Program 2009, e.g., see page 98 for info on terrestrial invasives in MN). The extent of the problem is nearly statewide (Figure 1). For example, recent documentation of invasive plants noted by DNR staff (data not shown) on state-owned land with management projects show that problems with invasives occur over most of the state. This shows that just by looking at state land management projects alone, one can see that problems with invasives are widespread throughout the state. As elsewhere the specific problem with invasives is that they can dominate and crowd out native plants, altering composition and ecosystem structure and function in ways deemed undesirable from both conservation and economic perspectives. This can include loss of habitat for other plants and animals; limited regeneration of both dominant plant species and of the diversity of the overall community; and state change of the plant ecosystem from one community type to another. Of particular concern in upland forest habitats in Minnesota are buckthorn and garlic mustard both of which have been shown to suppress regeneration of native forbs, shrubs, and trees (Fagan and Peart 2004, Heneghan *et al.* 2006, Rodgers *et al.* 2008, Stinson *et al.* 2007). Because of the undesired economic and ecological effects of invasive plant species, a substantial amount of funds are spent by the state, and other public and private groups, trying to control populations of invasives. The range of tools used in such control activities includes physical removal, chemical control, and biocontrol, among others. Unfortunately, despite the cost, control is often difficult, ineffective, and/or fleeting, and in many instances far from being cost-effective.

Our project will explore an alternative idea, one that might complement our other tools, and this is the notion of "healthy forests to resist invasion". It has been hypothesized generally that intact ecosystems resist invasion, with some evidence in support of this claim (e.g. Rejmánek 1989, Levine *et al.* 2004, Martin *et al.* 2009). We do not propose that managing for forest health can be a panacea by any means for Minnesota forests, but instead, it perhaps can be another strategic tool to be considered in forest management and planning. The first goal of the 2008-2012 National Invasive Species Management Plan (NISC 2008) is prevention – preventing the introduction and establishment of nonnative species. Prevention is often considered the most cost-effective method of invasive species management. It usually focuses on monitoring and reducing pathways of invasion, such as trade, recreational activities, and packing material. This project aims to support prevention strategies from a different angle – if healthy forests are more resistant to invasion, what management techniques can be implemented to further prevent the establishment and spread of invasive plants? It is worth adding here that what we specifically focus on are the attributes of forest ecosystems that might influence invasion, and only use the term "healthy forest" as short-hand for the notion that intact native systems might possess many attributes that slow invasion. However, we do not enter into the debate about how to define "healthy forests" as that it is outside the scope of our project.

What if healthy native forests resist invasion (Levine *et al*. 2004)? If this is true, would management that worked to maintain, restore, or enhance key forest characteristics be a useful strategy for resisting and slowing invasion of our forested land base? Might it in many cases be cheaper and more effective than trying to remove invaders once they are present? There is evidence that attributes of intact healthy ecosystems, such as high native diversity, can play an important role in conferring resistance to invasion (e.g., Knops *et al*. 1999, Kennedy *et al.* 2002). However, this idea, although venerable, is far from universally accepted (Lonsdale 1999; Stohlgren *et al*. 1999; Gilbert and Lechowicz 2005), at coarse scale, and sometimes fine-scale, native diversity is positively related to invader diversity and success. Although the debate is too complex to repeat here, our project is based on the notion that positive relationships of invader diversity and abundance with native diversity is usually due to co-variation in conditions and resources favorable to all species (both natives and invaders) with underlying biotic interactions between native and invasive species negative—there is some evidence in favor of this interpretation (e.g., Knight and Reich 2005, Shea and Chesson 2002, Knight *et al.* 2007) but it is far from resolved (Fridley *et al.* 2007). In fact, the lack of resolution of this issue is one reason why our project will be valuable from both basic and applied perspectives, as it will provide a further test of these ideas.

There is some evidence (Lake and Leishman 2004, Knight and Reich 2005, Knight *et al.* 2007, Martin *et al.* 2009, Funk and McDaniel 2009) that suggests that invading plants in forests are most successful when:

- Disturbed soil allows germination and establishment
- Sufficient light fuels growth
- Competition from native plants is low

Healthy native forests often have dense canopies that cast shade; an abundance of native trees, shrubs, and herbs to compete with exotics; and intact forest floors that are rarely the preferred microsite of successful invaders. There is substantial evidence that many invaders are more successful when there is greater light availability (Knight and Reich 2005, Gurevitch *et al*. 2008, Martin *et al.* 2009, Funk and McDaniel 2009, Hausman *et al.* 2009). It is also true however that shade tolerant invaders can be successful even in intact forests (Martin and Marks 2006, Huebner 2009) and can become major problems (Martin *et al.* 2009); this clearly indicates that healthy forests are by no means immune from invasion. Additionally, there is evidence that invader establishment success is increased under conditions where the soil is disturbed or the litter layer is reduced (Battles *et al.* 2001, Bartuszevige *et al.* 2007, Belote and Jones 2009). It is also possible that the apparent resistance of intact forests may in part be due both to the nature of species introduced for horticultural purposes and the slower growth rates possible under dense forest canopies (Martin *et al*. 2009). Even if true, this does not negate the possibility that managing for key forest attributes can decrease the susceptibility to and speed of invasion (Funk and McDaniel 2009). Thus healthy forests should resist establishment of invasive plants and slow the pace of invasion across the landscape, which gives more time for biocontrol agents to be developed, for natural pests or diseases to focus in on the novel and thus perhaps protected invader, and the like. However, a comprehensive assessment like we propose has not been made, and would be especially useful in Minnesota.

Many researchers have examined whether there are certain characteristics of successful invasive plants that contribute to their success in order to allow managers to better predict which novel nonnative species are most likely to become invasive (e.g. Rejmánek and Richardson 1996; Lake and Leishman 2004; Sutherland 2004; Funk and McDaniel 2009). While certain traits, such as vegetative propagation and high fecundity, are often cited as being characteristic of many invasive plants, no uniform theory has been accepted. In our project, we plan to compare the traits of native and nonnative species and examine how these traits interact with the environments in which the plants are growing and influence the establishment and persistence of invaders (Funk *et al*. 2008). This information will help us to assess whether healthy ecosystems are more likely to resist colonization in general (and have attributes that slow overall changes in species composition) or are more resistant specifically to nonnative or invasive plants, and what plant traits might be responsible.

III. Hypotheses

We will assess the following hypotheses regarding invasive species numbers and abundances in relation to forest attributes across multiple sites in Minnesota:

1. Abundance and richness of invasive plant species, standardized as possible to propagule availability, will be lower in forests and microsites with lower light levels (and higher LAI); this will be true at both patch and stand scales.

2. Abundance and richness of invasive plant species, standardized as possible to propagule availability, will be lower in forests and microsites with lower degrees of soil disturbance, regardless of whether soil disturbance is due to forest management or invasive soil organisms (i.e. exotic earthworms).

3. Abundance and richness of invasive plant species, standardized as possible to propagule availability, will be lower in forests and microsites with greater native understory diversity and abundance. In essence, even for a given overstory canopy light interception, the native understory acts as an additional filter (by competing for light and soil resources) on the success of invasive species.

4. Invasion is geographically variable - because propagule availability for invaders is likely to be greater further south and closer to urban areas, success (prior to standardizing for propagule supply) will be greater in those regions as well.

5. Invasion is geographically variable - with all else held equal (including propagule availability), colder northern sites will be less invaded than warmer more southerly sites because poorer overall environmental conditions act as a filter on the pool of possible invaders likely to be capable of successful colonization.

6. Given that the impact of management decisions on forest attributes is likely to influence invasion success, management history (timing, type, methodology, etc.) will be influential in explaining cross-site variability in invader diversity and abundance.

7. Forest communities with a greater diversity of plant functional traits and with traits that more closely match the traits of invaders will be more resistant to invasion. This

hypothesis tests the ideas that functional trait diversity confers resistance to invasion and that invaders are more successful when they fill empty niches. A trait-based hypothesis.

IV. Methodology

Result 1: Finalize research plans, select 80 sites, and establish 16 research plots in each site.

In establishing the project we will decide on both the set of study sites and the set of measurements to be made at each site. We have already begun work on this part of the project and through work in both the field and lab during spring 2010, anticipate finalizing the list of attributes of forests and of forest plant species to be measured, the specific protocol for such measurements, and the design for the measurements prior to the start of funding. We are basing this on prior studies (e.g. as done in the papers referenced in this proposal and similar published studies), as well as our own knowledge of Great Lakes forests and taxa based on extensive prior studies of forest ecosystem, community, and organismal attributes, processes, and interactions (e.g., Reich *et al.* 2001, Wright *et al*. 2004, Frelich *et al.* 2006, Knight and Reich 2005, Willis *et al*. 2009). In developing protocol, logistical considerations are paramount, as measuring any attribute at multiple locations in numerous sites is labor-intensive and time consuming.

We believe that even 80 sites is not enough replication to allow a completely random selection of forests across all topographic, edaphic, hydrological, climate, compositional, age, management, and disturbance axes of variation, because such variation could swamp our ability to detect and interpret relations of forest attributes and invader diversity and abundance. Thus we will select sites using certain criteria to narrow the range of variation included in the design, as we have done in previous studies in assessing impacts on composition of fire and logging history (Reich *et al*. 2001), earthworm invasion (Holdsworth *et al.* 2007), and wind disturbance (Rich *et al.* 2007), as well as of native diversity on plant invasion (Knight and Reich 2005). Sites will be limited to upland mesic northern hardwood stands dominated by oak species. This forest type covers a large proportion of Minnesota forestland, is both economically and ecologically important, and also is a preferred habitat for multiple invasive plant species (MN DNR 2003).

Given our interest in addressing whether invasion is influenced by geographic factors and by forest management (see Hypotheses) it will be necessary to include and incorporate geographic variation and forest management history in the design. We have experience in such designs, including geospatial impacts of distances from various elements of development (Holdsworth *et al.* 2007), impacts of natural disturbance vs. logging as agents of system change (Reich *et al.* 2001), impacts of spatial patterns of timber harvesting on understory communities (Montgomery *et al*. submitted and in prep), and recent ongoing studies of trait, climate change, and forest dynamics patterns across geographic gradients in the upper Midwest (Fisichelli *et al.* in process; Rich *et al*. in process; Putnam *et al.* in process). Study sites will be located on lands owned by the USDA Forest Service, Minnesota Department of Natural Resources, Minnesota counties, the Nature Conservancy, and the University of Minnesota. Information such as regional and statewide forest inventories (i.e. FIM and MCBS native plant community data) and management histories will be used to select candidate sites. To incorporate geographic factors, sites will be distributed across the state, wherever the upland mesic oak-dominated northern hardwood forest type is located (mainly across a swath running from southeastern Minnesota through north-

central Minnesota). Sites will be selected such that approximately equal proportion of sites will have experienced each of the following disturbance events within the past ten years: clear-cut timber harvest, shelterwood or other selective timber harvest, and wind throw or blow down. Additionally, a similar proportion of sites will not have experienced a major disturbance event within the past decade. These disturbance events were chosen because logging is a very common anthropogenic disturbance in Minnesota forests and blow down is the most frequent natural disturbance in this forest type. The exact number of sites within each disturbance type will depend on the availability of sites meeting all of the necessary criteria. In order to reduce the variability in results due to variation in stand age and development stage, all sites will be between 50 and 70 years old, prior to the recent disturbance event of interest.

An additional concern will be in choosing sites where invasive species have not been abundant in high enough numbers and sizes and for sufficient time to exert substantial impact on the attributes of the forest that we intend to test as regulators of invasion. Clearly, if a site has been so invaded, the impacts of the invasive species will confound the "original" site characteristics that may have made the site invasible. Thus for this study, the relatively small fraction of state forests already heavily invaded will not be selected for the study.

All study plots will be of equal size (discussed below), but plots will be located within a large range of forest stand sizes (4 ha to >1000 ha). This will allow us to examine impacts of forest fragmentation as well as help us to explore and assess propagule pressure.

At each site 16 plots will be established in a grid, with each plot separated by 25 meters. Each of the 16 plots will be centered around a single point, but different radii will be used to sample different elements of the forest composition, as this has proved to be an effective strategy in prior studies with related measurements (e.g., Reich *et al*. 2001, Knight and Reich 2005, Holdsworth *et al*. 2007, Rich *et al.* submitted). Plots will be marked so that they can be relocated in the future for a potential follow-up study.

Result 2: Assess degree of plant invasion, disturbance history, and health and structural integrity of native plant communities.

Over the course of two years, all plots in all sites will be censused for ecosystem attributes, plant traits, and the native and invasive plant community. Other data on climate, management history, and distance from development will be obtained and maintained in a geographical information system. The ecosystem attributes will likely include measurements at each of the 16 plots per site of canopy openness, soil depth, soil texture, soil pH, soil disturbance history, stage of earthworm invasion, deer abundance, other natural or anthropogenic disturbance, native overstory and understory diversity and abundance (by species), and invader overstory and understory diversity and abundance (by species). Plant traits will include growth form, taxonomy, mature height, specific leaf area, and woody density (if woody), among others.

Characterizing propagule availability of invasive species will be difficult, as this will require assessment both within and beyond the boundaries of the study sites. In the literature, studies that include propagule pressure in their models usually use proxy variables to estimate the propagule pressure at a given site (e.g. Chytry *et al.* 2008; also see Richardson and Pysek 2006),

based on assumptions that humans are a primary disperser of propagules and that more heterogeneous landscapes are likely to have higher propagule availability. We intend to measure some of these proxy variables, including proportional area of non-forest area surrounding the sites (proportion urban, agricultural, etc.), human population density in the surrounding county, distance to nearest roadway, and distance to nearest river or stream. Since few studies have attempted to directly measure propagule availability (but see Eschtruth and Battles 2009 and Rouget and Richardson 2003), we plan to compare the proxy measurements to estimates of local propagule availability based on more intensive sampling. In addition to surveying all native and nonnative plants within each of the 16 plots at each site, we will walk the perimeter of each site (at a distance of 25m from the edge of the plots) and record all invasive plants within 5 meters of the transect line. These data will allow us to develop a more direct and comparable measure of actual propagule availability at each site. Characterizing propagule availability will allow us to account for this in our statistical analyses and therefore be better able to tease out how environmental factors affect forest invasibility.

Result 3: Analyze data, develop management guidelines, and disseminate results via outreach presentations, workshops, reports, DNR/UM web site, and scientific publications.

Relatively standard statistical and ecological tools for analyzing and interpreting data are available and have been used before by the investigators. Collectively the project team has considerable experience in developing management guidelines, in presenting outreach presentations and workshops to agency and private forest managers, consultants, and foresters, and in preparing publications both for the scientific community and the management community. Guidelines for forest management to resist invasion will be developed. These will be provided to resource managers and the public through a series of presentations and workshops as well as via an interactive web site.

V. Description of the deliverables to produced from the proposed research

The deliverables of the project will be (1) regional-scale field study and resulting datasets that will serve to inform scientists and land managers on the relationships of forest attributes with plant invaders across a select strata of Minnesota forests; (2) recommendations regarding whether and how forest management strategies can be revised to make forests less susceptible to invasion; (3) land manager, public, and researcher education accomplished via a combination of workshops, reports, seminars, web-based information, and scientific publications.

VI. Timetable for the proposed research (organized by project results)

Identify and locate 80 forest sites	12/15/2010
Establish 16 plots at each site	6/30/2011
Field data collection completed on forest health and invasion status sites	9/30/2012
Final data base on plant invasion, forest health and integrity	12/31/2012
Final report, “Do healthy forests resist invasion?”	6/30/2013
Forest management guidelines	6/30/2013

Outreach via presentations, workshops, web site	6/30/2013
Scientific publications written	6/30/2013

VII. Dissemination and Use

We will work to ensure that the results of the study are widely disseminated and used. The third deliverable of our project (see above) is by definition the translation of our work to relevant public and private organizations and groups. This includes a variety of means, including workshops, reports available on the web, presented seminars, and the like. Additionally, we will work through relevant units within and outside management agencies (e.g., DNR Forestry, the Minnesota Forest Resources Council) to make recommendations widely known, and as appropriate, we will urge their adoption and implementation.

VIII. Budget

BUDGET ITEM	**AMOUNT**
Personnel:	
1 Research associate, 100%, coordination of day to day project activities ($44,596 salary + $14,405 fringe) for 2 years	$118,002
1 Graduate student, 50%, develop dissertation research project from some aspect of project research ($21,000 salary + $3,536 health insurance + $ 11,170 tuition for 2 years	$71,412
1 Project assistant, 50% ($36,000 salary + $6,660 fringe) for 2 years	$49,320
4 undergrad students (summer, 100%) 2000 hours @ $11/hour + $1,795 fringe) for 2 summers	$47,590
3 undergrad students (academic year, 25%) 8 hrs/week, 960 hours @ $11/hour for 2 academic years	$21,120
Equipment/Tools/Supplies: Misc. field supplies and tools (data sheets, labels, bags, vials, etc.) for 2 years; and laser range finders (2) and light sensors (2)	$15,976
Travel: Intensive in-state travel to 80 scattered and remote field sites, for 2 years, includes lodging and mileage on personal vehicles	$21,500
Chemical analyses of plants and soils: cost based on one vegetation and one soil sample per plot (16 plots x 80 sites, at a total cost of $11 for the two analyses), for 2 years	$14,080
TOTAL ENRTF PROJECT BUDGET	**$359,000**

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IX. Credentials

Biographical Sketches of Senior Personnel on Project

Curriculum Vitae - Peter B. Reich

Regents Professor and Distinguished McKnight University Professor
F.B. Hubachek, Sr., Professor
Department of Forest Resources
University of Minnesota, St. Paul, MN 55108
E-mail: preich@umn.edu
Phone: 612-624-4270; FAX 612-625-5212

Professional Preparation

Ph.D. (1983) Environmental Biology and Plant Ecology, Cornell University, Ithaca, NY
M.S. (1977) Forest Ecology, University of Missouri, Columbia, MO
B.A. (1974) Writing and Physics, Goddard College, Plainfield, VT

Appointments

F.B. Hubachek, Sr., Professor, Department of Forest Resources, University of Minnesota, St. Paul, MN, 1991-
Assistant/Associate Professor, Department of Forestry, University of Wisconsin, Madison, WI, 1985-1991.

University Course Taught

Forest Ecology
Plant Physiological Ecology
Plant Responses to Air Pollution
Science & Policy of Global Environmental Change
Tree Physiology
Tropical Forest Ecology
Landscape Ecology

Honors, Recognition, Service, Interdisciplinary Activities (Selected)

Invited speaker at more than 120 national/international symposium, research conferences, and university seminars; e.g., Cornell, Duke, Georgia, Harvard, Penn State, Princeton, Stanford, Texas A&M
Commencement Speaker, University of Minnesota Graduate School commencement, "Dancing on Thin Ice", May 9, 2008
Institute for Scientific Information (ISI) Science Citation Index: 1,755 citations in 2008; as of June 2009, H-Index = 67. Listed (by total numbers of citations) among 10 Most Cited Ecologists and Environmental Scientists in the World (out of ≈ 500,000), 2002-
Mahtomedi City Environmental Commission (2007-2010)
U.S. GAO/National Academy of Sciences Workshop on Climate Change Effects on Federal Lands, November 2006, Washington, D.C.
Department of Energy, National Institute on Climate Change Research, Midwestern Regional Panel, 2006/2007
National Science Foundation, Biocomplexity and the Environment Program, Coupled Biogeochemical Cycles Panel member, 2004

Member of the Editorial Review Board (or equivalent) for the journals Oecologia (2006- present), *Tree Physiology*, *(1987-88, 1993-95, 2004-) Trees (1991-97), Canadian Journal of Forest Research (1992-98)* and *Ecology/Ecological Monographs (1995-99)*

Selected grants (current):

US Department of Energy, "Warming-induced biome change at the temperate-boreal ecotone: an experimental test of key regeneration processes", 2007-2011 [P Reich, R Rich, S Hobbie, R Montgomery, J Oleksyn, PIs], ($1,806,000).

USDA National Research Institute, "Managing for complex structure and wood productivity in Great Lakes pine ecosystems", 2006-2009 [B Palik, P Reich, R Montgomery, PIs], ($400,000)

National Science Foundation, Long-Term Ecological Research Program, "Biodiversity, Environmental Change and Ecosystem Functioning at the Prairie-Forest Border ", 2006-2012 (D Tilman, P Reich and other co-PIs), $4,920,000.

National Institute for Climate Change Research, "Interactions of water, CO_2 and N in an experimental model system", 2006-2011 [P Reich PI], $620,000

Selected peer-reviewed publications (of >320 in total):

Fissore, C., J. Espeleta, E. Nater, S.E. Hobbie, P.B. Reich. 2009. Terrestrial carbon sequestration by land-use conversion shows only limited potential to offset CO_2 emissions in the Midwestern United States. Frontiers in Ecology and the Environment (in press).

Frelich, L.E., P.B. Reich. 2009. Will multiple environmental changes reinforce the impact of global warming on the prairie-forest border of central North America? Frontiers in Ecology and the Environment (in press)

Holdsworth AR, LE Frelich, PB Reich. 2007. Regional extent of an ecosystem engineer: earthworm invasion in northern hardwood forests. Ecol Applic 17: 1666-1677.

Knight KS, J Kurylo ,T Endress R Stewart , PB Reich. 2007. Ecology and Ecosystem Impacts of *Rhamnus cathartica*: A Review. Biological Invasions 9: 925-937.

Knight, K.S., J. Oleksyn, A.M. Jagodzinski, P.B. Reich, M. Kasprowicz. 2008. Overstory tree species regulate colonization by native and exotic plants: a source of positive relationships between understory diversity and invasibility. Diversity and Distributions 14:666-675

Ollinger S.V., A.D. Richardson, M.E. Martin, D.Y. Hollinger, S. Frolking, P.B. Reich, et al. 2008. Canopy nitrogen, carbon assimilation and albedo in temperate and boreal forests: functional relations and potential climate feedbacks. Proc National Acad Sci USA 105: 19336-19341.

Peterson, D., P.B. Reich. 2008. Fire frequency and tree canopy structure influence plant species diversity in a forest-grassland ecotone. Plant Ecology 194: 5-16

Pierce, A, PB Reich. 2009. The effects of eastern red cedar (*Juniperus virginiana*) invasion and removal on a dry bluff prairie ecosystem. Biological Invasions (in press)

Reich, P.B. 2009. Elevated CO_2 reduces loss of plant diversity caused by nitrogen deposition. Science (in press).

Reich, P.B., J. Oleksyn. 2008. Climate warming will reduce growth and survival of Scots pine except in the far north. Ecology Letters 11:588-597.

Reich, P.B., S.E. Hobbie, T. Lee, D.S. Ellsworth, J.B. West, D. Tilman, J. Knops, S. Naeem, J. Trost. 2006. Nitrogen limitation constrains sustainability of ecosystem response to CO_2. Nature 440:922-925.

Ann Pierce
Minnesota Department of Natural Resources
500 Lafayette Road, St. Paul, MN 55155
(651) 259-5119 ann.pierce@dnr.state.mn.us

EDUCATION:
Doctorate -Conservation Biology (Ecosystem Ecology emphasis), University of Minnesota TC— 2005: Dissertation Title: *South Slope Systems: Competition as a driving force of community structure and composition*

Masters of Science-Natural Resources (Forest Ecology emphasis), University of Wisconsin Stevens Point—1996: Thesis Title: *Herbaceous Understory Response to Prescribed Burning and Oak Wilt in a Degraded Oak Savanna*

PROFESSIONAL EXPERIENCE:

Supervisor, Conservation Management and Rare Resources Unit - Minnesota DNR, October 2008- Present

Direct the division of Ecological Resource's conservation and management of rare resources so that the state's ecosystems, rare and vulnerable plants and animals, and natural areas are protected, conserved, and enhanced. Direct the development of plans, strategies, policies, and procedures that effectively and consistently provide statewide direction for implementing programs. Provide technical assistance and represent the conservation management unit's interest within the division of Ecological Resources and other departmental divisions to help guide resource conservation efforts. Coordinate the unit's work activities with external partners and promote partnership opportunities in order to achieve conservation objectives through integrated, coordinated, and cooperative ventures.

As Conservation Management and Rare Resources Unit Supervisor I provide professional advice, consultation, and technical assistance to other disciplines in the department so that conservation objectives are met through integrated, coordinated, and cooperative resource management. The Conservation Management and Rare Resources Supervisor directs the development of legislative funding initiatives, makes presentations on initiatives and proposals and provides support to the Director of Ecological Resources on Forest, Prairie, Wetland Policy, Rare Resources Management, Conservation Planning, and Natural Areas Protection.

Terrestrial Invasive Plant Species Ecologist--- Minnesota DNR, July 2007- October 2008

Work collaboratively with resource managers, agency staff, local units of government, non-profits, federal agency staff and citizens to control and prevent the spread and negative impacts of non-native terrestrial invasive plant species. Determine and implement planning, policy, educational and research objectives focused on maintaining sustainable natural resource management in the face of non-native invasive species impacts. Provide an ecological perspective on invasive species management and control as they relate to department policy, land management, forest, wildlife, and fisheries, management and land use.

In this position I was coordinator and team leader for multi-disciplinary aquatic and terrestrial invasive species Divisional Guideline development team. I also assisted in the multi-divisional development of the DNR's Invasive Species Operational Order. Develop annual report that communicates the results of the terrestrial invasive species program and demonstrates the link between strategic goals of the program and budgetary expenditures by highlighting measured results. Developed a myriad of educational materials based on analysis and interpretation of scientific data to help guide the state's management of terrestrial invasive species and meet the priorities of multi divisional strategic goals.

As terrestrial invasive species ecologist I am currently working to identify indicators to help measure progress toward identified goals and priorities. Organized and implemented a series of eight workshops aimed at educating DNR managers, scientists, and other agency staff about terrestrial invasive species science and management. These workshops also served to introduce DNR staff to the requirements and expectations outlined in the Invasive Species Operations Order 113.

Regional Plant Ecologist- Minnesota DNR, October 19, 1999-June 2007.

Work collaboratively, following an adaptive management process, with natural resource managers, agency staff, local units of government, and citizens to identify and sustain sites that contain high priority native plant communities and rare species habitats. Determine and implement planning, educational, research, and policy objectives focused on sustaining native biodiversity. Provide an ecological perspective on such subjects as forest management, wildlife management, fisheries management, ecosystem-based forest management, and outdoor recreation management. Work with landowners to help incorporate management of non-timber species into their overall forest management plans. Much of this work focused on control, management, and reduction of invasive species.

Work with local units of government, watershed groups, and state and federal agencies in the implementation of large scale, cross-disciplinary planning processes to develop comprehensive regional and site level policies, priorities, and management plans. This included the development of environmental corridors based on GIS analysis and incorporated variables such as high biodiversity areas, ground water sensitivity, karst susceptibility, and steep slopes. I work with local units of government to provide information on the existing state and federal laws and regulations that govern natural resource planning (including: State Endangered Species Law, Federal Endangered Species Law, and State Shoreland Regulations) and develop laws and regulations through local ordinances that are specific to the local natural resource land use goals.

Coordinated the development and implementation of a Sustainable Forest Management Conference focused on the multi-state driftless area including topics such as forest wildlife management, invasive species control and management, forest certification, ecosystem based management, and land protection options.

Work with US Forest Service, MNDNR Division of Forestry, and MNDNR Division of Fisheries and Wildlife to design and implement research project focused on oak forest habitat management and non-native species invasion in the Blufflands Landscape.

Lead worker for the multi-faceted program "SE Forest Landowner Incentive Project (LIP)" acting to manage and implement the execution of the grant. As with other management and planning projects the majority of this work focused on invasive species management and control.

Bluffland Coordinator- Minnesota DNR, August 2, 1995-October 18, 1999

RESEARCH EXPERIENCE (selected):

- Coordinate the Minnesota DNR involvement, participate in the design and implementation, and provide local ecological information to a developing research project that will examine the Mississippi River Floodplain forest regeneration and a reed canary grass risk assessment as part of a partnership with the US Geological Survey, the US Army Corps of Engineers, the US Fish and Wildlife Service, and the Minnesota DNR, 2005-present.
- Coordinate the Minnesota DNR involvement and provide local ecological information as part of a research study focusing on oak forest and non-native species invasion in the Blufflands Landscape. As part of a partnership with the US Forest Service, Iowa State University and Minnesota DNR, 2004-present.

PUBLICATIONS:

- Pierce, A.M. 1994. The Herbaceous Understory Response of a Degraded Oak Savanna to Prescribed Burning. 197-201p. *In:* J.S. Fralish, R.C. Anderson, J.E. Ebinger, and R. Szafoni, (eds.). Proc. Of the North American Conference on Savannas and Barrens. Normal, Ill.
- Pierce, A.M. 1995. *The Herbaceous Understory Response of a Degraded Oak Savanna to Prescribed Burning.* M.S. Thesis. University of Wisconsin, Stevens Point.
- Pierce, A.M. 2005. Bluff prairies of Southeastern Minnesota: Competition as a driving force of community structure and composition. Ph.D. Dissertation. University of Minnesota
- Pierce, A.M., P.B. Reich, 2009. The effects of eastern red cedar (*Juniperous virginiana)* invasion on the dry bluff prairie system. Biological Invasions. DOI 10.1007/s10530-009-9446-z.

PUBLICATIONS SUBMITTED:

- Pierce, A.M., P.B. Reich, Evidence for competitive trade-offs across nitrogen and water gradients between sympatric C_4 grasses. New Phytologist

SCIENTIFIC OUTREACH (selected):

- Organized-- Series of eight Invasive Species Workshops. Minnesota Department of Natural Resources. Across the state, summer 2007.
- Organized-- Invasive Species Workshop. Minnesota Department of Natural Resource. Rochester, MN March 2007.

- Organized-- Invasive Species Workshop. Minnesota Department of Natural Resource. Grand Rapids, MN and Rochester, MN October 2006.
- Developed Forest Ecological Management Fact Sheets (Oak Savanna, Maple-Basswood, and Floodplain Forest). August 2006.
- Organized-- Vegetation Monitoring Workshop. Minnesota Department of Natural Resources. Bemidji MN, March 2006.
- Organized-- Invasive species workshop: Minnesota Department of Natural Resources. January 2005.
- Presentation to the Olmsted County Environmental Board on ecosystem function and the role of native plants. December 2001

Kathleen S. Knight
Research Ecologist, USDA Forest Service Northern Research Station
359 Main Road 740-368-0063
Delaware, OH 43015 ksknight@fs.fed.us

EDUCATION

PhD 2006 University of Minnesota Ecology, Evolution, and Behavior

Advisor: Peter Reich GPA: 3.97
Factors that influence the invasion success of two woody invaders of forest understories

B.A. 2001 Hiram College Biology; Music Performance

GPA: 3.95 Summa Cum Laude

EMPLOYMENT

Research Ecologist	USDA Forest Service NRS	2006 – present
Research Assistant	University of Minnesota	Summer 2002 – 2005
Teaching Assistant	University of Minnesota	Fall 2002 – Spring 2004

RESEARCH GRANTS

American Recovery and Reinvestment Act (ARRA) Grant to the Metropolitan Park District of the Toledo Area. Job Creation through Emerald Ash Borer (EAB) Containment and Ecosystem Restoration. KS Knight, USDA Forest Service Project Monitor. $1,344,000. 2009-2011.

NSF and USDA Forest Service Urban Long-Term Research Areas Exploratory (ULTRA-Ex). Urban Parks and Vacant Lands as Mechanisms of Ecological and Social Stability in the Cleveland Urban Ecosystem. BM Walton, JJ Mack, T Schwarz, P Grewal, and D Beech, Co-PI's. KS Knight and SG Jang, senior personnel. $272,075. 2009-2011.

Tree Fund. Survey for Tolerance to Emerald Ash Borer within North American Ash Species. DA Herms, J Koch, T Poland, and K Knight. $25,000. 2009-2010.

USDA Forest Service Forest Health Monitoring. Landscape patterns of white ash (*Fraxinus americana*) health in the Allegheny Plateau Region. A Royo and K Knight. $64,000. 2009-2010.

USDA Civil Rights Special Project Fund. Emerald Ash Borer at Dempsey middle school. J Rebbeck and KS Knight. $1115; 2009

USDA Forest Service and Animal and Plant Health Inspection Service Request for Technology

Development Proposals to improve the management of Emerald Ash Borer (EAB). A Tool for Assessing EAB Management Methods: A Model of Ash Decline for EAB-infested Forests. KS Knight, RP Long, and DA Herms. $67,938; 2008-2010.

USDA-NRI Weedy and Invasive Species in Agroecosystems. Responding to emerald ash borer impacts on forest structure and invasive plant colonization. J Cardina, DA Herms, and KS Knight. $499,959; 2007-2011

Anderson Fellowship, University of Minnesota. $2500; 2005

Doctoral Dissertation Improvement Grant, University of Minnesota. $2500; 2004

Applied Ecological Services Grant. $2000; 2004

Crosby Fellowship, University of Minnesota. $5000 stipend + $2000 grant; 2004

PUBLICATIONS (peer reviewed)

Knight KS, Karrfalt R, and Mason ME. 2009. Methods for collecting ash (*Fraxinus spp*.) seeds. USDA Forest Service GTR. *In press*

Kula RR, Knight KS, Rebbeck J, Cappaert DL, Bauer LS, and Gandhi KJK. 200_. New record of *Leluthia astigma* (Ashmead) (Hymenoptera: Braconidae: Doryctinae) as a parasitoid of *Agrilus planipennis* Fairmaire (Coleopteran: Buprestidae: Agrilinae), emerald ash borer, with a review of host use in *Leluthia* Cameron. Proceedings of the Entomological Society of Washington. *In press*

Knight KS, Oleksyn J, Jagodzinski AM, Reich PB and Kasprowicz M. 2008. Overstory tree species regulate colonization by native and exotic plants: a source of positive relationships between understory diversity and invasibility. Diversity and Distributions 14(4): 666-675

Kurylo JS, Knight KS, Stewart JR, and Endress AG. 2007. *Rhamnus cathartica*: Native and naturalized distribution and habitat preferences. Journal of the Torrey Botanical Society 134: 420-430.

Knight KS, Kurylo JS, Endress AG, Stewart JR and Reich PB. 2007. Ecology and Ecosystem Impacts of *Rhamnus cathartica*: A review. Biological Invasions 9:925-937.

Knight KS. 2006. Factors that influence invasion success of two woody invaders of forest understories. Dissertation, University of Minnesota

Knight KS and Reich PB. 2005. Opposite relationships between invasibility and native species richness at patch vs. landscape scales. Oikos 109:81-88.

PUBLICATIONS (selected recent presentations with published proceedings)

Rice KB*, Herms DA, Gandhi KJK, Knight KS and Cardina J. 200_. Lingering effects of EAB: canopy gaps and light in the understory. In: Emerald ash borer research and development meeting; 2009 October 20-21; Pittsburgh, PA. *In press*.

Klooster W*, Herms CP, Knight KS, Herms DA and Cardina J. 200_. Forest understory response to EAB-induced ash mortality. In: Emerald ash borer research and development meeting; 2009 October 20-21; Pittsburgh, PA. *In press*.

Herms DA, Klooster W, Knight KS, Herms CP, Smith A, McCullough DG and Cardina J. 200_. Ash regeneration in the wake of EAB: will it restore ash or sustain the outbreak? In: Emerald ash borer research and development meeting; 2009 October 20-21; Pittsburgh, PA. *In press*.

Knight KS, Herms DA, Cardina J, Long RP, Rebbeck J, Gandhi KJK and Smith A. 200_.

Monitoring and modeling EAB effects in forest ecosystems: an update on Ohio monitoring plots and ash mortality modeling. In: Emerald ash borer research and development meeting; 2009 October 20-21; Pittsburgh, PA. *In press*.

Flower CE*, Knight KS, and Gonzalez-Meler MA. 200_. Using stable isotopes as a tool to investigate impacts of EAB on tree physiology and EAB spread. In: Emerald ash borer research and development meeting; 2009 October 20-21; Pittsburgh, PA.

Knight KS, Rebbeck J, Cappaert DL, Kula RR, Bauer L, Bogard DA, Gandhi KJK, and Flower CE. 200_. Citizen science project leads to emerald ash borer parasitoid discovery. In: Emerald ash borer research and development meeting; 2009 October 20-21; Pittsburgh, PA. *In press*.

Knight KS, Long RP, Rebbeck J, Herms DA, Cardina J, Herms CP, Klooster WS, Gandhi K, Smith A, Costilow KC, Long LC, Smith SK, Flower C, and Cappaert D. 2009. Effects of emerald ash borer (*Agrilus planipennis*) on forest ecosystems in North America. Ecological Society of America Annual Meeting. Poster. August 4, Albuquerque, NM. http://eco.confex.com/eco/2009/techprogram/P19259.HTM

Flower CE*, Gonzalez-Meler MA, and Knight KS. 2009. Impacts of the invasive emerald ash borer (*Agrilus planipennis*) on tree and forest carbon dynamics in the Great Lakes region. In: Carbon in northern forests: integration of research and management. June 9-10 2009, Traverse City, MI: 47 http://forest.mtu.edu/cinf/CiNF_Abstract_Book_Web.pdf

Long LC** and Knight KS. 2008. Woodpecker activity in response to woodlot infestation by emerald ash borer. Midwest Fish and Wildlife Conference. December 15-17, Columbus, OH https://www.dnr.state.oh.us/wildlife/mwfwc/viewPosterDetail.aspx?AbstractID=314

Koch JL, Poland T, Knight K, Carey DW, Herms D, and Mason ME. 2009. Overview of ash breeding efforts. In: Bonello P(E) (editor), First EAB Minisymposium Book of Abstracts; 2008 Dec 12, Columbus OH. 17.

Knight KS, Cardina J, Herms CP, Gandhi KJK, Smith A, Long RP, and Herms DA. 2008. Invasive plants in forests infested by emerald ash borer: how scientists and managers worked together to design a useful research program. In: Hartzler RG and Hartzler AN, North Central Weed Science Society Proceedings. 63:210. North Central Weed Science Society, Champaign, IL, December 2008

*graduate student, **undergraduate student

SELECTED INVITED PRESENTATIONS

Knight KS and Rebbeck J. 2009. Emerald ash borer: the biology and ecological consequences of an exotic pest. Ohio State University Science Café. February 3, Marion, OH

Knight KS, Cardina J, Herms CP, Gandhi KJK, Smith A, Long RP, and Herms DA. 2009. Effects of emerald ash borer (*Agrilus planipennis*) on forest stands: Ash (*Fraxinus* spp.) decline and mortality. Ohio State University Buckeye Ecologist Symposium. January 16, Columbus, OH

Reynolds HL and Shannon S (moderators), Kirschbaum C, McCarthy B, Middleton EL, O'Leary C, Knight KS, and Marburger J (panel). 2008. Research-Management Collaboration Panel Discussion. Midwest Invasive Plants Network and North Central Weed Science Society annual meeting, December 10, Indianapolis, IN

Knight KS. 2008. How fast do ash trees die and how can the prediction model be a tool for you? "Out of the Ashes – What We Know About EAB" workshop. September 24, Dayton, OH

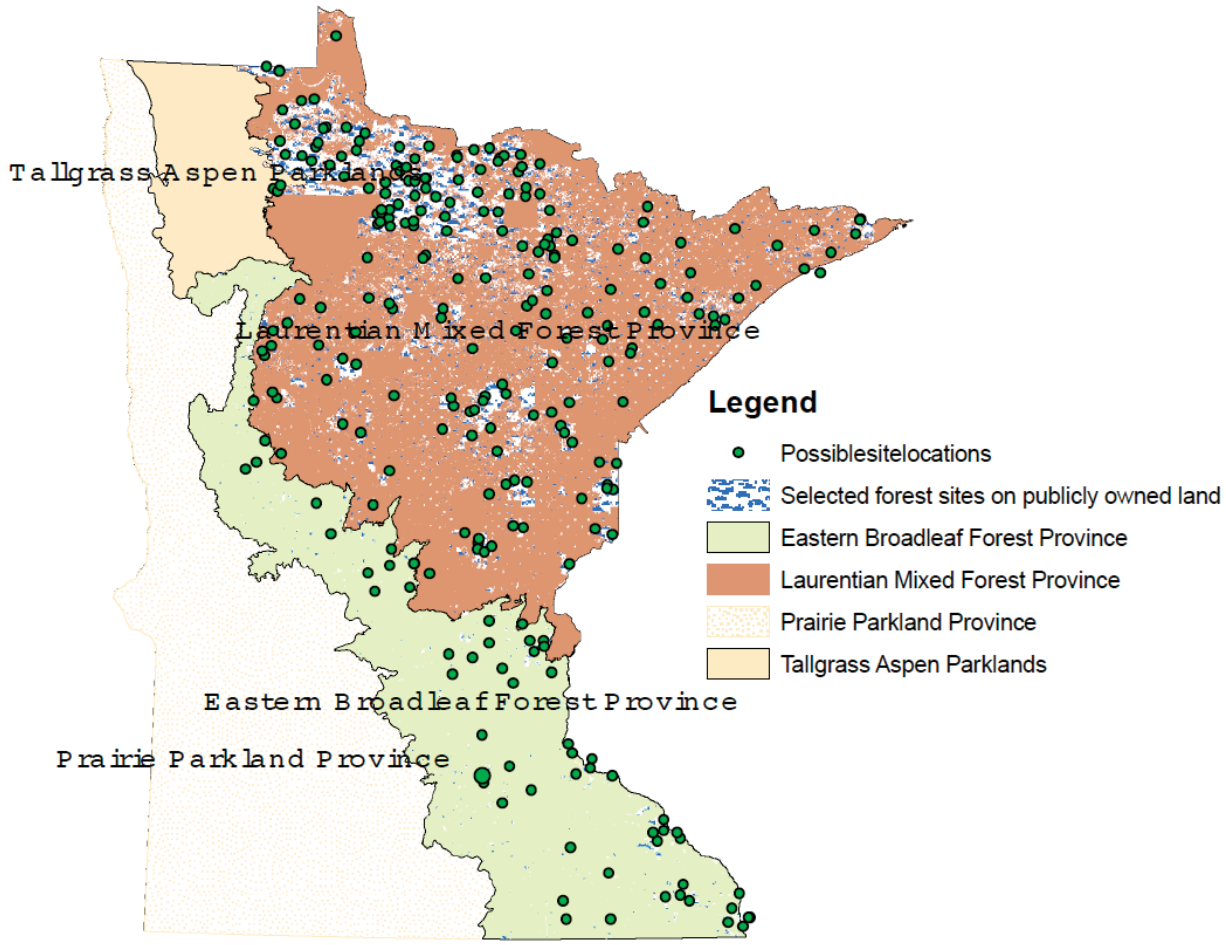
Knight KS and Herms DA. 2008. Emerald ash borer: biology, impacts, research results, and implications. Forest Health 2008: Insect and Disease Update Meetings. March 19, Bloomsburg, PA, and March 20, St. Marys, PA.

Knight KS. 2006. Buckthorn ecology and ecosystem impacts. Buckthorn Workshop, Midwest Invasive Plant Symposium. December Milwaukee, WI

Knight KS. 2005. Biology and impacts of buckthorn (*Rhamnus cathartica*) in the U.S. Biology, Ecology and Management of Garlic Mustard and European Buckthorn Workshop. MN DNR, U.S. Forest Service, University of Minnesota. 17 March St. Paul, MN

Knight KS and Reich PB. 2005. Biotic and abiotic constraints on buckthorn invasion. Biology, Ecology and Management of Garlic Mustard and European Buckthorn Workshop. MN DNR, U.S. Forest Service, University of Minnesota. 17 March St. Paul, MN

Figure 1.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Eastern Broadleaf Forest Province
Laurentian Mixed Forest Province
Prairie Parkland Province
Tallgrass Aspen Parklands