Proceedings: Workshop on the Future of Ash Forests

Science and Management of Ash Forests After Emerald Ash Borer

July 25-27, 2017
Duluth, Minnesota
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# Workshop Agenda

## Day 1 (Tuesday, July 25)

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<th>TIME</th>
<th>SESSION</th>
<th>PRESENTER</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:30</td>
<td>Registration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:50</td>
<td>Welcome</td>
<td>Randall Kolka (USDA-FS, NRS)</td>
<td></td>
</tr>
<tr>
<td>8:55</td>
<td>Opening Remarks I</td>
<td>Forrest Boe (Minnesota DNR)</td>
<td></td>
</tr>
<tr>
<td>9:05</td>
<td>Opening Remarks II</td>
<td>Kevin DuPuis (Fond du Lac Band)</td>
<td></td>
</tr>
<tr>
<td>9:15</td>
<td>Keynote Talk</td>
<td>Robert Venette (USDA-FS, NRS)</td>
<td>Where do we go with what we know about the ecology and management of emerald ash borer?</td>
</tr>
<tr>
<td>10:00</td>
<td>OS I-01</td>
<td>Ingrid Schneider (Univ. Minnesota)</td>
<td>Assessing urban forest visitor responses to emerald ash borer impacts &amp; management: a Minnesota example</td>
</tr>
<tr>
<td>10:20</td>
<td>OS I-02</td>
<td>Christopher Wynveen (Baylor Univ.)</td>
<td>Visitor perceptions of protected areas after tree-feeding beetle infestation</td>
</tr>
<tr>
<td>10:40</td>
<td>Coffee Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>OS I-03</td>
<td>Jason Kilgore (Washington &amp; Jefferson College)</td>
<td>Effects of ash loss on forest vegetation: Long-term monitoring at primarily undergraduate institutions (PUI's)</td>
</tr>
<tr>
<td>11:20</td>
<td>OS I-04</td>
<td>Daniel Kashian (Wayne State Univ.)</td>
<td>Will ash persist in the presence of emerald ash borer? Evidence from a multiple-year field study</td>
</tr>
<tr>
<td>11:40</td>
<td>OS I-05</td>
<td>Charles Flower (USDA-FS, NRS)</td>
<td>Effects of emerald ash borer on ash forests and considerations for forest management</td>
</tr>
<tr>
<td>12:00</td>
<td>Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:30</td>
<td>OS I-06</td>
<td>Mark Norris (Stevenson Univ.)</td>
<td>Community and ecosystem shifts following emerald ash borer outbreak in ash-dominated forests</td>
</tr>
<tr>
<td>1:50</td>
<td>OS I-07</td>
<td>Brian Palik (USDA-FS, NRS)</td>
<td>Evaluating replacement tree species in black ash forests threatened by EAB and climate change</td>
</tr>
<tr>
<td>2:10</td>
<td>OS I-08</td>
<td>Robert Slesak (Univ. Minnesota)</td>
<td>The impacts of emerald ash borer and silvicultural management strategies on black ash forest ground-layer communities</td>
</tr>
<tr>
<td>2:30</td>
<td>OS I-09</td>
<td>Joshua Davis (Michigan Tech.)</td>
<td>Vegetation responses to simulated emerald ash borer infestation in <em>Fraxinus nigra</em>-dominated wetlands: Implications for management</td>
</tr>
<tr>
<td>2:50</td>
<td>Coffee Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:10</td>
<td>OS I-10</td>
<td>Jacob Diamond (Virginia Tech.)</td>
<td>Six year effects of simulated emerald ash borer mortality and harvesting on black ash ecohydrology</td>
</tr>
<tr>
<td>3:30</td>
<td>OS I-11</td>
<td>Nicholas Bolton (Michigan Tech.)</td>
<td>Timing, microsite, site preparation, browse deterrent, and species selection for artificial regeneration within black ash dominated forest at risk of EAB infestation</td>
</tr>
<tr>
<td>3:50</td>
<td>OS I-12</td>
<td>Kathleen Knight (USDA-FS, NRS)</td>
<td>The survival and growth of planted tree seedlings in EAB-impacted floodplain forests depend on restoration methods and microsite factors</td>
</tr>
<tr>
<td>4:10</td>
<td>OS I-13</td>
<td>Christian Nelson (Fond du Lac Band)</td>
<td>Adapting to emerald ash borer: planting and assessing the survival, health, growth, and hydrological impacts of non-ash trees planted into black ash depressional wetlands</td>
</tr>
<tr>
<td>4:30</td>
<td>Poster Session</td>
<td>Core time for the odd numbered posters. All posters will be displayed for two days.</td>
<td></td>
</tr>
<tr>
<td>6:30</td>
<td>Welcome Dinner</td>
<td>Northern Lights Ballroom (~ 8:30 pm)</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Evening Registration - July 24 (Monday), 5:00 pm – 7:00 pm
## Workshop Agenda

### Day 2 (Wednesday, July 26)

<table>
<thead>
<tr>
<th>TIME</th>
<th>SESSION</th>
<th>PRESENTER</th>
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</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>Registration (– 8:50 am)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00</td>
<td>OS II-01</td>
<td>Jonathan Osthus (MDA)</td>
<td>Implementation of EAB biological control in Minnesota</td>
</tr>
<tr>
<td>9:20</td>
<td>OS II-02</td>
<td>Jian Duan (USDA-ARS)</td>
<td>Progress and challenges in protecting North American ash from the emerald ash borer through biological control</td>
</tr>
<tr>
<td>9:40</td>
<td>OS II-03</td>
<td>Kathleen Knight (USDA-FS, NRS)</td>
<td>The survivors: population dynamics of lingering ash and resistance to emerald ash borer</td>
</tr>
<tr>
<td>10:00</td>
<td>OS II-04</td>
<td>Mark Abrahamson (MDA)</td>
<td>When do you pull the trigger? Using monitoring data to optimize EAB management</td>
</tr>
<tr>
<td>10:20</td>
<td>Coffee Break</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:40</td>
<td>OS II-05</td>
<td>John Kotar (Univ. Wisconsin)</td>
<td>Ecological site classification system for wetland forests of northern Wisconsin</td>
</tr>
<tr>
<td>11:00</td>
<td>OS II-06</td>
<td>Colleen Matula (Wisconsin DNR)</td>
<td>Wisconsin’s black ash silviculture trials: field summary and management recommendations</td>
</tr>
<tr>
<td>11:20</td>
<td>OS II-07</td>
<td>Greg Edge (Wisconsin DNR)</td>
<td>A checklist for evaluating management options in lowland ash forest in Wisconsin</td>
</tr>
<tr>
<td>11:40</td>
<td>Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:30</td>
<td>Poster Session</td>
<td></td>
<td>Core time for the even numbered posters. All posters will be displayed for two days.</td>
</tr>
<tr>
<td>3:30</td>
<td>OS II-08</td>
<td>Dustin Bronson (Wisconsin DNR)</td>
<td>Remediation of post-EAB infested black ash stands in Wisconsin</td>
</tr>
<tr>
<td>3:50</td>
<td>OS II-09</td>
<td>Justin Pszwaro (TNC)</td>
<td>Long-term findings from the Wisconsin swamp hardwood trials: applying results to a new challenge</td>
</tr>
<tr>
<td>4:10</td>
<td>OS II-10</td>
<td>Paul Dubuque (Minnesota DNR)</td>
<td>Approaches for managing black ash forests in Minnesota</td>
</tr>
<tr>
<td>4:30</td>
<td>OS II-11</td>
<td>Anthony D’Amato (Univ. Vermont)</td>
<td>Recommendations for moving forward based on management experience and recent research in black ash wetlands</td>
</tr>
<tr>
<td>4:50</td>
<td>Panel Discussion on Operational Considerations (and Other Topics)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:30</td>
<td>Closing Remarks</td>
<td>Anthony D’Amato (Univ. Vermont)</td>
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</tbody>
</table>

**Notes:** We respectfully ask participants to be at the session room before 9:00 am.

### Day 3 (Thursday, July 27)

<table>
<thead>
<tr>
<th>TIME</th>
<th>GROUP A</th>
<th>GROUP B</th>
<th>GROUP C</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>Meet in Parking Lot of Inn on Lake Superior</td>
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</tr>
<tr>
<td>8:10</td>
<td>Stop I</td>
<td>Stop II</td>
<td>Stop III</td>
</tr>
<tr>
<td>11:00</td>
<td>Stop II</td>
<td>Stop III</td>
<td>Stop I</td>
</tr>
<tr>
<td>1:00</td>
<td>Lunch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td>Stop III</td>
<td>Stop I</td>
<td>Stop II</td>
</tr>
<tr>
<td>5:00</td>
<td>End Workshop (Canal Park)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** Tour will include box lunch and water. Participants for the field tours will be separated into three groups. Please check your group on your lanyard.
Opening Remarks

Forrest Boe serves as Director of Minnesota DNR Forestry since 2012. Boe has worked for the DNR in numerous leadership positions for 35 years. As Forestry Division director, Boe oversee a $70 million annual budget and a staff of 350 employees. Boe and his division are responsible for protecting people, property and natural resources from wildfire on 45.5 million acres of land in Minnesota. The division staff works with the forest products industry to provide 30 percent of the industrial wood fiber used in the state. The division also works to prevent disease and insect infestation on forest lands, and offers forest management assistance and advice to private forest landowners.

Boe began his DNR career in 1983 as a development specialist on the Root River Trail after earning a Bachelor of Science degree in natural resource management from University of Wisconsin-Stevens Point. In 1986, he became a supervisor for the Trails and Waterways Division in Brainerd. He became the division’s regional manager working out of Bemidji in 2001 and division director in 2006. When that division was merged with the Parks Division, Boe was appointed deputy director of the new Parks and Trails Division. He spent 20 years of his career in northern Minnesota with the agency’s former Trails and Waterways Division.

Kevin R. Dupuis Sr, serves as Chairman of the Fond du Lac Band (FDLB) of Lake Superior Chippewa since his election to that position in 2016. In that capacity, he is committed to improve the lives of the Band’s 4,200 members and the overall community of 7,300 Indian people who rely on the services that are provided by the Band in the region. In addition to serving as Chairman of the FDLB, Mr. Dupuis was, in 2016, also elected to serve as the President of the Minnesota Chippewa Tribe, which is comprised of the FDLB along with five other Chippewa Bands in Minnesota.

Mr. Dupuis has devoted his life to his people and his country. He served in the U.S. Marine Corps for eight years (1982-1990). After completing basic training, he volunteered for Marine Reconnaissance and was first stationed at Camp Talega Camp Pendleton CA. Thereafter he served as an instructor for ship defense force at the Naval Amphibious Base in Little Creek VA, and later as a reconnaissance instructor at Fort Story VA and then Camp Lejeune NC. He also was deployed overseas. As Mr. Dupuis has stated, “I have been given the greatest honor I believe a man can achieve and that is to lead my brothers in arms.” Following his honorable discharge in June of 1990, Mr. Dupuis returned home to the Fond du Lac Reservation where he has been actively involved in the Fond du Lac community and has studied the Band’s Treaties with the United States, along with tribal law and the principles of Indian law that affect tribal rights and responsibilities. In 2002, he ran for and was elected to Tribal office, serving as the Secretary/Treasurer of the FDLB for four years (2002-2006). Several years later, he was again elected as a Council member representing the Reservation’s Brookston District (2012-2016). At other times he has worked for the Band’s various business enterprises, as a cement mason and construction foreman, and as part of the security staff for the Band’s gaming enterprises. For several years he also worked on an oil rig in North Dakota. Through all his work, Mr. Dupuis has been guided by the teachings of his Anishinaabe grandfathers: humility (dabaađendiziwin), bravery (aakwa’ode’ewin), honesty (gwékwaadziwin), wisdom (niibwaakaawin), truth (dewbewin), and love (zaagidwin).
Keynote Talk

July 25, 2017, 9:15 am – 10:00 am

“Where do we go with what we know about the ecology and management of emerald ash borer?”

Robert Venette serves as Director for the Minnesota Invasive Terrestrial Plants and Pests Center (MITPPC) in College of Food, Agricultural and Natural Resource Sciences, University of Minnesota (UMN) since 2015. Venette is a research biologist for the USDA Forest Service and adjunct associate professor in the Department of Entomology, UMN. Venette provides intellectual leadership and administrative guidance to ensure the center is focused on with working closely with non-profit and for profit sectors, government and other educational and research organizations in shaping and fostering the center’s research. Venette also support policy making, application, and resource management practices and address the invasive species affecting Minnesota’s forests, prairies, urban landscapes and agricultural ecosystems.

Venette holds a Ph.D in ecology from the University of California-Davis and a B.S. in genetics and cell biology from the University of Minnesota. After working as a postdoctoral research associate at the University of Minnesota, Venette began his career in 1999 as an ecologist in the USDA, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Center for Plant Health Science and Technology. He later accepted the position of research assistant professor in the entomology department. Since 2004 he has worked as a research biologist for the USDA Forest Service located on the UMN St. Paul campus. He also serves as a member of the graduate faculty in entomology, biological sciences and natural resources science and management.

In his career, he’s been awarded nearly $10 million in grants for the study of invasive species that affect trees or agriculture. For nearly 15 years he has served on federal committees with the USDA APHIS. His keynote talk from extensive researches in invasive species risk assessment and control will give participants insights to better manage ash forests threatened by the emerald ash borer (EAB) and post-EAB ash forests. (See the abstract)
Oral Presentation List

Session I

OS I-01  Assessing Urban Forest Visitor Responses to Emerald Ash Borer Impacts & Management: a Minnesota Example
Ingrid E. Schneider¹*, Arne Arnberger², Renate Eder², Robert C. Venette¹, Stephanie A. Snyder¹, Paul H. Gobster¹, Ami Choi¹, Stuart Cottrell¹
¹University of Minnesota, ²University of Natural Resources and Life Sciences, ³USDA Forest Service, NRS, ⁴Colorado State University

OS I-02  Visitor Perceptions of Protected Areas after Tree-feeding Beetle Infestation
Christopher J. Wynveen¹*, Ingrid E. Schneider², Arne Arnberger³
¹Baylor University, ²University of Minnesota, ³University of Natural Resources and Life Sciences

OS I-03  Effects of Ash Loss on Forest Vegetation: Long-term Monitoring at Primarily Undergraduate Institutions (PUI’s)
Jason S. Kilgore¹*, Benjamin J. Dolan²
¹Washington & Jefferson College, ²The University of Findlay

OS I-04  Will Ash Persist in the Presence of Emerald Ash Borer? Evidence from a Multiple-Year Field Study
Daniel M. Kashian
Wayne State University

OS I-05  Effects of Emerald Ash Borer on Ash Forests and Considerations for Forest Management
Kathleen S. Knight¹*, Charles E. Flower¹*, Brian M. Hoven², Kyle C. Costilow³, Matt Higham², Valerie E. Peters¹, David L. Gorchov², Robert P. Long¹
¹USDA Forest Service, NRS, ²Miami University, ³USDA APHIS, ⁴Eastern Kentucky University

OS I-06  Community and Ecosystem Shifts following Emerald Ash Borer Outbreak in Ash-dominated Forests
Mark D. Norris
Stevenson University

OS I-07  Evaluating Replacement Tree Species in Black Ash Forests Threatened by EAB and Climate Change
Brian J. Palik¹*, Anthony D’Amato³, Christopher Looney³, Robert A. Slesak¹, Mitchell A. Slater¹
¹USDA Forest Service, NRS, ²The University of Vermont, ³University of Minnesota, ⁴Minnesota Forest Resources Council
OS I-08  The Impacts of Emerald Ash Borer and Silvicultural Management Strategies on Black Ash Forest Ground-layer Communities
Christopher E. Looney¹, Anthony W. D’Amato², Brian J. Palik³, Robert A. Slesak⁴*, Mitchell A. Slater³
¹University of Minnesota, ²The University of Vermont, ³USDA Forest Service, NRS, ⁴Minnesota Forest Resources Council

OS I-09  Vegetation Responses to Simulated Emerald Ash Borer Infestation in Fraxinus nigra-dominated Wetlands: Implications for Management
Joshua C. Davis¹*, Joseph P. Shannon¹, Nicholas W. Bolton¹, Randall K. Kolka², Thomas G. Pypker³
¹Michigan Technological University, ²USDA Forest Service, NRS, ³Thompson Rivers University

OS I-10  Six Year Effects of Simulated Emerald Ash Borer Mortality and Harvesting on Black Ash Ecohydrology
Jacob S. Diamond¹*, Robert Slesak², Daniel McLaughlin³, Tony D’Amato⁵, Brian Palik⁶
¹Virginia Polytechnic Institute, ²University of Minnesota, ³Virginia Polytechnic Institute
⁴The University of Vermont, ⁵USDA Forest Service, NRS

OS I-11  Timing, Microsite, Site Preparation, Browse Deterrent, and Species Selection for Artificial Regeneration within Black Ash-dominated Forest at Risk of EAB Infestation
Nicholas W. Bolton¹*, Joshua C. Davis¹, Joseph P. Shannon¹, Matthew G. Van Grinsven², Nam Jin Noh¹, Shon S. Schooler³, Joseph W. Wagenbrenner⁴, Randall K. Kolka⁵, Thomas G. Pypker⁶
¹Michigan Technological University, ²Northern Michigan University, ³Lake Superior National Estuarine Research Reserve, ⁴USDA Forest Service, Pacific Southwest Research Station, ⁵USDA Forest Service, NRS, ⁶Thompson Rivers University

OS I-12  The Survival and Growth of Planted Tree Seedlings in EAB-impacted Floodplain Forests Depend on Restoration Methods and Microsite Factors
Kathleen S. Knight¹*, Rachel Hefflinger², Robert Ford³, Kelly Baggett¹, James M. Slavicek¹
¹USDA Forest Service, NRS, ²Metroparks of the Toledo Area, ³The City of Columbus Division of Fire

Christian Nelson¹*, Shannon Kesner
Fond du Lac Band of Lake Superior Chippewa
Session II

**OS II-01** Implementation of EAB Biological Control in Minnesota  
Jonathan Osthus¹, Angie Ambourn¹, Chris Mallet¹, Monika Chandler¹, Brian Aukema², Rob Venette³  
¹Minnesota Department of Agriculture, ²University of Minnesota, ³USDA Forest Service, NRS

**OS II-02** Progress and Challenges in Protecting North American Ash from the Emerald Ash Borer through Biological Control  
Jian J. Duan¹*, Leah S. Bauer², Roy van Driesche³  
¹USDA, Agricultural Research Service, Beneficial Insects Introduction Research Unit, ²USDA Forest Service, NRS, ³University of Massachusetts

**OS II-03** The Survivors: Population Dynamics of Lingering Ash and Resistance to Emerald Ash Borer  
Kathleen S. Knight¹*, Jennifer L. Koch¹, Rachel Kappler², David W. Carey¹, Mary E. Mason³, Therese M. Poland¹  
¹USDA Forest Service NRS, ²Bowling Green State University, ³The Ohio State University

**OS II-04** When Do You Pull the Trigger? Using Monitoring Data to Optimize EAB Management  
Mark Abrahamson¹*, Angie Ambourn¹, Chris Mallet¹, Aubree Kees², Sam Fahrner², Brian Aukema², Rob Venette³  
¹Minnesota Department of Agriculture, ²University of Minnesota, ³USDA Forest Service, NRS

**OS II-05** Ecological Site Classification System for Wetland Forests of Northern Wisconsin  
John Kotar¹*, Colleen Matula²  
¹University of Wisconsin-Madison, Emeritus, ²Wisconsin Department of Natural Resources

**OS II-06** Wisconsin’s Black Ash Silviculture Trials: Field Summary and Management Recommendations  
Colleen F. Matula  
Wisconsin Department of Natural Resources

**OS II-07** A Checklist for Evaluating Management Options in Lowland Ash Forest in Wisconsin  
Greg Edge  
Wisconsin Department of Natural Resources
OS II-08 Remediation of Post-EAB Infested Black Ash Stands in Wisconsin
Dustin R. Bronson1*, Laura Reuling1, Robert A. Slesak2, Anthony W. D’Amato3
1Wisconsin Department of Natural Resources, 2Minnesota Forest Resources Council, 3The University of Vermont

OS II-09 Long-term Findings from the Wisconsin Swamp Hardwood Trials: Applying Results to a New Challenge
Justin L. Pszwaro1*, Anthony W. D’Amato2, Brian J. Palik3, Robert A. Slesak4, Greg Edge5, Colleen F. Matula6, Dustin R. Bronson3
1The Nature Conservancy, 2University of Vermont, 3USFS Northern Research Station, 4Minnesota Forest Resources Council, 5Wisconsin Department of Natural Resources

OS II-10 Approaches for Managing Black Ash Forests in Minnesota
Paul Dubuque
Minnesota Department of Natural Resources

OS II-11 Recommendations for Moving Forward based on Management Experience and Recent Research in Black Ash Wetlands
Anthony W. D’Amato1, Brian J. Palik2, Robert A. Slesak3, Greg Edge4, Colleen F. Matula4
1University of Vermont, 2USDA Forest Service, Northern Research Station, 3Minnesota Forest Resources Council, 4Wisconsin Department of Natural Resources
PS-01  The Future of Ash - Creative Research Project  
Kelly van Frankenhuyzen  
*Michigan State University*

PS-02  Plasticity in Cold Tolerance of Overwintering Emerald Ash Borer  
Robert C. Venette¹, Kathleen S. Knight¹*, Charles E. Flower²  
¹USDA Forest Service, NRS, ²University of Illinois at Chicago

PS-03  Potential Effects of Emerald Ash Borer Invasion on Wetland Community Composition  
Melissa B. Youngquist¹*, Sue L. Eggert², Anthony W. D'Amato³, Brian J. Palik², Robert A. Slesak¹, Mitchell Slater³  
¹University of Minnesota, ²USDA Forest Service, NRS, ³The University of Vermont

PS-04  Linking Emerald Ash Borer to Changes in Ecosystem Function: How Changes in Litter Quality May Influence Leaf Decomposition and Invertebrate Growth  
Melissa B. Youngquist¹*, Chandra Wiley¹, Sue L. Eggert², Anthony W. D'Amato³, Brian J. Palik², Robert A. Slesak¹, Mitchell Slater³  
¹University of Minnesota, ²USDA Forest Service, NRS, ³The University of Vermont

PS-05  Emerald Ash Borer Induced Ash Decline and its Effects on Belowground Nutrient and Microbial Community Dynamics  
Charles E. Flower¹*, Michael P. Ricketts², Kathleen S. Knight¹, Robert P. Long¹, Miquel A. Gonzalez-Meler³  
¹USDA Forest Service, NRS, ²University of Illinois at Chicago

PS-06  EAB-induced Tree Mortality Impacts on Ecosystem Respiration and Tree Water Use in an Experimental Forest  
Charles E. Flower¹*, Douglas J. Lynch², Kathleen S. Knight¹, Miquel A. Gonzalez-Meler³  
¹USDA Forest Service, NRS, ²Licor Biosciences, ³University of Illinois at Chicago

PS-07  Water Level Controls on Transpiration of Co-dominant Species in Black Ash Wetlands  
Joseph P. Shannon¹*, Joshua C. Davis¹, Matthew Van Grinsven², Nicholas Bolton¹, Nam Jin Noh¹, Thomas G. Pypker³, Randall K. Kolka¹, Joseph W. Wagenbrenner⁵  
¹Michigan Technological University, ²Northern Michigan University, ³Thompson Rivers University, ⁴USDA Forest Service, NRS, ⁵USDA Forest Service, Pacific Southwest Research Station
PS-08  Responses of Dissolved Carbon and Nitrogen Concentrations to Simulated Emerald Ash Borer Infestation in a Black Ash-dominated Paired Watershed
Nam Jin Noh1*, Matthew Van Grinsven1,2*, Joseph P. Shannon1, Nicholas W. Bolton1, Joshua C. Davis1, Stephen Sebestyen3, Thomas G. Pypker4,5, Randall K. Kolka3, Joseph W. Wagenbrenner1,5
1Michigan Technological University, 2Northern Michigan University, 3USDA Forest Service, NRS, 4Thompson Rivers University, 5USDA Forest Service, Pacific Southwest Research Station

PS-09  Black Ash Wetland Watershed Hydrology and Soil Biogeochemistry Responses to a Simulated Emerald Ash Borer Infestation
Matthew Van Grinsven1,2*, Joseph Shannon2, Evan Kane3,4, Nicholas Bolton2, Joshua Davis3, Nam Jin Noh2, Joseph Wagenbrenner2,3, Stephen Sebestyen1, Randall Kolka4, Thomas Pypker2,5
1Northern Michigan University, 2Michigan Technological University, 3USDA Forest Service, Pacific Southwest Research Station, 4USDA Forest Service, NRS, 5Thompson Rivers University

PS-10  Temperature and Water Level Effects on Greenhouse Gas Fluxes in Soil Cores from Black Ash (Fraxinus nigra) Wetlands in the Northern Great Lake States, USA
Alan J. Toczydlowski1*, Robert A. Slesak2, Randall K. Kolka3
1University of Minnesota, 2Minnesota Forest Resources Council, 3USDA Forest Service, NRS

PS-11  Soil Carbon and Nitrogen Pools across a Range of Black Ash Wetlands
Randy K. Kolka1*, Alan J. Toczydlowski2, Robert A. Slesak3
1USDA Forest Service, NRS, 2University of Minnesota, 3Minnesota Forest Resources Council

PS-12  The Effect of Emerald Ash Borer (Agrilus planipennis)-caused Tree Mortality on the Invasive Shrub Amur honeysuckle (Lonicera maackii) and their Combined Effects on Woody Seedlings
Brian M. Hoven1, David L. Gorchov1, Kathleen S. Knight2*, Valerie E. Peters3
1Miami University, 2USDA Forest Service, NRS, 3Eastern Kentucky University

PS-13  The Great Lakes Silviculture Library: A Tool to Link Management Practices for EAB within the Region
Marcella A. Windmuller-Campione1, Matthew Russell1,2*, Eli Sagor2, Kris Tiles3
1University of Minnesota, 2Sustainable Forests Education Cooperative, 3University of Wisconsin

PS-14  Density Dependent Survival of White Ash (Fraxinus americana) at the Allegheny National Forest
Eli D. Aubihl1*, Charles E. Flower2, Kathleen S. Knight2, Steve Forry3, Andrea Hille3, Alejandro Royo1, William Oldland4
1Miami University, 2USDA Forest Service, NRS, 3USDA Forest Service, Allegheny National Forest, 4USDA Forest Service, State and Private Forestry
Ash Mortality in a New Infestation of EAB is not Instantaneous
Aubree M. Kees*, Jonathan Osthus2, Monika Chandler2, Angie Ambourn2, Mark Abrahamson2, Robert C. Venette3, Brian H. Aukema1
1University of Minnesota, 2Minnesota Department of Agriculture, 3USDA Forest Service, NRS

Potential Species Replacements for Black Ash (Fraxinus nigra) at the Confluence of Two Threats: Emerald Ash Borer and a Changing Climate
Louis R. Iverson1, Kathleen S. Knight1*, Anantha M. Prasad1, Stephen N. Matthews1, Matthew P. Peters1, Daniel A. Herms3, Diane M. Hartzler2, Robert Long3, Annemarie Smith4, John Almendinger5
1USDA Forest Service, NRS, 2The Ohio State University, 3USDA Forest Service, NRS, 4Green Building Council, Central Ohio Chapter, 5Minnesota Department of Natural Resources

In-situ Genetic Conservation of White Ash through Insecticide Treatment at the Allegheny National Forest
Charles E. Flower1*, Jeremie Fant2, Kathleen S. Knight1, Laura Steger2, Steve Forry1,3, Andrea Hille1,3, Alejandro Royo1, Eli Aubihl1, William Oldland1,5
1USDA Forest Service, NRS, 2Chicago Botanic Gardens, 3Allegheny National Forest, 4Miami University, 5State and Private Forestry

What Can Biosurveillance for Emerald Ash Borer Tell Us about Other Native Tree Pests and Forest Condition?
Marie J. Hallinen*, Brian H. Aukema†
University of Minnesota

How Low Can You Go? Optimizing Systemic Insecticide Coverage for Tree Protection
Dora M. Mwangola*, Brian H. Aukema†
University of Minnesota

Potential Impacts of Emerald Ash Borer Biocontrol on Ash Health and Recovery in Southern Michigan
Daniel M. Kashian1*, Leah S. Bauer2, Benjamin A. Spei1, Jian J. Duan3
1Wayne State University, 2USDA Forest Service, NRS, 3USDA, Agricultural Research Service, Beneficial Insects Introduction Research Unit

Biomass and Sapwood of Green Ash (Fraxinus pennsylvanica) in the Twin Cities Metro Area
Derik Olson
University of Minnesota
Where do we go with what we know about the ecology and management of the emerald ash borer?

Robert C. Venette

USDA Forest Service, Northern Research Station
Minnesota Invasive Terrestrial Plants and Pests Center

Emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is the most destructive insect to have invaded North America. Information about the ecology and management of the insect has increased dramatically since 2002, when the insect was first detected in Michigan and Ontario. Much of that research suggests a bleak future for nearly all ash (Fraxinus spp.). Most North American ash species, including green ash (*F. pennsylvanica*) and black ash (*F. nigra*), are highly susceptible to emerald ash borer, and native natural enemies seem unable to keep populations of emerald ash borer in check. Results from monitoring studies consistently report that nearly 100% of ash are killed shortly after the insect arrives. Effective management depends on early detection, which has relied on visually-attractive traps for adults and/or inspections and dissections of trees for larvae or damage. Current management options include removing and destroying infested trees, treating surviving trees with insecticides, or biological control. Perspectives on preemptive management through phloem reduction are varied. The Slow-Ash-Mortality (SLAM) approach, wherein multiple management techniques are integrated to preserve ash, has proven effective. Most of these insights come from research in Michigan, Ohio, and Indiana. Management recommendations need to be tailored to conditions that are unique to Minnesota, where statewide spread, and subsequent tree mortality, have been slower than initially projected. Early detection, aggressive management, and cold winters likely contribute to these differences. In northern Minnesota, in particular, the future fate of ash is highly uncertain. Management strategies for ash are need that build on principles from Integrated Pest Management and are not driven by fear or apathy to the future impact of emerald ash borer.

Presenting Author: rvenette@fs.fed.us
Assessing urban forest visitor responses to emerald ash borer impacts & management: a Minnesota example

Ingrid E. Schneider1*, Arne Arnberger2, Renate Eder2, Robert C. Venette1,3, Stephanie A. Snyder3, Paul H. Gobster3, Ami Choi4, Stuart Cottrell4

1University of Minnesota, USA
2Institute of Landscape Development, Recreation and Conservation Planning University of Natural Resources and Life Sciences, Vienna, Austria
3USDA Forest Service, Northern Research Station, USA
4Human Dimensions of Natural Resources, Colorado State University, USA

Extensive outbreaks of the emerald ash borer (Agrilus planipennis; EAB) are having major impacts on the ecosystem services of forests. While environmental and economic research on EAB abounds, social research relating to cultural ecosystem services, such as recreation and aesthetics, is limited. To address this gap, multiple methods solicited visitors’ perceptions of EAB-impacted forests in an urban setting. First, interviews assessed how visitors responded to EAB-impacted landscapes. Second, a photo-based questionnaire was designed to simulate different levels of EAB impact and management treatments relative to other physical and social site attributes. Results from a sample of visitors to Fort Snelling State Park in Minneapolis-St. Paul, MN indicated visitors have varied responses to EAB impacts, visitation may be impacted but the relative impact of EAB is less important than surrounding viewscape development and visitor numbers. Specifically, stated choice modelling revealed respondents preferred dense trailside shrub vegetation and few trail users and disliked viewscapes showing city buildings and removal of most ash trees. As such, results suggest trail planning should not only consider near-view landscape impacts but also the visual quality of more distant viewscapes, and that urban forest managers need to be aware of how forest insect impacts and subsequent management responses affect recreation setting preferences.

*Presenting Author: ingridss@umn.edu
Visitor perceptions of protected areas after tree-feeding beetle infestation

Christopher J. Wynveen*, Ingrid E. Schneider2, Arne Arnberger3

1Baylor University
2University of Minnesota
3University of Natural Resources and Life Sciences, Vienna, Austria

Ongoing research concerning the biological and ecological impacts of the emerald ash borer, *Agrilus planipennis*, and other beetles (e.g., spruce bark beetles, *ips typographus*) continues. However, there has been less research regarding the social impacts and management of these beetles. One concept used to understand people’s perceptions of negative environmental impacts is place attachment—the intensity of the human-place bond (Kyle et al., 2003). Past research has shown impacts are correlated with a decrease in place attachment (Stedman, 2003; Vorkinn & Riese, 2001). However, for those already attached to a setting, researchers observed a positive association between place attachment and awareness of negative environmental impacts and propensity to seek information about the impacts’ mitigation (Wynveen et al., 2015). Hence, this investigation sought to identify the relationship among protected area visitors’ perceptions of the presence of beetle impact at two sites (Minnesota & Austria), common antecedents to place attachment, the respondents’ intensity of place attachment to the protected area, and in turn, the respondents’ self-reported knowledge about the beetle. Data were collected via on-site instruments (via English—German back-translation) to protected area visitors in the select countries. A series of confirmatory factor analyses and OLS and logistic regression analyses were used to identify and describe the relationship between the constructs. Results indicated that perceptions of beetle impacts were negatively associated with place attachment, but higher levels of attachment were associated with greater knowledge of bark beetles. Implications for managers seeking to engage stakeholders to mitigate bark beetle impacts will be discussed.

*Presenting Author: chris_wynveen@baylor.edu
Effects of ash loss on forest vegetation: long-term monitoring at primarily undergraduate institutions (PUI’s)

Jason S. Kilgore\textsuperscript{1*}, Benjamin J. Dolan\textsuperscript{2}

\textsuperscript{1}Washington & Jefferson College
\textsuperscript{2}The University of Findlay

Initially detected in North America in 2002, emerald ash borers (EAB, \textit{Agrilus planipennis}) have since been detected in 29 US states and 2 Canadian provinces where the phloem-feeding beetle causes widespread mortality of all native ash (\textit{Fraxinus} spp.). The loss of an entire plant genus from the forest flora is a major disturbance but with varying effects due to differences in ash dominance and remaining species. We are investigating impacts of changes in light availability on seedling density and composition, sapling growth rates, and invasive plant community. We utilize long-term research plots developed for the Permanent Forest Plot Project of the Ecological Research as Education Network (EREN), a consortium of over 230 primarily undergraduate institutions (PUI’s). We developed variables to quantify ash condition (EAB Impacts Study) and understory light environment and plant community (cVeg); all protocols can be found online at erenweb.org. At each site, data are collected by faculty and undergraduate students; on-site meetings and web-based technologies are used to enhance interinstitutional communication. Although this project is recently (2012) initiated with variable EAB infestation and frequency of data collection at the seven sites, we have observed positive associations of ash loss with seedling density, proportion of shade-intolerant tree species in the understory, and invasive plant density. As EAB continues to spread through forests of North America and data from additional sites are contributed to this collaborative project, we expect to further elucidate the role of factors such as prior vegetation composition, soil differences, and geographic location.

\textbf{Presenting Author:} jkilgore@washjeff.edu
Will ash persist in the presence of emerald ash borer? Evidence from a multiple-year field study

Daniel M. Kashian

Wayne State University

Emerald ash borer (EAB) has killed millions of trees near its introduction point in southeastern Michigan, and several researchers have predicted at least a functional elimination of green ash and other ash species from the landscape. Data that confirm the likelihood or unlikelihood of ash persistence in the presence of EAB is critical to justify intensive management in yet unaffected ash forests. I examined the potential for persistence of green ash in the presence of EAB by measuring surviving trees, regeneration, and seed rain characteristics in 17 small, near-pure stands of green ash in five consecutive growing seasons in southeastern Michigan. Ash mortality in these stands (58%) was significantly less than that reported for ash in mixed stands, although 20% of surviving ash still exhibited signs of EAB. Stump sprouting was very common, some (27%) producing seeds during a mast year, and advanced regeneration and new seedlings were significant over the five years of the study even when considering sapling and seedling mortality. Seed production was reduced compared to pre-EAB conditions but seed dispersal did not appear to limit seedling recruitment. Thus the seed-producing ability of small trees and basal sprouts may allow green ash to persist in the presence of EAB, although green ash populations and individual trees are unlikely to ever resemble the stature of those prior to EAB. The relationship between EAB and ash species remains fluid within the core outbreak area, but care should be taken when making genus-level predictions about future conditions of ash.

Presenting Author: dkash@wayne.edu
Effects of emerald ash borer on ash forests and considerations for forest management

Kathleen S. Knight†, Charles E. Flower*, Brian M. Hoven2, Kyle C. Costilow3, Matt Higham2, Valerie E. Peters4, David L. Gorchov2, Robert P. Long1

1USDA Forest Service, Northern Research Station
2Miami University
3USDA APHIS
4Eastern Kentucky University

The emerald ash borer (EAB) has decimated populations of multiple species of ash and threatens to alter forest ecosystems where ash is a dominant tree species. A decade of data from forest monitoring plots across Ohio provides high temporal resolution information on the effects of EAB across a range of ash forest ecosystems. The plots represent a gradient of ash density and all five ash species native to Ohio. Yearly data on ash mortality, ash tree fall, ash regeneration, EAB population density, native and non-native plant species and a snapshot of increases in coarse woody debris provide a multi-dimensional picture of the effects of EAB across a range of forest ecosystems. The results show that nearly all mature ash trees in the stand can progress from healthy to dead within 3-6 years, during which time the EAB population builds, peaks, and then crashes to low densities but persists. Stands with greater densities of dead ash trees experienced larger changes in carbon budgets and invasive shrub growth rates. Other forest stands exhibited resilience as forest gaps were filled by rapid growth of native trees. The results show which ecosystems are likely to experience impacts, as well as the timing of those impacts, allowing managers to tailor forest management strategies in forests affected by EAB.

*Presenting Author: charlesflower@fs.fed.us
†Corresponding Author: ksknight@fs.fed.us
Community and ecosystem shifts following emerald ash borer outbreak in ash-dominated forests

Mark D. Norris

Stevenson University

The prevalence of ash trees (Fraxinus species) in forests of western New York are concerning given the spreading population of the emerald ash borer (EAB, Agrilus planipennis). Our objectives were to evaluate both community and ecosystem-level consequences of simulated EAB outbreaks via girdling as well as in actual infestations, comparing these to adjacent control plots of unimpacted ash and/or non-ash stands. In each plot, we have examined the forest community composition and structure as well as various ecosystem-level variables including C dynamics and microclimate. Ash trees were dominant in all plots and in all strata but especially so in the canopy representing 85% of canopy stems and 80% by dominance. Two years following the outbreak simulation and 100% mortality of the girdled trees, canopy leaf area index was reduced more than 50% in the girdled plots. The understory responded favorably to the canopy reduction with a nearly 70% increase in LAI. Non-native shrubs and forbs are the primary drivers of this understory increase and represent a major shift in community composition. EAB outbreaks have resulted in shifts of the stands to C sources via a substantial reduction in canopy tree wood production (75%) and litter production (70%) coupled with modest increases in decay rates and soil respiration. Despite increased cover and productivity in the understory, it remained much less than that of the uninfested plots. In sum, EAB has had a tremendous impact on forest successional trajectory and ecosystem functioning but results varied by site depending on initial condition.

Presenting Author: mnorris@stevenson.edu
Evaluating replacement tree species in black ash forests threatened by EAB and climate change

Brian J. Palik*, Anthony D’Amato2, Christopher Looney3, Robert A. Slesak4, Mitchell A. Slater1

1USDA Forest Service, Northern Research Station
2The University of Vermont
3University of Minnesota
4Minnesota Forest Resources Council

Emerald ash borer is devastating ash species in forests of the Midwestern U.S., but has yet to reach wetlands of the western Great Lakes region, where black ash is a foundational species. In Minnesota alone, black ash wetlands cover over 400,000 ha, forming near mono-specific stands. Loss of ash from these forests will have profound impacts on ecosystem function. Here we discuss an operational-scale experiment designed to increase understanding of the ecological impacts of EAB and loss of black ash. Treatments include clearcutting, group selection, and girdling to simulate EAB. A component of this research is evaluation of “replacement” tree species, including those currently in this ecosystem, as well as future climate-adapted species. Survival and growth results show promise for several species, including balsam poplar and future climate-adapted swamp white oak. Survival and growth were often best in the group selection, where a water table rise with loss of trees was muted. Survival and growth were lowest in with clearcutting, due to a delay in water table drawdown and a shallower depth to water. Results suggest that preemptive removal of ash through clearcutting, as well as doing nothing by leaving ash to die, may be insufficient for sustaining trees in these wetlands. Strategies to mitigate hydrologic change may be needed to establish replacement species. Findings from this experiment are providing critical information for management aimed at mitigating impacts of EAB and for identifying replacement tree species that can transition these ecosystems into the future.

*Presenting Author: bpalik@fs.fed.us
The impacts of emerald ash borer and silvicultural management strategies on black ash forest ground-layer communities

Christopher E. Looney¹, Anthony W. D’Amato², Brian J. Palik³, Robert A. Slesak⁴*, Mitchell A. Slater³

¹University of Minnesota
²The University of Vermont
³USDA Forest Service, Northern Research Station
⁴Minnesota Forest Resources Council

The invasive insect, emerald ash borer (Agrilus planipennis, EAB), threatens black ash (Fraxinus nigra) wetland forests. Canopy treatments, such as clearcutting and group selection, are being evaluated to promote regeneration of non-ash tree species to maintain forest functions. Previous observational studies suggest clearcutting could raise water tables, lower natural tree regeneration, and shift the composition of woody and herbaceous ground-layer plant communities. To test this theory, we used a field experiment in northern Minnesota F. nigra wetlands to examine the response of ground-layer communities to four overstory treatments: clearcutting, group selection, F. nigra girdling, and unharvested forest. Our objectives were to determine: 1) to what degree established regeneration of non-ash tree species can be expected to contribute to post-EAB maintenance of forest cover under different canopy conditions; 2) the response of the black ash shrub layer to EAB and overstory management; and 3) the impact of canopy changes on herbaceous community height and composition. We found that regeneration density of associated tree species varied by treatment and fell short of stocking guidelines. Background variation in experimental blocks, likely reflecting differences in site hydrology, exerted a larger influence than treatment on overall woody community composition. Treatment influenced herbaceous layer height, and species richness and diversity increased in all treatments. The clearcut and group selection increased in graminoids, while the control and girdling treatments increased in wetland indicator species. Our findings suggest artificial regeneration, combined with herbaceous and shrub control treatments, will be necessary to restock F. nigra forests following EAB invasion.

*Corresponding Author: loone016@umn.edu
*Presenting Author: raslesak@umn.edu
Vegetation responses to simulated emerald ash borer infestation in *Fraxinus nigra*-dominated wetlands: Implications for management

Joshua C. Davis\(^1\)*, Joseph P. Shannon\(^1\), Nicholas W. Bolton\(^1\), Randall K. Kolka\(^2\), Thomas G. Pypker\(^3\)

\(^1\)Michigan Technological University  
\(^2\)USDA Forest Service, Northern Research Station  
\(^3\)Thompson Rivers University

The invasive emerald ash borer (EAB) (*Agrilus planipennis* (Coleoptera: Buprestidae)) is a significant threat to biodiversity and ecosystem processes in North American forests. Forests with a high proportion of ash (genus: *Fraxinus*) - such as the black ash (*F. nigra*) forests of the northern Great Lakes region - are of particular concern, due to the large quantity of forest canopy potentially at risk. A multi-year manipulative experiment to assess the potential short- and long-term effects of ash mortality on co-occurring vegetation was conducted on the Ottawa National Forest, Upper Michigan, USA. Within the overstory, growth rates of residual non-ash stems were unaffected by treatment over three post-treatment growing seasons, while positive understory responses were limited to the short-term treatment type. Mortality of *F. nigra* did not impact overall stem recruitment or regeneration, although species composition is shifting towards *Acer rubrum* (red maple) and *Betula alleghaniensis* (yellow birch) in the seedling layer. The herbaceous community exhibited the greatest response, nearly doubling in areal cover by the end of the study. Major implications for management are two-fold. First, preemptive removal of ash stems from the overstory of ash-dominated forests may reduce or delay positive growth responses from co-dominant species. Second, responses of herbaceous species lagged ash mortality by several years but were dramatic, suggesting that attempts to facilitate woody regeneration by planting should take place soon after EAB infestations are detected to improve chances of success against increased competition with herbaceous species.

*Presenting Author: joshuad@mtu.edu*
Six year effects of simulated Emerald Ash Borer mortality and harvesting on black ash ecohydrology

Jacob S. Diamond\textsuperscript{1*}, Robert Slesak\textsuperscript{2}, Daniel McLaughlin\textsuperscript{3}, Tony D’Amato\textsuperscript{4}, Brian Palik\textsuperscript{5}

\textsuperscript{1}Virginia Polytechnic Institute
\textsuperscript{2}University of Minnesota
\textsuperscript{3}Virginia Polytechnic Institute
\textsuperscript{4}The University of Vermont
\textsuperscript{5}USDA Forest Service, Northern Research Station

Hydrology is a primary driver of wetland structure and processes that can be modified by abiotic and biotic feedbacks. Large-scale disturbance to these feedbacks, such as loss of ash trees following EAB infestation or harvesting, can thus be expected to impact wetland hydrology. To predict ecohydrologic response and recovery to the loss of ash, we utilize a large scale experimental manipulation in the Chippewa National Forest, MN. The experiment uses a randomized complete block design with replicated, 4 acre plots in Black Ash-dominated (75–100% basal area) wetlands, with 4 treatments as follows: 1) clear cut, 2) girdling to simulate EAB mortality, 3) group-selection thinning, and 4) control. The monospecies dominance of ash in these systems minimizes variation associated with species-specific effects on water table levels, allowing for clearer interpretation of results regarding ecohydrologic feedbacks. Here, we present an analysis of six years of water table and soil moisture response in the experimental plots. We also present evapotranspiration time series estimates for each experimental plot to evaluate the biologic mechanisms contributing to the response. We test for hydrologic recovery to pre-disturbance conditions and explore aspects of these systems that may affect the rate of recovery (e.g., contributing area, stand characteristics). Finally, we present a conceptual model for these ecosystems and discuss how the model will be used to explore ecohydrologic feedbacks in other hydrogeomorphic settings.

*Presenting Author: jacdia@vt.edu
Timing, microsite, site preparation, browse deterrent, and species selection for artificial regeneration within black ash dominated forests at risk of EAB infestation

Nicholas W. Bolton1*, Joshua C. Davis1, Joseph P. Shannon1, Matthew G. Van Grinsven2, Nam Jin Noh1, Shon S. Schooler3, Joseph W. Wagenbrenner4, Randall K. Kolka5, Thomas G. Pypker6

1Michigan Technological University
2Northern Michigan University
3Lake Superior National Estuarine Research Reserve
4USDA Forest Service, Pacific Southwest Research Station
5USDA Forest Service, Northern Research Station
6Thompson Rivers University

Emerald ash borer (Agrilus planipennis) (EAB) is an insect that is effectively killing North American ash (Fraxinus spp.) trees. Artificial regeneration using non-ash species within black ash dominated forests may be a means to mitigate the impacts of EAB. This study investigated the effects of timing, microsite variables, site preparation, and browse treatments on planted species survival and growth in two black ash dominated ecotypes. Ten potential replacement tree species were planted within uninfested black ash wetlands during the summer of 2013 and three potential replacement tree species were planted within a riparian corridor during the fall of 2015. Black ash wetlands were manipulated to simulate the early and late stages of EAB infestation by girdling or felling all ash trees greater than 2.5 cm DBH and were compared to an unmanipulated black ash wetland. The unmanipulated riparian site was established to examine the efficacy of anti-browse treatments and small scale site preparation. Survival and growth rates were highest for seedlings planted upon natural hummocks within study wetlands. Preliminary findings indicate that constructed hummocks, analogous to mechanical mounding, may provide a similar benefit within riparian corridors. Due to the modest response of natural regeneration within black ash dominated forests, artificial regeneration may be an appropriate method to maintain woody plant communities within black ash dominated forests.

*Presenting Author: nwbolton@mtu.edu
The survival and growth of planted tree seedlings in EAB-impacted floodplain forests depend on restoration methods and microsite factors

Kathleen S. Knight1*, Rachel Hefflinger2, Robert Ford3, Kelly Baggett1, James M. Slavicek1

1USDA Forest Service, Northern Research Station
2Metroparks of the Toledo Area
3The City of Columbus Division of Fire

We planted a restoration experiment to study methods of reforestation for ash-dominated floodplains impacted by emerald ash borer (EAB, Agrilus planipennis) through plantings of native tree species. Three floodplain restoration sites in Ohio were chosen to encompass a gradient of EAB infestation duration and canopy openness. Containerized tree seedlings of three species were planted on a randomized grid in replicated plots in each floodplain in 2011. Sycamore (Platanus occidentalis) and pin oak (Quercus palustris) were from local seed sources. American elm (Ulmus americana) tree seedlings were generated from a cross between two DED-tolerant selections. The effects of restoration design and microhabitat on the survival and growth of the tree seedlings were examined. The elm seedlings performed better than the locally-adapted sycamore and oak seedlings. All three species tolerated severe flooding, surviving complete submersion in flood waters. Restoration design factors tested included deer protection, planting stock size, and tree species. Deer protection, using woven wire cages placed around individual trees, had a positive effect on seedlings of all species at all sites. The effect of planting stock size varied among different sites. Microhabitat effects measured for each planted seedling included canopy openness, moisture index, and herbaceous competition from native and invasive herbaceous species. Canopy openness had a positive effect on seedling survival, with the most pronounced effects on sycamore seedlings and moderate effects on elm seedlings. Understanding differences among tree species in their responses to restoration design and microhabitat variables will allow managers to customize planting strategies to maximize restoration success.

Presenting Author: ksknight@fs.fed.us
Adapting to emerald ash borer: planting and assessing the survival, health, growth, and hydrological impacts of non-ash trees planted into black ash depressional wetlands

Christian Nelson*, Shannon Kesner

Fond du Lac Band of Lake Superior Chippewa

Five different tree species were planted the fall of 2015 in six study sites in a randomized strip planting design. All seedlings were 6-month old containerized stock of the same size and from the same greenhouse. Plantskydd® was applied in spring and fall as a browse deterrent and weedmats were installed on every other seedling to assess the effects of vegetative competition control. Species were assessed twice a year to measure health, growth, and causes of stress or mortality. Stand attributes such as tree density and canopy closure, ground vegetation and diversity, and hydrological variables were also assessed at each site to determine affect on health and growth. After one growing season, seedling survival ranged from 53-95%, with browse being the largest contributor to mortality. Silver maple and river birch had the highest rates of survival, the least amount of browse, and exhibit resilience from browse. Although silver maple and river birch seem to be clear leaders with high survival rates, seedlings may further differentiate over time in terms of shade tolerance, recovery from repeated browse, hydrological conditions and weather tolerance. Long-term seedling growth, health, and survival will continue to be assessed semi-annually or annually for several more years. This project is a cooperative effort between the Fond du Lac Environmental Program and the Fond du Lac Forestry Program and has received technical assistance from the University of Minnesota’s Cloquet Forestry Center and the USDA Forest Service, with funding from the Environmental Protection Agency.

*Presenting Author: christiannelson@fdlrez.com
Implementation of EAB biological control in Minnesota

Jonathan Osthus¹, Angie Ambourn¹, Chris Mallet¹, Monika Chandler¹, Brian Aukema², Rob Venette³

¹Minnesota Department of Agriculture
²University of Minnesota
³USDA Forest Service, Northern Research Station

Biological control of emerald ash borer (*Agrilus planipennis*) (EAB) was initiated in Minnesota in 2010 and remains the most practical landscape level management option. Program implementation includes EAB detection, site assessment and parasitoid release and recovery. As of October 2016, a total of 449,049 parasitoid wasps (314,779 *Tetrastichus planipennisi*, 108,631 *Oobius agrili*, 24,026 *Spathius agrili* and 1,613 *Spathius galinae*) were released at 35 sites in the Twin Cities and southeastern Minnesota. Releases of *S. agrili* were discontinued in 2013 because national program researchers theorized that *S. agrili* and EAB lifecycles are not synchronized in northern latitudes. Both *T. planipennisi* and *O. agrili* were recovered. *Tetrastichus planipennisi* were recovered by peeling ash trees to look for wasp larvae and pupae. The species was also recovered by dissecting EAB larvae to look for internal wasp larvae. *Oobius agrili* was recovered using a bark sifting method. Recoveries over multiple years demonstrated that parasitoids are overwintering, dispersing, establishing and increasing in population. Further studies are needed to assess impact on EAB populations and evaluate a new biocontrol agent, *Spathius galinae*.

Presenting Author: Jonathan.Osthus@state.mn.us
Progress and challenges in protecting North American ash from the emerald ash borer through biological control

Jian J. Duan\textsuperscript{1*}, Leah S. Bauer\textsuperscript{2}, Roy van Driesche\textsuperscript{3}

\textsuperscript{1}USDA Agricultural Research Service, Beneficial Insects Introduction Research Unit, Newark, Delaware
\textsuperscript{2}USDA Forest Service, Northern Research Station, Lansing, MI
\textsuperscript{3}Department of Environmental Conservation, University of Massachusetts, Amherst, MA

Biological control, involving the introduction and establishment of specialized natural enemies of emerald ash borer (EAB) from Asia, is being evaluated as a management tool to protect ash trees in North America. We will report on the results of EAB population dynamics research from 2008 to 2016 at six biocontrol study sites in southern Michigan, where some of the first parasitoid releases against EAB began in 2007. We found that the introduced egg and larval parasitoids (\textit{Oobius agrili} and \textit{Tetrastichus planipennisi}) play a significant role in suppressing EAB larval densities in saplings, basal sprouts, and smaller trees (DBH <12 cm). The impacts of these parasitoids have increased geographically as these biocontrol agents spread from the initial points of release. We also found that innate tree resistance in young and/or healthy trees, as well as woodpecker predation and larval parasitism by some native parasitoids, are important in regulating EAB densities in regenerating and surviving ash trees at these Michigan study sites. However, as EAB expands to new regions of North America, future studies are needed to 1) evaluate the establishment of EAB biocontrol agents in different climate zones; 2) determine the impacts of established biocontrol agents, and other mortality factors, on different ash species that dominate different regions of the U.S. and Canada; 3) expand foreign exploration for EAB natural enemies in different regions of Asia; 4) identify EAB-resistant ash genotypes in EAB-aftermath forests; 4) develop an area-wide approach to the management of EAB by integrating biocontrol, cultural, and conventional methods.

*Presenting Author: jian.duan@ars.usda.gov
The survivors: population dynamics of lingering ash and resistance to emerald ash borer

Kathleen S. Knight¹*, Jennifer L. Koch¹, Rachel Kappler², David W. Carey¹, Mary E. Mason³, Therese M. Poland¹

¹USDA Forest Service, Northern Research Station
²Bowling Green State University
³The Ohio State University

Natural resistance or tolerance to exotic pests and pathogens has been found in many tree species, usually occurring in rare individual trees or populations. After emerald ash borer (Agrilus planipennis) (EAB) has swept through natural populations of ash (Fraxinus spp.), it is possible that some lingering (surviving after initial mortality wave) ash trees may exhibit resistance or tolerance to this exotic beetle. Monitoring data from forests across Ohio shows that >99% mortality of mature ash trees is typical in forest stands. However, we have identified a few populations of lingering ash trees that we are monitoring to understand survival and propagating to test for EAB resistance. Field-based monitoring of surviving ash trees >10 cm DBH at one site in northwest Ohio has identified factors including canopy health and woodpecker activity that predict survival over a six year time period. Trees with good canopy health and no evidence of woodpecker feeding after the other trees in the area experienced >95% mortality were the most likely to survive. 21 surviving lingering ash trees from this site have been propagated and tested as part of the EAB Resistance Breeding Program. Results from EAB egg bioassays on potted trees show that many of these lingering ash kill a larger proportion of developing larvae relative to control susceptible trees and the surviving larvae weigh less, an indication of poor fitness. Preliminary results from progeny of lingering ash trees indicate that resistance can be further enriched through breeding.

*Presenting Author: ksknight@fs.fed.us
When do you pull the trigger? Using monitoring data to optimize EAB management

Mark Abrahamson1*, Angie Ambourn1, Chris Mallet1, Aubree Kees2, Sam Fahrner2, Brian Aukema2, Rob Venette3

1Minnesota Department of Agriculture
2University of Minnesota
3USDA Forest Service, Northern Research Station

Emerald ash borer presents a particular challenge for cities and other developed areas because resource managers and residents in those areas must manage the problem to prevent dead ash trees from becoming hazards to safety and/or property. Fortunately, management options are available for these areas. Unfortunately, there are only two of them: remove the trees or treat them with insecticides. Moreover, there is the potential for significant environmental and economic loss if these tools are not applied wisely. For instance, removing desirable trees more quickly than is needed is costly and results in the loss of the environmental services such as storm water retention. Likewise, treating trees sooner than is needed is also costly and could also have environmental impacts. Ideally, EAB population thresholds would exist that would allow cities and other entities to monitor the insects abundance and use that information to determine when trees should be treated or removed so that costs are minimized while environmental benefits are maximized. We will present results from a three year project to assess the value of EAB monitoring data for informing management under different levels of EAB population pressure. We will also compare the efficiency and efficacy of different survey methods (visual survey, branch sampling and purple prism traps) for providing useful data.

*Presenting Author: mark.abrahamson@state.mn.us
Ecological site classification system for wetland forests of northern Wisconsin

John Kotar¹*, Colleen Matula²

¹University of Wisconsin-Madison, Emeritus  
²Wisconsin Department of Natural Resources

A site classification system for upland forests, based on floristic composition (forest habitat types), has been available to natural resource managers in Wisconsin for many years. A similar system has recently been completed for wetland forests of Northern Wisconsin. In its application the system uses dichotomous keys on plant species present, to identify site types. The types are depicted on graphs as clusters of sample plots ordinated along the soil moisture and available nutrient axes. Ecological interpretations and management implications for individual types are provided. The system offers a tool for evaluating and categorizing successes and failures of common management practices in wetland communities, up till now categorized simply as “swamp conifers” and “swamp hardwoods”. The system also shows promise for prioritizing and directing management activities in wetland forests in light of rapidly advancing threat of emerald ash borer infestation and other forest health threats. This new tool will be available online for forest managers to use in making management decisions.

*Presenting Author: jkotar@wisc.edu
Wisconsin's black ash silviculture trials: Field summary and management recommendations

Colleen F. Matula

*Wisconsin Department of Natural Resources*

In the Upper Great Lakes states, silviculture activities in lowland black ash covertype have been limited due to concerns of hydrology, low quality, commercial value and other. In an effort to gain more knowledge of these sites, information from 30 Wisconsin silviculture management trials (1974 to present) was gathered and database of site attributes analyzed. A summary of the trials and management recommendations will be presented.

**Presenting Author:** Colleen.Matula@wi.gov
A checklist for evaluating management options in lowland ash forests in Wisconsin

Greg Edge

Wisconsin Department of Natural Resources

As populations of the exotic insect Emerald Ash Borer (Agrilus planipennis) build and spread across Wisconsin, forest managers are transitioning from a strategy of detection and control to a strategy of managing the impacts of EAB on forest health and productivity. Of particular concern are the impacts to lowland forests, where black ash (Fraxinus nigra) and green ash (Fraxinus pennsylvanica) are often the dominant tree species. Silvicultural systems are not well understood in these lowland forests and managers are searching for treatments that encourage non-ash tree regeneration, while maintaining other ecosystem functions. Wisconsin DNR developed a checklist and decision tool to help our foresters assess lowland ash stand conditions and evaluate management options while developing prescriptions for these forests. The field checklist draws on a variety of information sources, including recent black ash silvicultural trials and research studies from the Lake States region.

Presenting Author: gregory.edge@wisconsin.gov
Remediation of post-EAB infested black ash stands in Wisconsin

Dustin R. Bronson\textsuperscript{1*}, Laura Reuling\textsuperscript{1}, Robert A. Slesak\textsuperscript{2}, Anthony W. D’Amato\textsuperscript{3}

\textsuperscript{1}Wisconsin Department of Natural Resources  
\textsuperscript{2}Minnesota Forest Resources Council  
\textsuperscript{3}The University of Vermont

The Wisconsin DNR is working on a new study with a focus on remediating black ash stands after emerald ash borer (EAB) infestation. We will simulate EAB infestation by administering clear cuts at three stands whose basal area is greater than ninety percent. We hypothesize that with the loss of black ash, the stands will experience a rising water table, with future vegetation dominated by alder and sedge species, thereby making it hard to establish future tree species. After our simulated post-EAB conditions have been created, we plan to test treatments which include: 1) Feecon Mowing, 2) one application of Oust Herbicide, 3) Feecon Mowing followed by one application of Oust Herbicide, 4) two annual applications of Oust Herbicide. A split plot design will allow for the testing of natural regeneration versus artificial regeneration. Species to be planted in the artificial regeneration treatments include: swamp white oak, resistant elm, non-resistant elm, tamarack, white pine and paper birch. Overall, we hope our results provide options to foresters for potential remediation treatments and the associated costs with the treatments.

\textbf{Presenting Author:} dustin.bronson@wi.gov
Long-term findings form the Wisconsin Swamp Hardwood trials: Applying results to a new challenge

Justin L. Pszwaro¹, Anthony W. D’Amato², Brian J. Palik³, Robert A. Slesak⁴, Greg Edge⁵, Colleen F. Matula⁶, Dustin R. Bronson⁵

¹The Nature Conservancy  
²University of Vermont  
³USDA Forest Service, Northern Research Station  
⁴Minnesota Forest Resources Council  
⁵Wisconsin Department of Natural Resources

Managing black ash forests within the context of emerald ash borer (EAB) is quite challenging given the limited number of non-ashe species and challenging operational and regeneration conditions in these lowland areas. Most black ash management guidelines were developed before EAB was introduced into the United States and focused primarily on increasing the quality and stocking of black ash on lowland sites given its historic ability to dominate these areas. The spread of this invasive pest across the upper Lake States has shifted management goals toward increasing the resilience of black ash-dominated forests to EAB-induced ash mortality by encouraging the development of tree regeneration layers composed of non-host species. There is limited experience with managing black ash forests for minor, non-host species; however, existing management trials may provide insights into potential strategies for minimizing EAB impacts. The Wisconsin Department of Natural Resources established a series of black ash silvicultural trials beginning in the 1970s for examining management systems for black ash wetlands. Although these trials were established at a time when EAB was not a threat on the landscape, they provide a unique opportunity to evaluate the effectiveness of different regeneration methods at increasing the non-ash component of these forests. These trials include strip clearcut, single-tree and group selection, and strip shelterwood harvests across 27 black ash-dominated lowlands. Results from this work indicate that strip shelterwood harvests appear most effective at naturally increasing the non-ash component in these stands while also protecting other ecosystem functions such as water table regulation.

Presenting Author: jlpszwaro@gmail.com
Approaches for managing black ash forests in Minnesota

Paul Dubuque

Minnesota Department of Natural Resources

Past forest management in black ash communities has focused primarily on intermediate thinning or group selection removals in high quality pole-sized stands with the goal of maintaining uneven aged stands across the landscape. Even-aged clearcutting has also been applied but reforestation success has been mixed with the risk of understocked stands and conversion to non-forested communities an unfortunate reality. With the recent discoveries of Emerald Ash Borer (EAB) in southern Minnesota and the city of Duluth, and the expectation that the exotic insect will spread further into the forested part of the state, Minnesota DNR has provided direction to significantly increase the management of ash on state land. Although several states to the east are addressing the effects of EAB on their ash components in upland mixed hardwood forests, Minnesota is challenged by having an abundance of wet to very wet black ash dominated plant communities. A stand selection spatial query tool has been developed by the Ecological Land Classification Program to aid field staff in selecting the most ecologically appropriate stands for management and reforestation to non-ash species. A summary of prescription and timber sale examples will be presented. Updating DNR ash management guidelines and monitoring a variety of silvicultural approaches to meet management objectives are important next steps.

Presenting Author: paul.dubuque@state.mn.us
Recommendations for moving forward based on management experience and recent research in black ash wetlands

Anthony W. D’Amato¹, Brian J. Palik², Robert A. Slesak³, Greg Edge⁴, Colleen F. Matula⁴

¹University of Vermont
²USDA Forest Service, Northern Research Station
³Minnesota Forest Resources Council
⁴Wisconsin Department of Natural Resources

The arrival and spread of emerald ash borer (EAB) across the upper Great Lakes region has shifted considerable focus towards developing silvicultural strategies that minimize the impacts of this invasive insect on the structure and functioning of black ash wetlands. Prior to the arrival of EAB, guidance for managing black ash forests centered on increasing the quality and stocking of black ash through partial harvesting based regeneration methods, including selection and shelterwood methods. Early experience with clearcutting approaches in these forests highlighted the risks of losing ash to EAB from these systems, with stands often retrogressing to marsh-like conditions with limited tree cover. Given these experiences and an urgency for increasing resilience to EAB, research efforts began in northern-central Minnesota in 2009 followed by similar studies in the Upper Peninsula of Michigan in 2011 to evaluate the potential for using regeneration harvests in conjunction with planting of non-ash species to sustain forested wetland habitats after EAB infestations. Along with these more formal experiments, a number of field trials and experimental harvests have been employed by managers across Minnesota and Wisconsin to determine effective ways for reducing the vulnerability of forest types with a large black ash component. Collectively, results from these recent experiences with managing black ash for resilience to EAB highlight potential in using regeneration methods, including group selection and strip shelterwoods, to naturally and artificially establish non-ash species and maintain hydrologic function. Nonetheless, significant challenges remain regarding competition and herbivory effects and adaptive approaches will need to weigh the economic costs of addressing these issues relative to the potential ecological impacts of losing tree cover in these areas.

Presenting Author: awdamato@uvm.edu
The Future of Ash- Creative Research Project

Kelly van Frankenhuyzen

*MICHIGAN STATE UNIVERSITY*

This in-depth research project explores recent work about ash tree resistance to emerald ash borer, focusing on a tree breeding program. Two scientists who are pioneering this work (a biologist and ecologist) are using lingering ash to breed resistance to the beetle. Lingering ash is defined as mature and large enough trees to be infested by emerald ash borer at the peak of the infestation, appear healthy and have a fully leaved canopy and found in a region where 90% of trees have died. Project leaders, landowners, educators and students in Michigan and Ohio shared more than 10 years of experience, research and knowledge crucial to understanding how to manage pests while protecting our forests. Landowners, educators and citizen scientists offer unique perspectives on the topic about forest health and invasive species. Scientists work alongside these groups of people providing valuable information about the future of ash.

An interactive website is critical to understanding this topic. Science jargon can be hard for the lay person to understand. By using various multimedia components, people are more likely to be engaged in the topic and understand the material than just reading an article or textbook. The audience (future landowners and educators) gets an inside look at the work being done to try to slow the spread of the beetle while protecting our resources.

**Presenting Author:** vanfrank@msu.edu
Plasticity in cold tolerance of overwintering emerald ash borer

Robert C. Venette¹, Kathleen S. Knight⁸*, Charles E. Flower²

¹USDA Forest Service, Northern Research Station
²University of Illinois at Chicago

The extent and rate of ash mortality at northern latitudes will depend on the population growth rates of emerald ash borer, *Agrilus planipennis* Fairmaire. Previous research from Canada and Minnesota has suggested that extensive mortality of larvae, the overwintering stage for this insect, may occur due to cold exposure. However, the potential for emerald ash borer to adapt to winter temperatures remains unknown. Might different populations of this insect have differing abilities to acclimatize to winter temperatures? A reciprocal transplant study was used to examine this question. Naturally infested green ash, *Fraxinus pennsylvanica* Marshall, were harvested in late autumn 2016 from Virginia, Ohio, and Minnesota and cut into bolts. Infested bolts from each source were held in confined but unheated conditions in Ohio and Minnesota. In December 2016 (pre-acclimatization) and January 2017 (post-acclimatization), bark was peeled from the bolts to collect J-stage larvae. Cold tolerance was assessed by measuring the supercooling point of individuals. Larvae that overwintered in Minnesota had lower supercooling points than larvae that overwintered in Ohio. The source of infested bolts appeared to have little effect. The results suggest that the cold tolerance response of emerald ash borer larvae may be more physiologically plastic than previous studies had suggested. Conditions prior to extreme cold exposure likely play a critical role in determining the degree of overwintering mortality in this invading insect.

*Presenting Author: ksknight@fs.fed.us*
Potential effects of emerald ash borer invasion on wetland community composition

Melissa B. Youngquist1*, Sue L. Eggers2, Anthony W. D’Amato3, Brian J. Palik2, Robert A. Slesak1, Mitchell Slater2

1University of Minnesota
2USDA Forest Service, Northern Research Station
3The University of Vermont

Forested wetlands provide vital habitat to a range of amphibian and invertebrate taxa and yet, they are one of the most threatened habitat types in North America. In the Great Lakes Regions, black ash wetlands are at risk from invasion by emerald ash borer (EAB; Agrilus planipennis); widespread infestation by EAB will dramatically alter the physical environment within and around these wetlands, with consequences for the biotic community. However, to date, relatively little is known about the aquatic community within these wetlands. Our objective was to understand how the aquatic community might respond to EAB invasion by sampling amphibians and aquatic invertebrates within intact (control) black ash plots and areas that were clear-cut to mimic EAB die-offs. We sampled breeding anurans using call surveys. We also used quantitative sampling to collected data on the larval amphibian community and aquatic invertebrate community. We found six species of anurans within the study area; however only three anurans and one salamander species used the ephemeral pools for breeding within the experimental plots. There was no difference in larval amphibian composition between controls or clear-cuts. Aquatic invertebrates tended to have higher abundance in clear-cut wetlands; clear-cuts also had higher Coleoptera abundance. Taxon richness was positively correlated with pond hydroperiod and area. Our results suggest that, on a small spatial and temporal scale, aquatic communities may be resistant to EAB invasion.

*Presenting Author: myoungquist@umn.edu
Linking emerald ash borer to changes in ecosystem function: how changes in litter quality may influence leaf decomposition and invertebrate growth

Melissa B. Youngquist*, Chandra Wiley¹, Sue L. Eggert², Anthony W. D’Amato³, Brian J. Palik², Robert A. Slesak¹, Mitchell Slater²

¹University of Minnesota  
²USDA Forest Service, Northern Research Station  
³The University of Vermont

The invasion by emerald ash borer (EAB; *Agrilus planipennis*) of black ash wetlands will lead to changes in the plant community and leaf litter inputs. We conducted two experiments to examine how changes in the quantity and quality of allochthonous inputs could alter ecosystem function. The first experiment tested how changes in forest structure following EAB might affect the decomposition of leaf litter. We placed litter bags containing black ash (*Fraxinus nigra*), swamp white oak (*Quercus bicolor*), and lake sedge (*Carex lacustris*) in either control or clear-cut plots (cut to mimic EAB induced die-offs). We found that leaves decomposed faster in intact black ash wetlands and that black ash decomposed faster than swamp white oak or lake sedge. For the second experiment, we tested how caddisfly larval feeding and growth responded to different species of leaf litter. We fed caddisflies one of six species: black ash, swamp white oak, lake sedge, balsam poplar (*Populus balsamifera*), American elm (*Ulmus americana*), or speckled alder (*Alnus incana*) for 14 days. We found that caddisflies had higher survival probabilities and faster growth when fed ash or alder; caddisfly larvae consumed ash and alder at faster rates than other leaf litter species. These results suggest that loss of ash might alter ecosystem processes and food web structure via changes in nutrient cycling and caddisfly (and potentially other shredder invertebrate) biomass production.

*Presenting Author: myoungquist@umn.edu*
Emerald ash borer induced ash decline and its effects on belowground nutrient and microbial community dynamics

Charles E. Flower1*, Michael P. Ricketts2, Kathleen S. Knight1, Robert P. Long1, Miquel A. Gonzalez-Meler2

1USDA Forest Service, Northern Research Station
2University of Illinois at Chicago, Biological Sciences

Considerable efforts have focused on the aboveground implications of ash mortality, yet the implications for belowground microbial associations are understudied, despite the importance of soil microbial communities to soil ecological function and integrity. To characterize associations between ash trees and soil bacterial communities, we sampled soils from ash (n=23) and non-ash (n=9) plots across 7 forests in central Ohio. Concurrently, we censused the tree community and ash tree health. Soil nutrients were analyzed, DNA was extracted from soils, and paired-end sequencing of 16S rRNA amplicons was conducted. Results suggest that ash trees associate with a unique belowground community. Ash and non-ash plots differed in overall bacterial community structure (PERMANOVA; p=0.002). The most abundant bacterial phylum, Acidobacteria, had higher relative abundance in non-ash plots (Welch’s T-test; p<0.001), and of the remaining 6 most abundant phyla, all had lower abundances in non-ash plots (p<0.05). Soil pH, a major driver of bacterial abundance, was lower in non-ash plots (p<0.001), explaining the greater abundance of the acidophilic Acidobacteria. The presence of ash may mediate soil pH through cation accumulation, indirectly influencing bacterial community structure. Functionally, community differences in non-ash plots significantly increased the genetic potential for carbohydrate and nitrogen metabolic pathways. Increases in the relative abundance of these genes could indicate higher rates of decomposition and nitrogen transformations in future non-ash forests. Untangling ash tree associations with soil bacterial communities may help anticipate changes in ecosystem dynamics following the loss of ash.

*Presenting Author: charlesflower@fs.fed.us
EAB induced tree mortality impacts on ecosystem respiration and tree water use in an experimental forest

Charles E. Flower1*, Douglas J. Lynch2, Kathleen S. Knight1, Miquel A. Gonzalez-Meler3

1USDA Forest Service, Northern Research Station
2Licor Biosciences
3Department of Biological Sciences, University of Illinois at Chicago

The mechanism by which EAB impacts ash trees is through larval gallery formation which alters the transport of water and nutrients. Such disturbances impact photosynthesis and indirectly soil respiration and hydrology which respectively drives forest nutrient cycling and successional dynamics. Here we assess the impacts of EAB larval feeding on tree-level water relations and the impacts of EAB induced ash mortality on soil respiration. In an EAB infested ash dominated experimental forest located near Delaware, OH we randomly assigned eleven 12x12m plots to the following treatments: girdle, insecticide and control. Soil respiration (Rsoil) was measured weekly during mid-day at 22 locations (2 collars per plot). Additionally, thermal dissipation probes were deployed to measure sap flow in 9 ash trees along a gradient of EAB infestation. The treatments resulted in significant shifts in rates of soil respiration. Specifically, the insecticide and control treatments exhibited significantly greater Rsoil than the girdled treatment (RMANOVA; P<0.05). The girdling treatment resulted in ~30% reduction in Rsoil compared to the non-girdled treatments. As expected, ash trees exhibited diurnal variability in sap flux density, driven by the photoperiod (RMANOVA; P<0.01). Heavily infested trees exhibited lower sap flux densities compared to lightly infested trees which led to reduced quantities of daily water use (ANOVA; P<0.01). This research demonstrates how the pest disturbances may impact ecosystem carbon budgets through reductions in soil respiration and highlights how EAB-induced tree decline can reduce sapflux rates and alter forest water use driving shifts in local hydrology.

*Presenting Author: charlesflower@fs.fed.us
Water level controls on transpiration of co-dominant species in black ash wetlands

Joseph P. Shannon1*, Joshua C. Davis1, Matthew Van Grinsven2, Nicholas Bolton1, Nam Jin Noh1, Thomas G. Pypker3, Randall K. Kolka4, Joseph W. Wagenbrenner5

1Michigan Technological University
2Northern Michigan University
3Thompson Rivers University
4USDA Forest Service, Northern Research Station
5USDA Forest Service, Pacific Southwest Research Station

Canopy dominance exhibited by black ash (Fraxinus nigra) in regularly inundated wetland and riparian settings suggests the species has an advantageous adaptation. Our study examined the response of sap flux to water level in three common co-dominant species in depressional black ash wetlands in western Michigan. Sap flux was measured on 6 black ash, 5 red maple (Acer rubrum), and 6 yellow birch (Betula alleghaniensis). Normalized water levels were used to test for differences in sap flux among species and sap flux responses to atmospheric drivers. Red maple and yellow birch displayed a slight increase and decrease in sap flux as water levels increased, respectively. Black ash showed a strong reduction in sap flux as water levels increased. At low water levels red maple and yellow birch sap flux were not significantly different (1.8 m$^3$ m$^{-2}$ d$^{-1}$), and black ash (3.9 m$^3$ m$^{-2}$ d$^{-1}$) was significantly greater than both. When water levels were elevated sap flux was significantly higher in black ash (2.8 m$^3$ m$^{-2}$ d$^{-1}$) than yellow birch (1.9 m$^3$ m$^{-2}$ d$^{-1}$), which was significantly higher than red maple (1.7 m$^3$ m$^{-2}$ d$^{-1}$). Differences in canopy water use and response of sap flux to water level among these species has important implications. Following the loss of black ash, a persistent reduction in canopy transpiration may exacerbate observed increases in water levels and decreases in water table drawdown throughout the growing season. Decreased transpiration and amplified hydrologic stress will likely affect future forest health and productivity.

*Presenting Author: jpshanno@mtu.edu
Responses of dissolved carbon and nitrogen concentrations to simulated emerald ash borer infestation in a black ash-dominated paired watershed

Nam Jin Noh1*, Matthew Van Grinsven1,2, Joseph P. Shannon1, Nicholas W. Bolton1, Joshua C. Davis1, Stephen Sebestyen3, Thomas G. Pypker1,4, Randall K. Kolka1, Joseph W. Wagenbrenner1,5

1Michigan Technological University  
2Northern Michigan University  
3USDA Forest Service, Northern Research Station  
4Thompson Rivers University  
5USDA Forest Service, Pacific Southwest Research Station

The ash mortality caused by the invasive emerald ash borer (EAB) may affect the export of dissolved organic matter (DOM) from ash-dominated forests because of increased dead wood inputs and decreases in nutrient uptake by woody species. We implemented a manipulative study in a pair of black ash-dominated wetland watersheds in the Ottawa National Forest, Michigan to understand the impacts of ash tree mortality on the carbon and nitrogen cycle. Wetland surface water, peat pore water and stream water were analyzed for dissolved organic carbon (DOC) and total dissolved nitrogen (TDN) 2 years before and 2 years after one of the watersheds was treated by cutting all ash trees. The mean increases in DOC and TDN concentrations of stream water for the first year after ash cutting were 26% and 8%, respectively. The DOC and TDN concentrations in stream water were significantly correlated with those in wetland surface water and peat pore water. In addition, our results indicate that the DOC:TDN ratio could be used to trace the changes in both DOC and TDN dynamics caused by EAB infestation. We conclude that EAB infestation could affect stream and surface water quality because of increased DOC and TDN exports from these ash-dominated wetland forests, with implications for changes in downstream productivity.

*Presenting Author: nnoh@mtu.edu
Black ash wetland watershed hydrology and soil biogeochemistry responses to a simulated emerald ash borer infestation

Matthew Van Grinsven1,2*, Joseph Shannon2, Evan Kane2,4, Nicholas Bolton2, Joshua Davis2, Nam Jin Noh2, Joseph Wagenbrenner2,3, Stephen Sebestyen4, Randall Kolka4, Thomas Pypker2,5

1Northern Michigan University
2Michigan Technological University
3USDA Forest Service, Pacific Southwest Research Station
4USDA Forest Service, Northern Research Station
5Thompson Rivers University

Forested headwater wetlands regulate numerous physical, chemical and biological watershed processes. Collectively, headwater wetland watersheds have a large influence on carbon cycling processes within larger order watersheds. Recent advances in fluorescence spectroscopy have increased dissolved organic matter (DOM) composition understanding, and capacity to detect sources. DOM characterization methods were combined with high resolution sampling strategies to quantify water, dissolved organic carbon (DOC), and total dissolved nitrogen (TDN) loads in two forested headwater wetland watersheds in the Upper Peninsula of Michigan. After a two-year baseline monitoring period, an EAB disturbance was simulated by felling (ash-cut) all black ash trees with diameters greater than 2.5-cm within one wetland. Over two thousand samples were collected from surface and ground water, and excitation emission matrix and absorbance data were collected on over four hundred samples during a four-year period. The largest loads of water, DOC, and TDN were detected during the spring, when DOM was largely composed of more humic-like, higher molecular weight molecules. A significant increase in protein-like, lower molecular weight DOM molecules associated with recent biological activity was detected in wetland and stream waters during the fall. Co-examination of seasonal DOC export and DOM composition increased the capacity to detect shifts in carbon sources, and provided unique insights regarding the ecological significance of EAB infestations to downstream water bodies.

*Presenting Author: mvangrin@nmu.edu
Temperature and water level effects on greenhouse gas fluxes in soil cores from black ash (*Fraxinus nigra*) wetlands in the northern Great Lake States, USA

Alan J. Toczydlowski1*, Robert A. Slesak2, Randall K. Kolka3

1Department of Forest Resources, University of Minnesota, St. Paul, MN
2Minnesota Forest Resources Council, St. Paul, MN
3USDA Forest Service, Northern Research Station, Grand Rapids, MN

Forested black ash (*Fraxinus nigra*) wetlands in the northern Great Lake States, USA are threatened by the invasive insect, emerald ash borer (*Agrilus planipennis Fairmaire* (EAB)). Emerald ash borer-induced ash dieback can alter wetland hydrology by, elevating the water table. Changes in water table levels will alter carbon and nutrient cycling and gaseous fluxes from wetlands. We incubated soil cores from black ash wetlands in northern Minnesota and Michigan with mineral and organic soils, respectively, and measured the efflux of carbon dioxide, methane, and nitrous oxide. The 50 cm soil cores were incubated in growth chambers at 10°C, 15°C, and 20°C with two water level treatments; a completely saturated control and a treatment in which water levels were incrementally decreased and then increased. Each gas species is hypothesized to respond differently to water level. Methane production is expected to be greater in the organic soil and increase with saturation. Nitrous oxide efflux will be greatest at moderate saturation, and carbon dioxide efflux will be greatest in unsaturated soils. As expected, preliminary data suggest temperature is a driving factor controlling gas efflux in both mineral and organic soils.

*Presenting Author: toczy003@umn.edu*
Soil carbon and nitrogen pools across a range of black ash wetlands

Randy K. Kolka*, Alan J. Toczydlowski, Robert A. Slesak

1USDA Forest Service, Northern Research Station
2University of Minnesota, Department of Forest Resources
3Minnesota Forest Resources Council

Little research has been conducted on black ash wetland soils. Considering the impending ecosystem-level changes resulting from the invasion of emerald ash borer (EAB), understanding soil carbon and nitrogen pools in these imperiled ecosystems prior to EAB invasion will be critical to understand subsequent changes to these pools. We sampled soils to a minimum of one meter across a range of black ash wetlands in northern Minnesota and the Upper Peninsula of Michigan. Soils ranged from organic to mineral across the range of wetlands. We analyzed the soils for carbon and nitrogen at 0-50 cm and 50-100 cm depth increments, and with knowledge of bulk density, calculated the pools of soil carbon and nitrogen. We discuss the possible factors that control the pools of soil carbon and nitrogen across the range of black ash wetlands we sampled, and how the invasion of EAB could alter these pools.

*Presenting Author: rkolka@fs.fed.us
The effect of emerald ash borer (Agrilus planipennis)-caused tree mortality on the invasive shrub Amur honeysuckle (Lonicera maackii) and their combined effects on woody seedlings

Brian M. Hoven¹*, David L. Gorchov¹, Kathleen S. Knight²*, Valerie E. Peters³

¹Department of Biology, Miami University, Oxford, OH 45056
²USDA Forest Service, Northern Research Station, Delaware, OH 43015
³Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475

Invasive insects and plants are major threats to the health and viability of North American forests. Emerald ash borer (Agrilus planipennis) (EAB) may cause extensive changes to forest composition due to rapid ash (Fraxinus spp.) mortality. Invasive shrubs like Amur honeysuckle (Lonicera maackii) may benefit from EAB and have negative effects on woody seedlings. We predict that ash mortality has positive effects on seedling abundance, recruitment, and survival, but that these effects are influenced by L. maackii abundance. We sampled 16 sites, representing a chronosequence of ash mortality throughout western Ohio. We tested whether L. maackii growth and fecundity varied in relation to ash decline. We also investigated effects of ash decline, stand basal area (BA), L. maackii abundance (BA and percent cover) on woody seedling abundance, recruitment, and survival using linear mixed models evaluated with Akaike’s Information Criterion. These same responses were also investigated for four seedling groups: L. maackii, invasive plants (excluding L. maackii), shade tolerant natives, and shade intolerant natives. We found a significant positive relationship between ash decline and L. maackii BA growth. Lower seedling species richness, recruitment, and abundance corresponded with greater L. maackii BA, whereas ash decline was related to few seedling responses. Sites with poorer quality ash and greater L. maackii BA had more L. maackii seedlings. These findings indicate that the negative effects of L. maackii are more important to future forest composition than ash decline; however ash decline increases L. maackii growth, hence exacerbating the effects of this invasive shrub.

*Presenting Author: ksknight@fs.fed.us
¹hovenbm@miamioh.edu
The Great Lakes Silviculture Library: A tool to link management practices for EAB within the region

Marcella A. Windmuller-Campione\textsuperscript{1}, Matthew Russell\textsuperscript{1*}, Eli Sagor\textsuperscript{2}, Kris Tiles\textsuperscript{3}

\textsuperscript{1}University of Minnesota
\textsuperscript{2}Sustainable Forests Education Cooperative
\textsuperscript{3}University of Wisconsin

The continued expansion of the emerald ash borer (EAB) within the Great Lakes Region is and will continue to challenge natural resource managers to develop and test different silvicultural prescriptions. Each silviculture prescription and subsequent treatment is an experiment. These experiments shape the career of the individual foresters and his or her employer and have the potential to contribute to important local knowledge and institutional memory. However, these experiments are often not shared across agencies which limits our capacity to manage for new threats. The Great Lakes Silviculture Library was developed to fill this void and enhance the collective institutional memory of the Great Lakes forestry community. The Library is populated with “case studies” composed of text, HTML links, maps, and geographic data, photographs, and supplemental documents. Anyone with direct experience managing forest land in the Great Lakes is welcome to submit a case study. These studies highlight not only the successes of management but also when silvicultural treatments did not meet the desired objectives. As such, these successes and failures can help land managers identify new silvicultural approaches as they plan new treatments, especially for invasive species like EAB. Case studies can also build learning networks by connecting land managers across agencies and locations. Currently there are two case studies on EAB and ash management from the Wisconsin DNR and Chippewa National Forest. We are actively increasing content in this area and welcome new submissions.

\textsuperscript{*Presenting Author:} russellm@umn.edu
\textsuperscript{†}mwind@umn.edu
Density dependent survival of white ash (*Fraxinus americana*) at the Allegheny National Forest

Eli D. Aubihl*, Charles E. Flower2, Kathleen S. Knight2, Steve Forry3, Andrea Hille3, Alejandro Royo3, William Oldland4

1Miami University  
2USDA Forest Service, Northern Research Station  
3USDA Forest Service, Allegheny National Forest  
4USDA Forest Service, State and Private Forestry

An in-situ genetic conservation project being conducted by the USDA Forest Service in the Allegheny National Forest (ANF) has provided an opportunity for investigation of the disturbance severity caused by the emerald ash borer. We are monitoring the health of ash trees in 27 treatment plots with 20 white ash (*Fraxinus americana*) trees treated with emamectin benzoate in each plot, as well as in a number of untreated control plots. Ash density in each plot varies, resulting in a range of 9.7%-86.9% of ash trees in the treatment plots injected with insecticide. The type of data being collected includes, but is not limited to ash canopy condition, diameter at breast height, and presence/absence of epicormic sprouts. Data from 2010, 2015, and 2017 show the rapid spread of ash mortality across the forest over time, with plots at the southern part of the forest showing the greatest declines in ash health. This data will be used to gain a better understanding of the disturbance severity caused by the emerald ash borer in the ANF. The data will also be used to examine, density dependent survival of ash trees and the associational protection provided by treated ash trees to untreated ash trees. These results will provide insights into regional conservation efforts of tree species in decline from invasive forest pests such as the emerald ash borer.

*Presenting Author: aubihld@miamioh.edu*
Ash mortality in a new infestation of EAB is not instantaneous

Aubree M. Kees1*, Jonathan Osthus2, Monika Chandler2, Angie Ambourn2, Mark Abrahamson2, Robert C. Venette3, Brian H. Aukema1

1University of Minnesota
2Minnesota Department of Agriculture
3USDA Forest Service, Northern Research Station

As emerald ash borer continues to spread, it has left hundreds of millions of dead ash trees in its wake. Population growth in a new area tends to follow an exponential curve, with crown symptoms in infested trees not usually manifested until three or four years after introduction. In general, tree mortality becomes noticeable in the fifth or sixth year. We followed three hundred trees surrounding the earliest detection of emerald ash borer in the Twin Cities metro area beginning in 2011. We divided the area into three concentric zones emanating from the initial detection site, covering an ellipse with a radius of approximately 3 miles. Emerald ash borer likely arrived in 2009, and we expected to see substantial mortality across trees in the study by 2015. Instead, branch sampling indicated that only one quarter to one third of the trees in the outer zones were infested after six years. Cold weather during the winter of 2013-2014 appeared to temporarily slow population growth. These results suggest that landscape-level spatiotemporal patterns of mortality of ash may deviate from those seen in other states as the insect spreads into northern regions of Minnesota.

*Presenting Author: aubree.kees@gmail.com
Potential species replacements for black ash (*Fraxinus nigra*) at the confluence of two threats: emerald ash borer and a changing climate

Louis R. Iverson¹, Kathleen S. Knight*, Anantha M. Prasad¹, Stephen N. Matthews¹, Matthew P. Peters¹, Daniel A. Herms², Diane M. Hartzler², Robert Long³, Annemarie Smith¹, John Almendinger⁵

¹Northern Research Station, USFS, Delaware OH  
²Department of Entomology, The Ohio State University  
³Northern Research Station, USFS, Irvine PA; U.S.  
⁴Green Building Council, Central Ohio Chapter  
⁵Division of Forestry, Minnesota Department of Natural Resources

The emerald ash borer (*Agrilus planipennis*; EAB) is causing widespread mortality of ash (*Fraxinus* spp.) and climate change is altering habitats of tree species throughout large portions of North America. Black ash (*F. nigra*), a moist-soil species common in the Northwoods, is under a double threat of losing habitat from climate change and near annihilation from EAB. Because black ash often occurs in nearly pure stands, planting non-ash species is a management strategy already underway or being planned for thousands of acres. This study explores the implications of threats to black ash ecosystems by using analyses of field data and models to assess both the threats to, and potential replacement species for, black ash in Minnesota. For our analysis we (1) assessed the status of ashes and co-occurring species in forest inventory plots throughout Minnesota; (2) modeled the risk of EAB attack for multiple years in Minnesota; (3) modeled potential impacts of climate change on tree species with current or potential future habitat in Minnesota; (4) evaluated species co-occurring with black ash in plots in Ohio and Michigan, southeast of Minnesota; and (5) synthesized these results to provide a classification for candidate replacement species, both from within Minnesota and from points farther south. We provide a list of 46 non-ash species and rank their capacity to thrive as replacements for black ash in the Northwoods; these include swamp white oak, a species from farther south but one thriving well in planted sites on the Chippewa NF.

*Presenting Author: ksknight@fs.fed.us*
In-situ genetic conservation of white ash through insecticide treatment at the Allegheny National Forest

Charles E. Flower, Jeremie Fant, Kathleen S. Knight, Laura Steger, Steve Forry, Andrea Hille, Alejandro Royo, Eli Aubihl, William Oldland

1USDA Forest Service
2Chicago Botanic Gardens
3Allegheny National Forest
4Miami University
5State and Private Forestry

The emerald ash borer-induced loss of mature ash trees across the eastern United States poses a serious threat to the genetic diversity of the species. Efforts to conserve the standing genetic diversity of ash species, including ash seed collection and in-situ protection of ash trees with insecticides, are ongoing. To best optimize conservation strategies, a better understanding of the current distribution of genetic diversity will be needed. An ongoing insecticide treatment study at the Allegheny National Forest (ANF) was used as a case study to examine the amount of genetic diversity conserved using several management approaches. The ANF treated 20 white ash (Fraxinus americana) trees in each of 27 plots spread across the >500,000 acre forest. We sampled leaves from >330 ash trees in 13 plots to determine the amount and distribution of ash genetic diversity on the landscape. Using microsatellite markers, we determined the percent of the genetic diversity of ash that is expected to be conserved through the current treatment approach. We generated scenarios for five other treatment approaches, varying the total number and distribution of treated trees, to calculate the expected percent of genetic diversity that would be conserved. The results will allow managers to consider the genetic “bang for the buck” when planning in-situ conservation of ash and similar species threatened by invasive pests and pathogens.

*Presenting Author: charlesflower@fs.fed.us
What can biosurveillance for emerald ash borer tell us about other native tree pests and forest condition?

Marie J. Hallinen*, Brian H. Aukema†

*Presenting Author: Marie Hallinen
†Corresponding Author: BrianAukema@umn.edu

Emerald ash borer continues to devastate native Fraxinus spp. as its spreads across North America. Self-sustaining biological control strategies are easily deployed to natural ash forests, even though it is unlikely that natural enemy pressure will dampen initial waves of mortality. We are working with one component of the natural enemy complex during the invasion stage. Cerceris fumipennis is a native, solitary, ground-nesting wasp that provisions its nest with beetles in the family Buprestidae. Because these wasps are relatively docile to people, provisioned prey can be intercepted, allowing people to exploit this predator-prey relationship for unique biosurveillance tactics (e.g., bronze birch borer, two-lined chesnut borer, and emerald ash borer). We are beginning a new project examining what prey of “smoky winged beetle bandit wasps” tell us about surrounding forest composition and tree condition.
How low can you go? Optimizing systemic insecticide coverage for tree protection

Dora M. Mwangola*, Brian H. Aukema†

University of Minnesota

Emerald ash borer, *Agrilus planipennis*, is an invasive insect that was accidentally introduced into Michigan in the 1990s. Since its discovery in 2002, it has spread to more than two dozen American states and Canadian provinces. Much research has been focused on integrated pest management strategies that can be deployed in both urban and natural settings. This work profiles a new project funded by the Minnesota Invasive Terrestrial Plants and Pests Center on tree injections with systemic insecticides. Our goal is to quantify what proportion of a susceptible ash population must be treated in order to maintain canopy at different densities of emerald ash borer, and examine any potential effects on non-target species. Although much work to date has been focused on urban ash, quantification of coverage over wider areas and advanced application technologies may allow inclusion of systemic insecticides as a component of an integrated pest management system for ash borer in natural areas.

*Presenting Author: Dora Mwangola
†Corresponding Author: BrianAukema@umn.edu
Potential impacts of emerald ash borer biocontrol on ash health and regeneration in southern Michigan

Daniel M. Kashian1*, Leah S. Bauer2, Benjamin A. Speit1, Jian J. Duan3

1Wayne State University
2USDA Forest Service, Northern Research Station, Lansing, MI
3USDA Agricultural Research Service, Beneficial Insects Introduction Research Unit, Newark, Delaware

Infestations of emerald ash borer (EAB) are now known across much of eastern North America with eradication unsuccessful and future control or containment unlikely. Three hymenopteran species found parasitizing EAB in China were released in 2007 and 2008 in Lower Michigan, northern Ohio, and Illinois, and in 13 EAB-infested states by 2012. Assessing and monitoring changes in ash condition where these biocontrol agents are present is critical if we are to determine the long-term impact that parasitoids will have and the outcome for ash species in the U.S. Live tree, sapling, and seedling data were collected in summer 2012 at release and control plots in southeastern and central Michigan. Where parasitoid establishment is confirmed, seedlings were more abundant in the release plots; higher density of seedlings in the smallest size classes may indicate a more available seed source in the release plots. No consistent pattern between control and release plots emerged when assessing the proportion of trees and saplings showing visible indications of EAB infestation. Parasitism data were mixed, but diameter of the largest trees was larger in all release plots. Sapling size did not differ between release and control plots, and mean condition class between release and control plots was inconsistent for trees and saplings at the three sites. We have too few and inconsistent data to conclude that biocontrol is yet having a positive effect on ash health and regeneration, but at least some patterns warrant further sampling and investigation.

*Presenting Author: dkash@wayne.edu
Biomass and sapwood of green ash (*Fraxinus pennsylvanica*) in the Twin Cities Metro Area

Derik Olson

*University of Minnesota*

A primary objective of this study was to compare field measurements to quantities predicted by established models, or model validation. A secondary objective was to examine the sapwood content, with an end to more accurate application of chemical dosages in treatments for emerald ash borer (EAB, *Agrilus planipennis*). A stem dimensional analysis, described by Woodell and Whitaker (1968), was conducted for 40 trees across a range of size classes, grown in the Twin Cities Metro Area of Minnesota. Characteristics of biomass and sapwood volume are presented. The biomass model developed by Hahn (1984) demonstrated a good fit with field data, and can be modified to accurately predict biomass content of an urban-grown green ash trees in the Twin Cities Metro Area. The model developed by Jenkins et al. (2003) was less precise compared to that of Hahn, when analyzing the field data. Sapwood was shown to have strong correlations with crown surface area and a combined height × diameter variable. A model is presented here which predicts aboveground sapwood volume with a residual standard error 8.457 cubic feet. As trees play an increasing role in the sustainable design of urban areas, it would be advantageous to know as much about their characteristics as possible. Urban woody biomass is increasingly employed as an energy source, therefore biomass estimators are needed to accurately describe this resource. With this study, measurements were used to successfully modify published models for use in urban settings.

*Presenting Author: derikolson@fs.fed.us*
Field Tours

Field Tours
July 27, 2017, 8:00 AM – 5:00 PM

GROUP A. Stop I (Fond du Lac) → Stop II (Pokegama River) → Stop III (Ash forest land)

GROUP B. Stop II (Pokegama River) → Stop III (Ash forest land) → Stop I (Fond du Lac)

GROUP C. Stop III (Ash forest land) → Stop I (Fond du Lac) → Stop II (Pokegama River)

Notes: Please bring appropriate clothing, foot wear, and bug-shirts for more fun.

Stop I. Planting Replacement Species in the Understory, Fond du Lac
(Organizers: Christian Nelson, Shannon Kesner)

Fond du Lac has over 1,300 acres of black ash depressional wetlands, all of which are threatened by the emerald ash borer. With no cure for emerald ash borer available the ecological and hydrological qualities of these sites are threatened. In an attempt to keep forested wetlands forested, five different native tree species, river birch, red maple, silver maple, balsam poplar, and white cedar, were planted in the fall of 2015 in six ash different sites. Plantskydd® was applied in spring and fall as a browse deterrent and weed mats were installed on every other seedling to assess if they’d give seedlings an advantage. Survival, health, stress cause, native plant community, and other
forestry attributes, in addition to hydrological and wetland attributes have been assessed. We will visit one of the study sites and will also discuss wild rice management and blueberry management on the shores of a nearby lake. (see OS I-13 for the details)

**Stop II. Riparian Ash Forest Planting Site, Pokegama River**  
(Organizers: Nicholas Bolton, Shon Schooler)

The Pokegama River runs through the Superior Municipal Forest within the city limits of Superior, Wisconsin. The fluctuating river stage, sandy or silt soils, and herbivore pressures influence planting efforts within the forest. Northern white cedar, red maple, and hackberry were planted using three different microsite treatments within three different herbivore deterrent enclosures throughout a section of the Pokegama. This field trip will introduce participants to the forested riparian corridor ecosystem and the planting study. (see OS I-11 for the details)

**Stop III. Ash Forest Land with Emerald Ash Borer Treatments**  
(Organizers: Louise Levy, Craig Brown, Brian Palik)

On October 23, 2015, two years after the August 2013 confirmation of emerald ash borer in neighboring Superior, WI, the insect was positively identified in the City of Duluth in ash trees located near the beach house and recreation fields on Park Point (http://levytreecare.com/). We will visit ash stands on non-industrial private forest land. The land in the Knife River Watershed has been treated with the recommended insecticide course beginning in 2015 to protect against anticipated emerald ash borer infestation and hence to maintain and enhance the ecological quality and function of the land owner’s property.  
(Click! EAB Treatment Map by LevyTreeCare)
Conference Venue: Inn on Lake Superior

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<tr>
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<td>Welcome dinner</td>
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Meeting Attendee Parking - Meeting Room Parking Passes are available and valid until 4:30PM the day of the event. Parking is not guaranteed for meeting room guests and payment may be required to park in the city owned pay lot to the East of the hotel. Complimentary Parking in the hotel's lot is guaranteed for Sleeping Room Guests Only.
Organizing Committee

Bolton, Nick  School of Forest Resources and Environmental Science, Michigan Tech.
Cotey, Stacy  School of Forest Resources and Environmental Science, Michigan Tech.
D’Amato, Tony  Rubenstein School of Environmental and Natural Resources, The Univ. of Vermont
David, Josh  School of Forest Resources and Environmental Science, Michigan Tech.
Kesner, Shannon  Fond du Lac Band of Lake Superior Chippewa
Kolka, Randy  USDA Forest Service, Northern Research Station
Nelson, Christian  Fond du Lac Band of Lake Superior Chippewa
Noh, Nam Jin  School of Forest Resources and Environmental Science, Michigan Tech.
Palik, Brian  USDA Forest Service, Northern Research Station
Pypker, Tom  Thomson Rivers University
Schooler, Shon  Lake Superior National Estuarine Reserve Station, Univ. of Wisconsin-Superior
Shannon, Joe  School of Forest Resources and Environmental Science, Michigan Tech.
Slesak, Rob  Minnesota Forest Resources Council, Univ. of Minnesota
Van Grinsven, Matt  Northern Michigan University
Wagenbrenner, Joe  USDA Forest Service, Pacific Southwest Research Station

Sponsors

U.S. Department of Agriculture Forest Service  University of Minnesota
Great Lakes Restoration Initiative  Minnesota Forest Resources Council
U.S. Environmental Protection Agency  Minnesota Forest Resources Partnership
Michigan Technological University  Fond du Lac Band of Lake Superior Chippewa
Ecosystem Science Center, Michigan Tech.  Lake Superior National Estuarine Reserve Station
The University of Vermont  Forests (an open access journal by MDPI)

https://ashworkshop.org
### Participant List

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<tr>
<th>NO.</th>
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<th>FIRST NAME</th>
<th>AFFILIATION</th>
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<td>1</td>
<td>Abrahamson</td>
<td>Mark</td>
<td>Minnesota Department of Agriculture</td>
<td><a href="mailto:mark.abrahamson@state.mn.us">mark.abrahamson@state.mn.us</a></td>
<td>OS II-04, PS-15</td>
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<td>2</td>
<td>Anderson</td>
<td>Kyle</td>
<td>MN DNR</td>
<td><a href="mailto:kyle.e.anderson@state.mn.us">kyle.e.anderson@state.mn.us</a></td>
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<td>3</td>
<td>Arends</td>
<td>Andrew</td>
<td>MN DNR - Division of Forestry</td>
<td><a href="mailto:andrew.arends@state.mn.us">andrew.arends@state.mn.us</a></td>
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<td>4</td>
<td>Aukema</td>
<td>Brian</td>
<td>University of Minnesota</td>
<td><a href="mailto:BrianAukema@d.umn.edu">BrianAukema@d.umn.edu</a></td>
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<td>Heather</td>
<td>MN DNR</td>
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<td>Bednar</td>
<td>Josh</td>
<td>Natural Resources Research Institute</td>
<td><a href="mailto:bedn0050@d.umn.edu">bedn0050@d.umn.edu</a></td>
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<td>Andrew</td>
<td>Audubon MN</td>
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<td>MN DNR</td>
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<td>Brian</td>
<td>USDA Forest Service</td>
<td><a href="mailto:brianbergman@fs.fed.us">brianbergman@fs.fed.us</a></td>
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<td>Bernu</td>
<td>Greg</td>
<td>Carlton County Land Department</td>
<td><a href="mailto:greg.bernou@co.carlton.mn.us">greg.bernou@co.carlton.mn.us</a></td>
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<td>Callie</td>
<td>American Bird Conservancy</td>
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<td>David</td>
<td>Forester DCFD</td>
<td><a href="mailto:dave.cizmas@douglascountywi.org">dave.cizmas@douglascountywi.org</a></td>
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<td>Cotey</td>
<td>Stacy</td>
<td>SFRES, Michigan Technological University</td>
<td><a href="mailto:sncotey@mtu.edu">sncotey@mtu.edu</a></td>
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<td>D’Amato</td>
<td>Anthony</td>
<td>University of Vermont</td>
<td><a href="mailto:awdamato@uvm.edu">awdamato@uvm.edu</a></td>
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<td>Joshua</td>
<td>SFRES, Michigan Tech.</td>
<td><a href="mailto:joshuad@mtu.edu">joshuad@mtu.edu</a></td>
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<td>WI DNR</td>
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<td>Ben</td>
<td>University of Findlay</td>
<td><a href="mailto:dolan@findlay.edu">dolan@findlay.edu</a></td>
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<td>Jian</td>
<td>USDA-ARS</td>
<td><a href="mailto:jian.duan@ars.usda.gov">jian.duan@ars.usda.gov</a></td>
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<td>MN DNR</td>
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<td>Chris</td>
<td>The Nature Conservancy</td>
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<td>Greg</td>
<td>Wisconsin DNR</td>
<td><a href="mailto:gregory.edge@wisconsin.gov">gregory.edge@wisconsin.gov</a></td>
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<td><a href="mailto:melissa.rodriguez@pokagonband-nsn.gov">melissa.rodriguez@pokagonband-nsn.gov</a></td>
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<td>University of Illinois at Chicago</td>
<td><a href="mailto:cflowe3@uic.edu">cflowe3@uic.edu</a></td>
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<td><a href="mailto:mike@compasslandconsultants.com">mike@compasslandconsultants.com</a></td>
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<td><a href="mailto:fries060@umn.edu">fries060@umn.edu</a></td>
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<td>University of Minnesota</td>
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<td>Graff</td>
<td>Marshall Beltrami County Natural Resource Management</td>
<td><a href="mailto:marshall.graham@co.beltrami.mn.us">marshall.graham@co.beltrami.mn.us</a></td>
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<td>Natural Resources Research Institute</td>
<td><a href="mailto:agrinde@d.umn.edu">agrinde@d.umn.edu</a></td>
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<td>MN DNR</td>
<td><a href="mailto:chris.gronewold@state.mn.us">chris.gronewold@state.mn.us</a></td>
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<td>MN DNR - Division of Forestry</td>
<td><a href="mailto:steven.hatvenstein@state.mn.us">steven.hatvenstein@state.mn.us</a></td>
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<td>The Forestland Group</td>
<td><a href="mailto:shawn@forestlandgroup.com">shawn@forestlandgroup.com</a></td>
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<td>Forester DCFD</td>
<td><a href="mailto:mark.hager@douglascountywi.org">mark.hager@douglascountywi.org</a></td>
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<td>University of Minnesota</td>
<td><a href="mailto:wilke137@umn.edu">wilke137@umn.edu</a></td>
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<td><a href="mailto:lindsay.hause@state.mn.us">lindsay.hause@state.mn.us</a></td>
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<td><a href="mailto:lars.helleloid@state.mn.us">lars.helleloid@state.mn.us</a></td>
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<td><a href="mailto:dhernandez@fs.fed.us">dhernandez@fs.fed.us</a></td>
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<td><a href="mailto:bradley.hutnik@wi.gov">bradley.hutnik@wi.gov</a></td>
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<td><a href="mailto:chad.jacobson@co.beltrami.mn.us">chad.jacobson@co.beltrami.mn.us</a></td>
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<td>72</td>
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<td>MN DNR</td>
<td><a href="mailto:Adam.James@state.mn.us">Adam.James@state.mn.us</a></td>
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<td>73</td>
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<td>USDA FS Hiawatha National Forest</td>
<td><a href="mailto:jordan@fs.fed.us">jordan@fs.fed.us</a></td>
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<td>Forester DCFD</td>
<td><a href="mailto:jason.jordan@douglascountywi.org">jason.jordan@douglascountywi.org</a></td>
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<td>St. Louis County Land &amp; Minerals</td>
<td><a href="mailto:kallanenm@stlouiscountygn.gov">kallanenm@stlouiscountygn.gov</a></td>
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<td>Wayne State University</td>
<td><a href="mailto:dkash@wayne.edu">dkash@wayne.edu</a></td>
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<td><a href="mailto:wilke137@umn.edu">wilke137@umn.edu</a></td>
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<td><a href="mailto:kelso026@umn.edu">kelso026@umn.edu</a></td>
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<td><a href="mailto:shannonkesner@fdirez.com">shannonkesner@fdirez.com</a></td>
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<td><a href="mailto:jeffrey.lee@state.mn.us">jeffrey.lee@state.mn.us</a></td>
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<td><a href="mailto:Andrew.R.Meier@usace.army.mil">Andrew.R.Meier@usace.army.mil</a></td>
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<td>Meyer</td>
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<td><a href="mailto:meyerj@stlouiscountymn.gov">meyerj@stlouiscountymn.gov</a></td>
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<td>Miller</td>
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<td><a href="mailto:laura.murphy@state.mn.us">laura.murphy@state.mn.us</a></td>
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<td>Dora University of Minnesota</td>
<td><a href="mailto:wilke137@umn.edu">wilke137@umn.edu</a></td>
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<td><a href="mailto:christiannelson@fdiriez.com">christiannelson@fdiriez.com</a></td>
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<td>Noh</td>
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<td>Norris</td>
<td>Mark Stevenson University</td>
<td><a href="mailto:mnorris@stevenson.edu">mnorris@stevenson.edu</a></td>
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<td>Olesiak</td>
<td>Rachael UMN-Cloquet Forestry Center</td>
<td><a href="mailto:rolesiak@umn.edu">rolesiak@umn.edu</a></td>
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<td><a href="mailto:derikolson@fs.fed.us">derikolson@fs.fed.us</a></td>
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<td>Osthus</td>
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<td><a href="mailto:jonathan.osthus@state.mn.us">jonathan.osthus@state.mn.us</a></td>
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<td><a href="mailto:moriah.otto@state.mn.us">moriah.otto@state.mn.us</a></td>
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<td><a href="mailto:thor.pakosz@state.mn.us">thor.pakosz@state.mn.us</a></td>
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<td>Palk</td>
<td>Brian USDA Forest Service, Northern Research Station</td>
<td><a href="mailto:bpalik@fs.fed.us">bpalik@fs.fed.us</a></td>
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<td><a href="mailto:pannukuk@stlouiscountymn.gov">pannukuk@stlouiscountymn.gov</a></td>
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<td>Parisio</td>
<td>Michael MN DNR</td>
<td><a href="mailto:michael.parisio@state.mn.us">michael.parisio@state.mn.us</a></td>
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<td>Linda USDA Forest Service</td>
<td><a href="mailto:lrparker@fs.fed.us">lrparker@fs.fed.us</a></td>
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<td><a href="mailto:ryan.pennesi@cco.carlton.mn.us">ryan.pennesi@cco.carlton.mn.us</a></td>
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<td>Sarah MN DNR - Fisheries</td>
<td><a href="mailto:sarah.pennington@state.mn.us">sarah.pennington@state.mn.us</a></td>
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<td><a href="mailto:emily.peters@state.mn.us">emily.peters@state.mn.us</a></td>
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<td>Bailey MN DNR - Wildlife</td>
<td><a href="mailto:bailey.petersen@state.mn.us">bailey.petersen@state.mn.us</a></td>
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<td>Pike</td>
<td>Carrie USDA Forest Service</td>
<td><a href="mailto:cpike@fs.fed.us">cpike@fs.fed.us</a></td>
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<td>Plattner</td>
<td>Dawn MN DNR</td>
<td><a href="mailto:dawn.plattner@state.mn.us">dawn.plattner@state.mn.us</a></td>
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<tr>
<td>Poznanovic</td>
<td>Sarah USDA FS, Superior National Forest Gunflint Ranger District</td>
<td><a href="mailto:sarahkpoznanovic@fs.fed.us">sarahkpoznanovic@fs.fed.us</a></td>
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<td>Prior</td>
<td>Ross Priority Timberlands LLC</td>
<td><a href="mailto:rossp@ez-net.com">rossp@ez-net.com</a></td>
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<td>Pszwaro</td>
<td>Justin University of Minnesota The Nature Conservancy</td>
<td><a href="mailto:jipszwaro@gmail.com">jipszwaro@gmail.com</a></td>
<td>OS II-09</td>
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<td>Queloz</td>
<td>Valentin WSL Birmensdorf Switzerland</td>
<td><a href="mailto:valentin.queloz@wsl.ch">valentin.queloz@wsl.ch</a></td>
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<tr>
<td>Quincer</td>
<td>Tim MN DNR</td>
<td><a href="mailto:tim.quincer@state.mn.us">tim.quincer@state.mn.us</a></td>
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129 Raj Jake Chippewa National Forest/ MTU jraj@fs.fed.us -  
130 Reilly Theresa Bureau of Indian Affairs theresa.reilly@bia.gov -  
131 Reith Erica Bureau of Indian Affairs erica.reith@bia.gov -  
132 Reuling Laura Wisconsin DNR laura.reuling@wisconsin.gov OS II-08  
133 Rowe Alex Forister DCFD alex.rowe@douglascountywi.org -  
134 Russell Matthew University of Minnesota russellim@umn.edu PS-13  
135 Sanders Robert Little River Band of Ottawa Indians rsanders@irboi-nsn.gov -  
136 Scherer Sawyer Blandin Paper Company sawyer.scherer@upmn.com -  
137 Schneider Ingrid UMN ingridss@umn.edu OS I-01 02  
138 Schoewe Martin Molpus Woodlands Group mschoewe@molpus.com -  
139 Schooler Shon Lake Superior NERR sschoole@uwuper.edu OS I-11  
140 Schuller David MN DNR - Forestry david.schuller@state.mn.us -  
141 Shannon Joseph SFRES, Michigan Tech. jshannon@mtu.edu OS I-09 11, PS-07 08 09  
142 Skurla Dave St. Louis County Land & Minerals skurlad@stlouiscountymn.gov -  
143 Slesak Rob MN Forest Resources Council raslesak@umn.edu OS I-07 08 10, OS II-08 09 11 PS-03 04 10 11  
144 Spry River Grand Portage Forestry rspry@grandportage.com -  
145 Steffensen Dave USDA Forest Service dsteffensen@fs.fed.us -  
146 Stover Kyle USDA FS, Superior NF kylestover@fs.fed.us -  
147 Theimer Myra USDA FS, Superior NF mtheimer@fs.fed.us -  
148 Thompson Dennis Aitkin County SWCD dennis.thompson@mn.nacdnet.net -  
149 Tjader Harvey MN DNR harvey.tjader@state.mn.us -  
150 Toczydlowski Alan UMN - Forest Resources toczy003@d.umn.edu PS-10 11  
151 Trudell James Western State Colorado University james.trudell@western.edu -  
152 Tucker Charlie MN DNR charles.tucker@state.mn.us -  
153 Turton Michelle US Fish & Wildlife Service michelle_turton@fws.gov -  
154 Tyler Matthew Nadarra Forestry LLC nadarraforestry@gmail.com -  
155 Van Cleve Jerry USDA Forest Service jvanclave@fs.fed.us -  
156 Van Grinsven Matthew Northern Michigan University mvangrins@nmu.edu OS I-11/ PS-07 08 09  
157 Van Frankenhuyzen Kelly Michigan State University vanfrank85@gmail.com PS-01  
158 Venette, Robert USDA FS, NRS & MITPPC, University of Minnesota rvenette@fs.fed.us KT, OS I-01 OS II-01 04, PS-02 15  
159 Wagenbrenner Joe USDA Forest Service, PSRS jwagenbrenner@fs.fed.us OS I-10, PS-07 08 09  
160 Waite Mark MN Office of School Trust Lands mark.waite@state.mn.us -  
161 Walton Nicholas Natural Resources Research Institute ngwalton@d.umn.edu -  
162 Wattenhofer Daniel Mississippi Park Connection dwattenhofer@parkconnection.org -  
163 West Benjamin Itasca County Land Dept Benjamin.West@co.itasca.mn.us -  
164 Westphal Mark Carlton County Land Department mark.westphal@co.carlton.mn.us -  
165 White Marc Tree Farm marcwhitemedia@pro@gmail.com -  
166 Wieten Alex Gun Lake Tribe travel@gtl-nsn.gov -  
167 Williams Linda Wisconsin DNR Linda.Williams@wisconsin.gov -  
168 Wrobel Alexandra Great Lakes Indian Fish and Wildlife Commission awrobel@gliwc.org -  
169 Wynveen Chris Baylor University Chris_Wynveen@baylor.edu OS I-02  
170 Youngquist Melissa University of Minnesota myoungquist@umn.edu PS-03 04  
171 Zomer Frank Bay Mills Indian Community fzomer@baymills.org -