Research Addendum for Peer Review

Project Manager: **Anthony D'Amato (damato@umn.edu)**

Ecological and Hydrological Impacts of Emerald Ash Borer

Project number: **239-D**

Submitted by:

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I. Abstract - The Emerald Ash Borer (EAB) poses a tremendous threat to ash forests in Minnesota. Of particular concern is the impact EAB will have on the ecology and functioning of black ash (*Fraxinus nigra*) wetlands, which cover over one million acres in Minnesota and represent the state's most common ash forest type. Black ash often occurs in relatively pure stands within poorly drained sites where it serves as a foundation species exerting a strong control over ecosystem structure and functioning. Correspondingly, extirpation of this species by EAB could have negative cascading effects, including dramatic rises in water tables and shifts in vegetation composition towards shrub- and graminoid-dominated wetlands with little to no tree component. Nonetheless, much of our understanding of the impacts of EAB on ash forests in the Lake States comes from green ash (*Fraxinus pennsylvanica*) and white ash (*Fraxinus americana*) systems, limiting our understanding of how EAB will affect black ash wetlands and what management strategies could mitigate these impacts.

This project is designed to increase our understanding of the ecological and hydrological impacts of EAB through the establishment of a network of research sites in black ash forests in Minnesota. Treatments simulating EAB-induced ash mortality will be implemented at each site to characterize how the loss of ash from these systems will impact native plant communities, the spread of invasive species, and site hydrology. In addition, the survival and growth of naturally regenerating trees, as well as a mixture of planted tree seedlings, will be evaluated to determine what species might be able to mitigate the ecological impacts of the loss of black ash from these forests. Results from this project will (1) provide predictions of how EAB will affect northern Minnesota's forests, and (2) provide critical information for informing management recommendations aimed at mitigating the impacts of this exotic insect, including the identification of successful replacement species and their management.

II. Background

The Emerald Ash Borer (EAB) has been decimating ash throughout the Great Lake States (Poland and McCullough 2006) and is currently advancing into Minnesota, threatening the future of the ash-dominated forests that occur across much of the state (Fig 1). Of particular concern is the impact EAB will have on the ecology and functioning of black ash wetlands, which cover over one million acres in Minnesota and represent the state's most common ash forest type. Although research from other states is currently addressing how to detect and control EAB within urban areas (e.g., Liu and Bauer 2008, McCullough et al. 2009, Mota-Sanchez et al. 2009), these approaches are not logistically feasible within rural, forested settings, thus making the threat of losing black ash from Minnesota quite serious once EAB reaches the northern portion of the state; an event expected to occur within several decades if not sooner.

Within northern Minnesota, black ash often occurs in relatively pure stands on poorly drained sites, serving as a foundation tree species that strongly regulates ecosystem processes and community structure (sensu Ellison et al. 2005). Because black ash occupies a unique wet niche where few other tree species grow, the loss of ash from these systems due to EAB will likely be extreme, resulting in dramatic shifts in native plant communities and increasing the potential for invasion by exotic plant species (Kenis et al. 2009). Moreover, the reduction in transpiration accompanying the loss of black ash from these areas will result in a greater volume of water in these sites, concomitantly shifting the vegetation in these communities towards marsh-like conditions (Erdmann et al. 1987) and increasing the likelihood of flooding in adjacent forests,

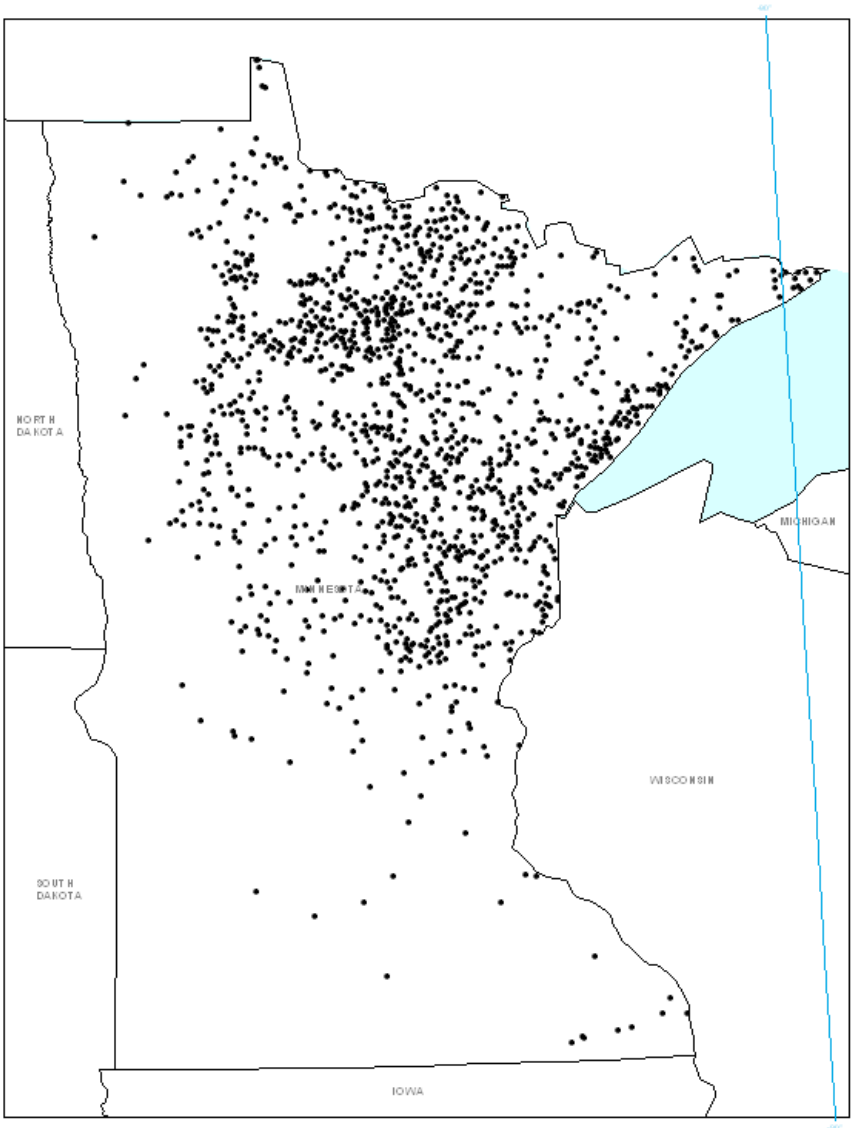

Figure 1. USDA Forest Service Forest Inventory and Analysis (FIA) plots in Minnesota on which black ash is present (2003-2007 FIA inventory period).

agricultural lands, private property, and public road infrastructure. As a result, immediate research is needed to assess the impacts of EAB on native plant communities, ecosystem functioning, and hydrology, as well as to evaluate possible mitigation strategies for increasing the resilience of these systems to loss of black ash due to EAB.

Although preliminary work suggests that EAB will be able to survive the temperature regimes found in northern Minnesota (Sobek, personal communication), questions still exist regarding how colder temperatures will affect the reproductive biology of EAB. In particular, EAB normally takes one year to complete its life cycle; however, field evidence suggests that it may shift to two-year life cycles under colder temperature regimes and in outlying infestation areas (Cappaert et al. 2005). These findings have important implications regarding the rate at which EAB will spread through the landscapes of northern Minnesota, as well as the time managers may have in devising strategies to increase stand resiliency to EAB once it has arrived. Understanding the behavior of EAB under the temperature regimes and conditions found in

black ash wetlands in northern Minnesota will be critical in developing predictive models of EAB spread and determining appropriate management actions.

This proposal seeks to increase our understanding of the ecological and hydrological impacts of EAB through the establishment of a network of research sites in black ash forests in Minnesota. Treatments simulating EAB-induced ash mortality, as well as preemptive silvicultural manipulation, will be implemented on these sites to characterize how the loss of ash from these systems will impact native plant communities, including natural regeneration of native trees, the spread of invasive species, and site hydrology. In addition, the survival and growth of a mixture of planted tree seedlings will be evaluated to determine what species might be able to mitigate the ecological impacts of the loss of black ash from these forests. Finally, laboratory experiments assessing the cold tolerance of EAB will be used to determine the potential for EAB spread into northern Minnesota. Importantly, results from this project will allow for predictions into how EAB will affect northern Minnesota's forests and will serve to inform management recommendations for mitigating the impacts of this exotic insect prior to its establishment in black ash stands.

III. Hypotheses

We put forth the following hypotheses regarding the impacts of black ash mortality and EAB on black ash forest systems in northern Minnesota:

- **a.** Mortality of black ash will lead to increases in water levels within black ash swamp systems resulting in subsequent shifts towards vegetation communities dominated by grasses, sedges, alder, and willow.

- **b.** The magnitude of change observed in hydrology and vegetation following black ash mortality will be greater in harvested stands (preemptive silviculture) compared to those experiencing simulated EAB-induced mortality (girdling treatments). This greater magnitude will be due to the rapid tree death and greater extremes in microenvironmental conditions occurring on harvested sites versus areas with girdled, but still standing trees.

- **c.** Shallow-rooted, shade tolerant tree seedlings, including northern white cedar, black spruce, and balsam fir, will have the greatest growth and survival beneath black ash overstories, whereas wetland shrub species, including speckled alder and willow, will have the greatest growth and survival within areas of ash mortality.

- **d.** Emerald ash borer is able to survive and complete its life cycle under temperature regimes found in northern Minnesota.

IV. Methodology

Result 1: Develop a network of research sites within black ash forests to assess impacts of EAB on biodiversity and productivity

Currently, little information exists on the potential ecological impacts of EAB on black ash forest systems. To address this need, we will establish large-scale manipulations of black ash systems allowing us to assess the ecological impacts of EAB on black ash forests, and to evaluate

potential adaptive management actions for sustaining the ecological functions of black ash systems after the loss of this species to EAB. In particular, research will be conducted at 8 black ash forest sites, selected to represent a range of black ash wetland conditions. Each site will be a minimum of 90 acres to allow for an assessment of hydrological impacts of EAB. Study sites will be located on lands owned by the USDA Forest Service and Minnesota Department of Natural Resources. At each site, the following treatments will be replicated using a split-plot, complete block design:

a) ***Ash mortality*:** Three levels of ash mortality will be implemented in each of eight blocks of stands (n=8 for each mortality treatment): 1) retain all ash (control), 2) simulated EAB mortality by girdling all ash, and 3) harvest of all ash. For girdling treatments, all trees within 2 acre patches will be girded using draw knives and pruning saws. Similarly, harvest treatments will involve 2 acre clearcuts of all trees. Comparisons between these treatments will allow for an assessment of the impacts of ash mortality on site hydrology and native vegetation communities. In addition, comparisons between harvest and EAB mortality treatments will allow for an evaluation of whether pre-emptive harvesting of black ash prior to EAB arrival has a greater impact on hydrology and vegetation than mortality of ash due to this introduced insect. Each treatment will be surrounded by a 5 acre, untreated buffer to minimize influence on adjacent treatments.

b) ***Planting*:** Each ash mortality treatment will be split with two levels of planting treatment: no planting and planting. For the planting treatments, we will plant seedlings of a range of native species most likely to grow within the wet forest conditions. Half of the seedlings will be planted the growing season prior to the implementation of the mortality treatments and the other half at the beginning of the growing season following treatment implementation. Evaluations of seedling survival and growth within each mortality treatment will allow for an assessment of which species may be able to serve as suitable replacement species on areas experiencing ash mortality from either EAB or preemptive harvests. In addition, assessments of seedling survival in unharvested stands will provide insight into which species could be underplanted within black ash communities to build site-level resilience to future EAB infestation.

Result 2: Determine the impacts of ash mortality from EAB on native plant communities, survival and growth of possible replacement tree species, spread of invasive species, and hydrologic patterns

Vegetation measurements

Within each ash mortality treatment, six 400 m^2 sampling plots will be established for collecting vegetation data, with each of the larger sampling plots split into 200 m^2 subplots for implementing planting treatments. All vegetation will be measured annually within a series of nested plots. The largest plot (400 m^2) will be used for sampling living and standing dead overstory trees (DBH $\geq$ 10 cm), recording species and DBH for all trees. Species and DBH will be recorded for all saplings (DBH $\geq$ 2.54 cm and < 10 cm) occurring within three nested 25 m^2 plots. Advance tree regeneration and shrubs (< 2.54 cm DBH and $\geq$ 0.15 cm tall) will be tallied by species and measured (diameter at 15 cm) in three, 10 m^2 subplots nested within the sapling plots. Tree seedlings of natural origin (<15 cm tall) within these plots will be tallied by species. Finally, percent cover of understory vegetation will be measured in 8 randomly located 1m^2

plots. All plot locations will be marked and photographed to allow for repeated measurements and interpretation of results over the duration of the study.

The survival and growth of all planted seedlings will be measured annually within the 200 m^2 subplots. Basal stem diameter and total height will be measured on each seedling. In addition, the presence of deer browse damage will also be recorded. Volumetric moisture will be measured periodically within the seedling subplots throughout the growing season using TDR moisture probes. Light availability will be assessed at the center of each 200 m^2 tree plot using a LAI-2000 plant canopy analyzer. Paired measurements in nearby open areas will allow for calculation of percent transmittance and leaf area index.

Hydrological measurements

Hydrological impacts of ash mortality treatments will be assessed with a series of piezometers (screened PVC tubing) installed at each plot. Groundwater tables will be continuously monitored with pressure transducers during the growing season to directly assess treatment effects on groundwater storage and transport. Diurnal variation in groundwater levels will be used to estimate transpiration at each treatment plot (Martinet et al. 2009, Loheide et al. 2005). Meteorological data (precipitation, temperature, wind speed, relative humidity, solar radiation) will be collected continuously to estimate surface and soil evaporation with the Penman equation. Estimates of evapotranspiration components will be used to model hydrologic impacts at a range of spatial scales under variable climate and management scenarios.

Result 3: Determine potential for spread of EAB into northern Minnesota

The potential for EAB to impact black ash communities in Minnesota hinges on the cold tolerance and reproductive biology of this insect. We will conduct laboratory experiments investigating the tolerance of EAB larvae to winter temperatures commonly occurring in northern Minnesota. We will measure (i) the supercooling point (SCP) of the insects (the temperature at which the insects freeze); (ii) the lower lethal temperature (the temperature at which 50% of the insects die; this temperature is expected to be warmer than the SCP for chill-intolerant insects); and (iii) lower lethal time (the time required for 50% of the insects to die at a particular life stage.

Larvae will be collected from St. Paul, MN in the spring from green ash. If inadequate numbers can be found, we will obtain larvae from a laboratory colony in Brighton, MI. We will then transfer larvae to cut bolts of un-infested green ash and black ash. Ash bolts will be screened with aluminum mesh and held indoors until late summer and then moved outside into a double enclosure field cage. A subset of larvae will be extracted, staged, and tested for cold hardiness. Bark from black and green ash will be peeled and larvae extracted in November, January, and March. All data will be analyzed with PROC LIFETEST in SAS.

For SCP measures, we will follow the methods of Carrillo et al. (2004). In brief for each overwintering life stage, insects will be held on a copper-constantan thermocouple with high vacuum grease. An insect and thermocouple will be placed in a polystyrene cube which will then be put into a -80°C freezer. Temperature is recorded once per second. SCP is the lowest temperature recorded before detecting the exotherm. We will measure SCP on ca. 20 early and late instars from each ash species (total n = 80 per month).

For lower lethal temperature measurements, we will follow the methods of Koch et al. (2004). Groups of 10 larvae of the same stage will be placed in a vial with a thermocouple. Larvae will be chilled at approximately -1°C/minute down to -5, -10, -15, or -20°C. After reaching the target temperature, larvae will be gradually warmed to 22°C and held in high humidity to prevent desiccation. Survivorship will be assessed after 24 hrs, 48 hrs, and 1 week and then allowing adults to eclose. We will test 30 individuals from each lifestage for each ash species (total n = 120 per month).

For lower lethal time measurements, we will prepare 39 vials each with 10 EAB larvae and EAB diet. Three vials will be held at 22°C (positive control). Twelve vials will be placed at 10, 7, and 4°C. At weekly intervals, one vial from each of the cool temperatures will be moved to 22°C. Afterwards, movement and development (measures of survival) will be monitored weekly for up to 6 weeks. Data will be analyzed with PROC LIFETEST in SAS.

Supercooling points, lower lethal temperatures and lower lethal times will then be compared with long-term climate records for more than 40 weather stations across Minnesota.

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

The deliverables of the project will be (1) operational-scale field experiments that will serve to inform scientists and land managers on the impacts of EAB on the structure and function of black ash forest systems; (2) datasets that enable an evaluation of the plant community, tree seedling, and hydrological responses of black ash systems to EAB-induced mortality and pre-emptive harvests of black ash; (3) recommendations regarding the tree species and management options that would result in the greatest level of resilience to EAB; (4) predictive models on the rate of EAB spread through northern Minnesota given current and future temperature regimes; and (5) policy-maker, land manager, and public education accomplished via a combination of conferencing, reports, seminars, and web-based information.

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

Result 1: Develop a network of research sites within black ash forests to assess impacts of EAB on biodiversity and productivity

Date	Milestone
July 2010	Project begins
October 2010	Black ash forest study sites are identified
November 2010	Pre-treatment measurements of forest conditions completed
March 2011	Treatment implementation completed (timber sales carried out and all trees girdled)

Result 2: Determine the impacts of ash mortality from EAB on native plant communities, survival and growth of possible replacement tree species, spread of invasive species, and hydrologic patterns

Date	Milestone
July 2010	Project begins
September 2010	Seedlings planted at all study sites
November 2010	Observational wells for hydrological measurements installed study sites
September 2011	2011 vegetation, planted seedling, and hydrological measurements completed
September 2012	2012 vegetation, planted seedling, and hydrological measurements completed
September 2013	2013 vegetation, planted seedling, and hydrological measurements completed
September 2014	2014 vegetation, planted seedling, and hydrological measurements completed
June 2015	Data synthesis complete, final report complete, project end

Result 3: Determine potential for spread of EAB into northern Minnesota

Date	Milestone
July 2010	Project begins
December 2010	2010 cold tolerance measurements completed
December 2011	2011 cold tolerance measurements completed
December 2012	Models of EAB spread complete

VII. Dissemination and Use

The final product of this project will be an interpretive report describing (a) the early impacts of black ash mortality on the native plant communities and hydrology of black ash forest systems in northern Minnesota, (b) the survival and growth of other tree species to conditions resulting from black ash mortality, and (c) predictive models of emerald ash borer spread based on cold tolerance and life cycle characteristics. This report will be made available on the internet as a Department of Forest Resources Staff Paper Report. In addition, several manuscripts will be written based on this research and submitted for publication in peer-reviewed journals. A fact sheet summarizing principal findings of this project will be distributed to LCCMR members and legislators at the state and federal level. Results will be presented at state and national forest management and forest health conferences, and notably to agency and individual participants in the Sustainable Forests Education Cooperative. All reports and publications from this project will be made available via the Department of Forest Resources web site.

VIII. Budget

The total budget request is 636,000 over a five-year period. These funds will be used to support salary and fringe for two graduate students; one for four years and the other for 2 years. Graduate fringe is budgeted at 0.7694 of salary load and includes tuition for the academic year, health care for the fiscal year, and social security and Medicare for 6.5 pay periods (summer). One of these graduate students will be responsible for collecting and analyzing vegetation data associated with Results 1 and 2, whereas the other graduate student will be responsible for Result 3. These funds are also for supporting salary and fringe (0.1812) for a post-doctoral research associate for four years. This post-doctoral research associate will be responsible for ecohydrological analyses and measurements associated with Results 1 and 2. Salary and fringe

(0.3230) for a research associate for three years (0.5 FTE) is also budgeted. This research associate will be responsible for identifying field sites, overseeing treatment implementation, and coordinating field research crews. Finally, salary and fringe (0.0743) for two summer students is budgeted for four years to assist with field measurements associated with Results 1 and 2. Note none of the requested funds are being used to pay any PI salaries.

A portion of the requested funds will be used for buying equipment associated with Results 1 and 2. Equipment includes rebar for permanently marking plot centers ($550), supplies for constructing wells for monitoring hydrology at each site ($15500), Haglof distance measuring equipment ($700), stake whiskers for marking subplots ($110), calipers for measuring seedling growth ($320), supplies for constructing frames for measuring understory vegetation ($150), draw knives and pruning saws for girdling trees ($1000), gloves for field crews girdling trees ($60), diameter tapes for measuring overstory trees ($150), and data loggers for micrometeorological measurements ($3460).

Due to the high number of study sites and logistics associated with establishing the harvest treatments and baseline data collection, $25,000 is budgeted for domestic travel within Minnesota. This money will be used to pay for mileage (75%) and lodging (25%) for researchers, the field technician, post-doc, graduate students, and undergraduate students. Mileage includes trips from UMN St. Paul campus to 8 field sites located across northern Minnesota.

BUDGET ITEM	**AMOUNT**
Personnel: Salary and 76.94% fringe for two graduate students; one for four years and the other for 2 years.	$208,460
Salary and 18.12 % fringe for a post-doctoral research associate for four years.	$225,282
Salary and 32.3% fringe for a research associate for three years (0.5 FTE)	$118,044
Salary and 7.43% fringe for two summer students for four years	$37,214
Equipment/Tools/Supplies	$22,000
Travel: This money will be used to pay for mileage (75%) and lodging (25%) for researchers, the field technician, post-doc, graduate students, and undergraduate students.	$25,000
TOTAL PROJECT BUDGET REQUEST TO LCCMR	$636,000

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ Being Applied to Project During Project Period: U.S. Forest Service "Evaluating black ash decline in the upper Midwest." Forest Health Monitoring Grants.	$160,000	*Secured*
In-kind Services During Project Period: In-kind salaries provided by researchers on the project. Trust fund is not being charged for these in-kind salaries.	$107,000	*Secured*

References

Cappaert, D., D. G. McCullough, and T. M. Poland. 2005. Emerald ash borer life cycle: a reassessment. Pages 19-20 *in* Mastro, V., and R. Reardon, comps. Proceedings of the emerald ash borer research and development meeting. US Forest Service, Forest Health Enterprise Team., Morgantown, WV.

Carrillo, M. A., N. Kaliyan, C. A. Cannon, R. V. Morey, and W. F. Wilcke. A simple method to adjust cooling rates for supercooling point determination. CryoLetters 2004. 25:155–160.

Ellison, A. M., M. S. Bank, B. D. Clinton, E. A. Colburn, K. Elliott, C. R. Ford, D. R. Foster, B. D. Kloeppel, J. D. Knoepp, G. M. Lovett, J. Mohan, D. A. Orwig, N. L. Rodenhouse, W. V. Sobczak, K. A. Stinson, J. K. Stone, C. M. Swan, J. Thompson, B. Von Holle, and J. R. Webster. 2005. Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. Frontiers in Ecology and the Environment **3**:479-486.

Erdmann, G. G., T. R. Crow, R. M. Peterson, and C. D. Wilson. 1987. Managing black ash in the Lake States. U.S. Dept. of Agriculture, Forest Service General Technical Report NC-115., St. Paul, Minn.

Kenis, M., M.-A. Auger-Rozenberg, A. Roques, L. Timms, C. Péré, M. Cock, J. Settele, S. Augustin, and C. Lopez-Vaamonde. 2009. Ecological effects of invasive alien insects. Biological Invasions **11**:21-45.

Liu, H. P., and L. S. Bauer. 2008. Microbial control of Agrilus planipennis (Coleoptera : Buprestidae) with Beauveria bassiana strain GHA: field applications. Biocontrol Science and Technology **18**:565-579.

Loheide, S. P., II, J. J. Butler Jr., and S. M. Gorelick (2005), Use of diurnal water table fluctuations to estimate groundwater consumption by phreatophytes: A saturated-unsaturated flow assessment. Water Resources Research, 41, W07030

Martinet, M. C., E. R. Vivoni, J. R. Cleverly, J. R. Thibault, J. F. Schuetz, and C. N. Dahm (2009), On groundwater fluctuations, evapotranspiration, and understory removal in riparian corridors. Water Resources Research, 45, W05425

McCullough, D. G., T. M. Poland, and D. Cappaert. 2009. Attraction of the emerald ash borer to ash trees stressed by girdling, herbicide treatment, or wounding. Canadian Journal of Forest Research **39**:1331-1345.

Mota-Sanchez, D., B. M. Cregg, D. G. McCullough, T. M. Poland, and R. M. Hollingworth. 2009. Distribution of trunk-injected C-14-imidacloprid in ash trees and effects on emerald ash borer (Coleoptera: Buprestidae) adults. Crop Protection **28**:655-661.

Poland, T. M., and D. G. McCullough. 2006. Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. Journal of Forestry **104**:118-124.

IX. Credentials

Biographical Sketches of Senior Personnel on Project

BIOGRAPHICAL SKETCH – Anthony W. D'Amato

Assistant Professor – Department of Forest Resources, University of Minnesota
1530 Cleveland Ave. North, St. Paul, MN 55108 – (612) 625-3733 – damato@umn.edu

Education and training

University of Maine	Forest Ecosystem Science	B.S., 2000
Oregon State University	Forest Science	M.S., 2002
University of Massachusetts	Forest Resources	Ph.D., 2007
University of Massachusetts	Forest Resources	Post-Doc, 2007

Research and professional experience

2007 –	Assistant Professor	University of Minnesota, St. Paul, MN
2007	Post-Doctoral Fellow	University of Massachusetts, Amherst, MA
2002–2006	Research Assistant	Harvard Forest, Harvard University/University of Massachusetts, Amherst, MA

5 Publications related to proposed project:

D'Amato, A.W., D.A. Orwig, and D.R. Foster. 2009. Understory vegetation in old-growth and second-growth *Tsuga canadensis* forests in western Massachusetts. *Forest Ecology and Management* 257: 1043-1052.

D'Amato, A.W., and D.A. Orwig. 2008. Stand and landscape-level disturbance dynamics in western Massachusetts. *Ecological Monographs* 78: 507-522.

D'Amato, A.W., D.A Orwig, and D.R. Foster. 2008. The influence of successional processes and disturbance on the structure of *Tsuga canadensis* forests. *Ecological Applications* 18: 1182-1199.

Puettmann, K.J., A.W. D'Amato, M. Arikian, and J.C. Zasada. 2008. Spatial impacts of soil disturbance and residual overstory on density and growth of regenerating aspen. *Forest Ecology and Management* 256: 2110-2120.

Orwig, D.A., R.C. Cobb, A.W. D'Amato, M.L. Kizlinski, and D.R. Foster. 2008. Ecosystem response to hemlock woolly adelgid outbreaks in southern New England forests. *Canadian Journal of Forest Research* 38: 834-844.

5 other peer-reviewed publications

Puettmann, K.J., A.W. D'Amato, U. Kohnle, and J. Bauhus. In press. Growth dynamics of *Abies alba* during repeated group shelterwood (Femelschlag) cuttings. *Canadian Journal of Forest Research.*

D'Amato, A.W., P. Catanzaro, D.A. Damery, D.B. Kittredge, and K. Ferrare. In press. Are family forest owners facing a future where forest management is not enough? *Journal of Forestry*

Kittredge, D.B., A.W. D'Amato, P.F. Catanzaro, J. Fish, and B. Butler. 2008. Estimating ownerships and parcels on non-industrial private forest in Massachusetts. *Northern Journal of Applied Forestry* 25: 93-98.

D'Amato, A.W., and K.J. Puettmann. 2004. The relative dominance hypothesis explains interaction dynamics in mixed species *Alnus rubra*/*Pseudotsuga menziesii* forests. *Journal of Ecology* 92: 450-463.

Puettmann, K.J., and A.W. D'Amato. 2002. Selecting plot sizes when quantifying growing conditions in understories. *Northern Journal of Applied Forestry* 19: 137-140.

Synergistic Activities

- Member, Black ash management guidelines development group, Minnesota Department of Natural Resources, 2009.
- Session organizer, Ecological classification systems in forests. 7th North American Forest Ecology Workshop, 2009.
- Field tour organizer and leader, Improving Productivity of Minnesota's Forest Resources. Workshop coordinated by the Minnesota Forest Resources Partnership, 2007.
- Member, Silviculture Task Force, coordinated by the Minnesota Forest Resources Partnership, 2007.
- In-coming chair, Forest and Range Ecology Working Group, Society of American Foresters
- Reviewer for several interdisciplinary scientific journals, including *Ecology, Ecological Applications, Forest Science, Journal of Ecology, Journal of Forestry, Northern Journal of Applied Forestry, Annals of Forest Science, The Journal of the Torrey Botanical Society,* and *Western Journal of Applied Forestry*

BIOGRAPHICAL SKETCH - 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
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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 *Ecologyy/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, PB , SE Hobbie, T Lee, DS Ellsworth, JB West, D Tilman, J Knops, S Naeem, J Trost. 2006. Nitrogen limitation constrains sustainability of ecosystem response to CO_2. Nature 440:922-925.

BIOGRAPHICAL SKETCH – Brian J. Palik

Team Leader and Research Ecologist, USDA Forest Service, Northern Research Station
1831 Hwy. 169 E, Grand Rapids, MN 55744 (Ph: 218-326-7116; e-mail: bpalik@fs.fed.us)

Education

Ph.D., Department of Forestry, Michigan State University, 1992, Forest Ecology.
M.S., Department of Botany, Michigan State University, 1988, Plant Ecology.
B.S., Alma College, 1983, Biology.
Organization for Tropical Studies, Costa Rica, 1987, Tropical Ecology.

Professional experience

2007-present: Team Leader, Northern Research Station, USFS, Grand Rapids, MN.
2002-2007: Project Leader, North Central Research Station, USFS, Grand Rapids, MN.
1996-2002: Research Ecologist, North Central Research Station, USFS, Grand Rapids, MN.
1993-1996: Assistant Scientist, Joseph W. Jones Ecological Research Center, Newton, GA.
Adjunct Faculty: University of Minnesota, Michigan Technological University, Iowa State University, Lakehead University

Publications related to proposed project

Palik, B., K. Cease, L. Egeland, and C. Blinn. 2003. Regeneration in Riparian Management Zones of Northern Hardwood-Aspen Forests: Effects of Residual Overstory and Harvest Method. Northern Journal of Applied Forestry 20: 79-84.

Goebel, P.C., B.J. Palik, and K.S. Pregitzer. 2003. Plant diversity contributions of riparian areas in watersheds of the northern Lake States, USA. Ecological Applications, 13:1595-1609.

Palik, B., Streblow, D., Egeland, L., and Buech, R. 2007. Landscape variation of seasonal pool plant communities in forests of northern Minnesota, USA. Wetlands 27: 12-23.

Ward, K, Ostry, M., Venette, R., Palik, B., Hansen. M., and Hatfield, M. 2008. Assessment of black ash decline in Minnesota. Proceedings of the 8th Annual Forest Inventory and Analysis Symposium. WO GTR 2008.

Palik, B. J.. amd Kastendick, D. 2009. Woody plant regeneration after blowdown, salvage logging, and prescribed fire in a northern Minnesota forest. Forest Ecology and Management 258: 1323-1330.

Five other publications

Palik, B. J., P. C. Goebel, L. K. Kirkman, and L. West. 2000. Using landscape hierarchies to guide restoration of disturbed ecosystems. Ecological Applications 10: 189-202.

Palik, B. J., R. J. Mitchell, and J. K. Hiers. 2002**.** Modeling silviculture after natural disturbance to maintain biological diversity: balancing complexity and implementation. Forest Ecology and Management: 155: 347-356.

Palik, B., R. J. Mitchell, S. Pecot, M. Battaglia, and P. Mou. 2003. Spatial distribution of overstory retention influences resources and growth of longleaf pine seedlings. Ecological Applications 13: 674-686.

Palik, Brian; Batzer, Darold, P.; Kern, Christel. 2006. Upland forest linkages to seasonal wetlands: litter flux, processing, and food quality. Ecosystems 9: 142-151.

Powers, M. D., Webster, C. R., Pregitzer, K. S., and Palik, B. J. 2009. Spatial dynamics of radial growth and growth efficiency in residual Pinus resinosa following aggregated retention harvesting. Can J. For. Res. 39: 109-117.

Synergistic Activities

2008-present: Research Needs Advisory Panel, Minnesota Forest Resources Council
2008-present: Chair, Forest Ecology and Range Working Group, Society of American Foresters
2007-present: Science Advisory Committee, Natural Resources Research Institute, U of MN.
2006: Technology Transfer Award, Northern Research Station, USFS
2004-present: Member, Riparian Science Technical Committee, MN Forest Resources Council.

2003-2009: Member-National Experimental Forest Working Group, USDA Forest Service.

2008-present: Resource Management and Use Research Advisory Panel, USDA Forest Service.

1998: Presidential Award for Early Career Scientists and Engineers
1997: Chief's Early Career Scientist Award, USDA Forest Service
Member, Society of American Foresters, Forest Guild

Peer Reviewer: Ecology, Can. J. For. Res., J. of Ecol., Am. Midl. Nat., J. of Veg. Sci., Biotropica, For. Ecol. Manage. J. of For. Res., Plant Eco., For. Sci., Cons. Ecol., Land. Ecol., For. Snow, Lands. Res., J. of For., J. Biog., Northwest Sci., New Forests, USDA Competitive Grants, NSF Competitive Grants, British Columbia Forest Service

BIOGRAPHICAL SKETCH-Robert A. Slesak

Minnesota Forest Resources Council
2003 Upper Buford Circle, St. Paul, MN 55108

Education

2008: Doctor of Philosophy in Forest Soil Science, Department of Forest Engineering, Oregon State University, Corvallis, OR

2004: Master of Science in Forest Ecosystem Science, State University of New York College of Environmental Science and Forestry, Syracuse NY

2002: Bachelors of Science in Forest Resources Management *summa cum laude*, co-salutatorian; State University of New York College of Environmental Science and Forestry, Syracuse, NY

2000: Associate of Applied Science in Forest Technology *magna cum laude*, salutatorian; State University of New York College of Environmental Science and Forestry - Ranger School, Wanakena, NY

Professional Experience

Current: Site-level Program Manager, Minnesota Forest Resources Council
2008: Post-Doctoral Associate, Department of Forest Engineering, Oregon State University
2005-2008: Graduate Research Assistant, Department of Forest Engineering, Oregon State University
2004: Watershed Program Assistant, Skaneateles Lake Watershed Agriculture Program
2003-2004: Graduate Research Assistant, Research Foundation of the State University of New York
2002: Forester (research branch) USDA Forest Service, Hubbard Brook Experimental Station

Publications

Slesak, R.A, T.B. Harrington, and S.H. Schoenholtz. In press. Soil and Douglas-fir (*Pseudotsuga menziesii*) foliar nitrogen responses to logging-debris retention and competing vegetation control in the Pacific Northwest. Canadian Journal Forest Research.

Slesak, R.A., S.H. Scheonholtz, T.B. Harrington, and B.D. Strahm. 2009. Dissolved carbon and nitrogen leaching following variable logging-debris retention and competing vegetation control in Douglas-fir plantations of western Oregon and Washington. Canadian Journal Forest Research 39:1484-1497.

Slesak, R.A. and R.D. Briggs. 2007. Christmas tree response to N fertilization and the development of critical foliar N levels in New York. Northern Journal Applied Forestry 24(3):209-217.

Slesak, R.A, S.H. Schoenholtz, T.B. Harrington, and N.A. Meehan. In review. Initial response of soil carbon and nitrogen to harvest intensity and competing vegetation control in Douglas-fir (*Pseudotsuga menziesii*) plantations of the Pacific Northwest. Forest Science.

Slesak, R.A, S.H. Schoenholtz, and T.B. Harrington. In review. Soil respiration and carbon responses to variable logging-debris retention and competing vegetation control in the Pacific Northwest. Soil Science Society America Journal.

Slesak, R.A. and R.D. Briggs. In review. Foliar mass and nutrition of *Abies concolor* Christmas trees following application of organic and inorganic fertilizer. Northern Journal Applied Forestry.

Awards and Activities

Arnold and Vera Meier Fellowship, Oregon State University, 2006
Alfred W. Moltke Scholarship, Oregon State University, 2006
Forestry Graduate Fellowship**,** College of Forestry, Oregon State University, 2005
College Scholar, SUNY ESF, 2002
New York State Scholarship of Academic Achievement, 2001
Wesson Award, SUNY ESF- Ranger School, 1999

In-coming co-chair, Soils Working Group, Society of American Foresters

Reviewer for *Forest Science*, *Forest Ecology and Management*, *Journal of Environmental Quality, Northern Journal of Applied Forestry*

BIOGRAPHICAL SKETCH-Robert Charles Venette

Northern Research Station
US Department of Agriculture, Forest Service
1561 Lindig Avenue, St. Paul, MN 55108
Office: 651-649-5028 email: rvenette@fs.fed.us

Education

1997	Ph.D., University of California, Davis, Ecology
1991	B.S., University of Minnesota, Minneapolis/St. Paul, Genetics and Cell Biology

Relevant Employment

2004-Present	Research Biologist, US Department of Agriculture, Forest Service & Adjunct Associate Professor, Department of Entomology, University of Minnesota
2001-2004	Research Assistant Professor, Department of Entomology, University of Minnesota
1999-2001	Adjunct Assistant Professor, Department of Entomology, University of Minnesota
1999-2001	Ecologist, US Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Center for Plant Health Science and Technology (USDA-APHIS-PPQ-CPHST), University of Minnesota, Minneapolis/St. Paul.
1997-1999	Postdoctoral Research Associate, Department of Entomology, University of Minnesota, Minneapolis/St. Paul
1991-1997	Research Assistant, Department of Nematology, University of California, Davis

Honors and Awards

2005	Accommodation for service to the national Commodity Agricultural Pest Survey program, USDA APHIS
2005	Service Award, Entomological Society of America
2003	Certificate of excellence, Section E, Entomological Society of America
2002	Service Award, Entomological Society of America
2001	Spot Award for contributions to risk assessment projects, US Dept. of Agriculture

Graduate Students

Abigail J. Walter, 2009 PhD, Entomology (co-advised with S. Kells). Thesis: Potential host use by the Mediterranean pine engraver on novel tree species.

Robert L. Koch, 2005 PhD, Entomology (co-advised with W.D. Hutchison). Thesis: Non-target effects of the multicolored Asian lady beetle, *Harmonia axyridis*, on monarch butterfly, *Danaus plexippus*, populations.

Michael Lopez, 2003 MBS, Biological Sciences. Thesis: Tapping into the maple sugaring tradition: perceptions of risk toward the Asian longhorned beetle (*Anoplophora glabripennis*) among Minnesota Anishinaabeg.

Synergistic Activities

Co-instructor, Interdisciplinary graduate minor on Risk Analysis for Introduced Species and Genotypes (ISG): ISG 5010, ISG 5020, ISG 8021, and ISG 8001

Co-Coordinator, Distributed Graduate Seminar, Economic Impact Assessment of Exotic Invasive Species in Forests, Sponsored by National Center for Ecological Analysis and Synthesis (2008)

Chair, Invasive Species Research Advisory Team, North Central Research Station, US Department of Agriculture, Forest Service (2004-2006).
Chair (2006) and Secretary (2004), USDA Regional Committee NCR-148, "Migration and dispersal of agriculturally important biota."
Subject Editor, Sampling and Biostatistics, Journal of Economic Entomology, 2002-2005

Relevant Publications (Selected from previous 5 years)

Venette, R.C., and Koch, R.L. 2009. IPM for exotic invasive species pp. 424 - 436. *In* E.B. Radcliffe, W.D. Hutchison, and R.E. Cancelado (eds). Integrated Pest Management. Cambridge University Press, Cambridge.

Gomez, N.N., Venette, R.C., Gould, J. and Winograd, D. 2009. A unified degree day model describes survivorship of *Copitarsia corruda* Pogue & Simmons (Lepidoptera: Noctuidae) at different constant temperatures. Bulletin of Entomological Research 99:65-72.

Venette, R.C., Walter, A.J., and Seybold, S.J. 2008. Comparing risks from native and exotic bark beetles to the health of Great Lakes forests. In: Proceedings, Society of American Foresters National Convention, Reno, NV, November 4-9, 2008.

Venette, R.C. 2008. Pine Commodity-Based Survey Reference. Cooperative Agricultural Pest Survey. Animal and Plant Health Inspection Service, U.S. Dept. of Agriculture. 187 pp. [Available on-line at: http://ceris.purdue.edu/caps/adm2008/adm2008000032.pdf]

Mehta, S.V., Haight, R.G., Homans, F.R., Polasky S., and Venette, R.C. 2007. Optimal detection and control strategies for invasive species management. Ecological Economics 61: 237-245.

Koch, R.L., Venette, R.C., and Hutchison, W.D. 2006. Predicted impact of an exotic generalist predator on monarch butterfly (Lepidoptera: Nymphalidae) populations: a quantitative risk assessment. Biological Invasions 8:1179-1193.

Koch, R.L., Venette, R.C., and Hutchison, W.D. 2006. Invasions by *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in the Western Hemisphere: Implications for South America. Neotropical Entomology 35:421-434.

Venette, R.C., and Cohen, S.D. 2006. Potential climatic suitability for establishment of *Phytophthora ramorum* within the contiguous United States. Forest Ecology and Management 231:18-26.

Venette, R.C., and Gould, J.R. 2006. A pest risk assessment for *Copitarsia* spp., insects associated with importation of commodities into the United States. Euphytica 148:165-183.

Gould, J., Venette, R., and Winograd, D. 2005. Effect of temperature on development and population parameters of *Copitarsia decolora* (Lepidoptera: Noctuidae). Environmental Entomology 34:548-556.

Koch, R.L., Venette, R.C., Hutchison, W.D. 2005. Influence of alternate prey on predation of monarch butterfly (Lepidoptera: Nymphalidae) larvae by the multicolored Asian lady beetle (Coleoptera: Coccinellidae). Environmental Entomology 34:410-416.

McCornack, B.P., Carillo., M.A., Venette, R.C., and Ragsdale, D.W. 2005. Physiological constraints on the overwintering potential of the soybean aphid (Homoptera: Aphididae). Environmental Entomology 34:235-240.