2010 Project Abstract
For the Period Ending June 30, 2015

PROJECT TITLE: Ecological and Hydrological Impacts of Emerald Ash Borer
PROJECT MANAGER: Anthony D'Amato
AFFILIATION: Department of Forest Resources, University of Minnesota
MAILING ADDRESS: 1530 Cleveland Avenue North
CITY/STATE/ZIP: Saint Paul, MN 55108
PHONE: 802-656-8030
E-MAIL: damato@umn.edu
WEBSITE: http://silviculture.forestry.umn.edu/index.htm
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2010, Chp. 362, Sec. 2, Subd. 6b

APPROPRIATION AMOUNT: $636,000

Overall Project Outcomes and Results

The Emerald Ash Borer (EAB) has been decimating ash throughout the Lake States and is currently threatening the future of the ash forests that occur across much of Minnesota. Of particular concern is the impact of EAB on black ash swamps, which cover over one million acres. This project was designed to increase our understanding of the impacts of EAB through the establishment of a network of research sites in black ash forests. Treatments simulating EAB-induced mortality (all trees girdled in 4-acre areas) and associated management responses (i.e., clearcutting and group selection harvests) were implemented at eight, large-scale (20 acre) research sites on the Chippewa National Forest. Each treatment included two levels of planting (planting or no planting) to evaluate the potential for planting non-host species to increase the resilience of these areas to EAB. Planted seedlings included American elm, white cedar, yellow birch, tamarack, and swamp white oak. Results from this project indicate that loss of black ash will have significant impacts on the hydrology of these areas with clearcut and girdled (EAB mortality) plots experiencing flooded conditions that extended six to eight weeks longer than other areas. Estimates of black ash's contribution to the water budget indicate it accounts for 40-80% of total evapotranspiration, reinforcing the important role it plays in ash swamp hydrology. Three-year survival of planted seedlings also reflect its hydrologic influence, with lowest overall survival rates in clearcuts due to flooded, marsh-like conditions in these areas. Swamp white oak, hackberry, and American elm had the greatest survival rates of planted species (>80% in non-clearcut areas) with the lowest rates observed for black spruce, northern white cedar, and tamarack (<20%). Collectively, these results underscore the importance of maintaining black ash canopies in these areas to increase the success of plantings aimed at reducing vulnerability to EAB.

Project Results Use and Dissemination

The results of this project have been shared on numerous occasions with resource professionals, policy makers, citizens, and scientists over the past five years in efforts to inform forest conservation decisions regarding the impacts of emerald ash borer on black ash forests in Minnesota. These dissemination activities have included the development of a fact sheet for LCCMR members that was distributed on the LCCMR tour of Itasca State Park on July 18, 2013. In addition, we have shared the results from this project with private forest landowners, and county, state, tribal and federal natural resource managers on multiple occasions, including at the Aitkin County Land Department Ash Workshop on March 9, 2012, Forest Health Workshop in Walker, MN on February 12, 2013, and North Central Forest Pest Workshop in Frontenac, MN on September 24, 2013. We organized and led a Black Ash Field Day at our research sites on August 21, 2013 for 38 field foresters, loggers, and landowners and also included several stops at our research sites as part of a Climate-Informed Forest Management field tour of the Chippewa National Forest on May 8, 2014 for 100 participants. We have developed a "silviculture case study" of the five-year results of this project that will posted online on the "Great Lakes Silviculture Prescription Library" website this fall. Result of the project have also been presented at the Midwest-Great Lakes Society for Ecological Restoration Chapter Meeting in St. Paul,

MN on March 28, 2014, Midwest Invasive Species Conference in Duluth, MN on October 22, 2014, Black Ash Symposium in Orono, ME on November 4, 2014, and Sustainable Forests Education Cooperative Wildlife and Forest Research Review in Cloquet, MN on February 24, 2015. Finally, the project PI has served on the Minnesota DNR black ash management guideline committee since the inception of this project and has shared project results to influence the current recommendations for managing MN black ash forests in the face of EAB. Publications resulting from this work are available for download from the Department of Forest Resources web site (www.forestry.umn.edu). Additional publications from this work that are currently in development will also be posted on this site and shared with LCCMR staff for dissemination.

Environment and Natural Resources Trust Fund (ENRTF)
2010 Work Program Final Report

Date of Progress Report: August 4, 2015
Date of Next Progress Report: Final Report
Date of Work Program Approval: June 9, 2010
Project Completion Date: June 30, 2015

I. PROJECT TITLE: Ecological and Hydrological Impacts of Emerald Ash Borer

Project Manager: Anthony D'Amato
Affiliation: Department of Forest Resources, University of Minnesota
Mailing Address: 1530 Cleveland Avenue North
City / State / Zip: Saint Paul, MN 55108
Telephone Number: 802-656-8030
E-mail Address: damato@umn.edu
FAX Number: 612-625-5212
Web Site Address: http://silviculture.forestry.umn.edu/index.htm

Location: Aitkin, Beltrami, Cass, Itasca, Koochiching, and St. Louis Counties.

Total ENRTF Project Budget:	**ENRTF Appropriation**	**$**	**636,000**
	Minus Amount Spent:	**$**	**636,000**
	Equal Balance:	**$**	**0**

Legal Citation: M.L. 2010, Chp. 362, Sec. 2, Subd. 6b

Appropriation Language:
$636,000 is from the trust fund to the Board of Regents of the University of Minnesota to assess the potential impacts of emerald ash borer on Minnesota's black ash forests and quantify potential impacts on native forest vegetation, invasive species spread, and hydrology. This appropriation is available until June 30, 2015, by which time the project must be completed and final products delivered.

II. Project Summary and Results: The Emerald Ash Borer (EAB) has been decimating ash throughout the Great Lake States and is currently advancing into Minnesota, threatening the future of the ash forests that occur across much of the state. Of particular concern is the impact EAB will have on the ecology and functioning of black ash swamps, which cover over one million acres in Minnesota and represent the state's most common ash forest type. Black ash trees grow and thrive in swamps and occupy a unique wet niche where few other tree species grow. As a result, EAB impacts on black ash swamps will likely be extreme, resulting in dramatic changes in native plant communities and increasing the potential for invasion by exotic plant species.

This project will increase our understanding of the ecological and hydrological impacts of EAB through the establishment of a network of research sites in black ash forests in Minnesota. Treatments simulating EAB-induced ash mortality will be implemented at

each site to characterize how the loss of ash from these systems will impact native plant communities, the spread of invasive species, and site hydrology. In addition, the survival and growth of a mixture of planted tree seedlings will be evaluated to determine what species might be able to mitigate the ecological impacts of the loss of black ash from these forests. Results from this project will allow for predictions into how EAB will affect northern Minnesota's forests and will inform management recommendations for mitigating impacts of this exotic insect.

III. Progress Summary as of:

February 27, 2011:
We have located and established 8 study sites within black ash forests on the Chippewa National Forest in northern Minnesota. Within each site, we have randomly assigned four experimental treatments: retain all ash, simulated emerald ash borer (EAB) mortality by girdling all ash, harvest all ash, and group selection harvests (removal of 0.1 acre groups of ash). Each of these treatments includes two levels of planting (planting or no planting) and planted seedlings represent 11 different non-host species, including American elm, northern white cedar, yellow birch, tamarack, and swamp white oak. Plots and monitoring wells have been established across all treatments for assessing the vegetation and hydrologic responses of these ecosystems to black ash mortality. These plots and wells will be measured this upcoming spring/summer to provide a pre-harvest baseline for the black ash mortality treatments. In addition, initial assessments of the survival of EAB larvae exposed to winter temperatures representative of northern Minnesota have been conducted. This work suggests that under 10% of EAB larvae can survive winter temperatures typically found in the Grand Rapids region. Additional assessments are ongoing this winter.

July 27, 2011
We have completed pre-harvest measurements of vegetation across 4 of the 8 study sites within black ash forests on the Chippewa National Forest in northern Minnesota and will complete measurements on the remaining 4 sites by September 2011. In addition, baseline hydrological measurements have been collected across all 4 study areas and indicate that hydrologic regimes are similar across sites allowing for a broad assessment of EAB impacts on the hydrology of black ash forests. Black ash and green ash logs have been harvested near these research areas and are currently being used to rear EAB larvae for assessments of winter survival this upcoming winter.

January 26, 2012
We have completed pre-harvest measurements of vegetation across all of the study sites within black ash forests on the Chippewa National Forest in northern Minnesota. The implementation of experimental harvest and girdling treatments has begun and will be completed in March 2012. Comparisons of survival of EAB larvae between black ash and green ash logs indicate that host species has no effect on the supercooling point of larvae. In addition, evaluations of cold tolerance indicate that all larvae freeze by the time temperatures reach -30 to -38° C. The lowest temperature recorded beneath ash bark in northern Minnesota (Grand Rapids) was -37° C, suggesting that temperatures

may be reached that limit population growth of EAB. A second season of winter survival assessments is currently being conducted.

August 3, 2012

We have completed post-harvest seedling planting across all of the study sites within black ash forests on the Chippewa National Forest in northern Minnesota. In addition, post-harvest measurements of vegetation across 4 of the 8 study sites have been completed and we will complete measurements on the remaining 4 sites by September 2012. The first season of post-harvest hydrological measurements is currently ongoing and will be completed in October 2012. Analyses of pre-treatment hydrological data suggests that evapotranspiration is lower than expected within these systems and subsequent monitoring of water table responses to each treatment will improve our ability to determine the hydrological magnitude of the death of black ash trees in these areas. The second season of EAB larvae winter survival was completed and trends were similar to those documented in the first season; however, the fraction of larvae that remained active during the winter was greater. The reason for this higher level of winter survivorship is unclear, but may be due to the warmer fall temperatures in the second season that allowed more larvae to develop to the prepupal stage before the winter. Prepupae may form pupal cells in the outer sapwood, and thereby increase the thickness of host tissue between the insect and the environment. This layer may provide insulation and protection from short-term drops in temperature. Experiments testing these hypotheses are currently being conducted.

January 31, 2013

We completed post-harvest seedling planting across all of the study sites within black ash forests on the Chippewa National Forest in northern Minnesota. In addition, post-harvest measurements of vegetation across all of the study sites have been completed. Analyses of first-year survival of seedlings indicate that seedlings planted in the spring, regardless of treatment, had the greatest levels of survival relative to fall-planted seedlings. These trends were most pronounced for the clearcut treatments and likely reflect the lack of snowpack in these areas during the winter they were harvested (2012). As a result, seedlings were less protected from harvesting disturbance and winter desiccation when planted in the fall before treatment. The greatest levels of seedling survival were observed for cottonwood (78.1± 1.4%), hackberry (73.7± 1.5%), red maple (51.8 ± 1.8%), and northern white cedar (50.6 ± 2.1%), whereas tamarack had the lowest level of survival (21.8 ± 1.6%). The first season of post-harvest hydrological measurements was completed and water table dynamics during the growing season indicated that clearcut and girdle treatments (simulated EAB infestation) resulted in higher water tables than no-harvest and group selection harvests. Monitoring in future years will indicate if these are transient impacts or if the death of black ash in these areas has lasting effects on local hydrology. Analysis of the second season of EAB larvae winter survival indicate that survival was greater at southern locations than in northern locations, but that a number of larvae survived low temperatures common in the Grand Rapids, MN area.

September 3, 2013

We completed the second year of post-harvest vegetation measurements across all of the study sites on the Chippewa National Forest, with the exception of our assessments of planted seedling survival and growth, which are scheduled to be completed in late September. Analyses of two-year trends in natural forest regeneration following harvest treatment application indicate that black ash is the primary species reproducing following harvesting in these ecosystems with over 2000 stems/acre in the group selection and clearcutting treatments. Other species also recruiting naturally in these areas include American elm, quaking aspen, burr oak, basswood, and balsam poplar; however, these non-ash species constitute a very small proportion (< 20%) of naturally occurring seedlings. These initial results suggest that harvesting alone will not increase the resilience of these areas to EAB. Measurements of understory plant community responses to our treatments indicate that clearcut harvesting of black ash areas has led to an increase in sedge and grass species cover, which may present challenges to reforestation efforts in these areas. The second season of post-harvest hydrological measurements will be completed in late October. Detailed analyses of water table dynamics during the first growing season following treatment implementation indicated that clearcut treatments resulted in flooded conditions that persisted six to eight weeks longer than in no-harvest, girdled, and group selection areas. Analysis of the third season of EAB larvae winter survival indicate that on average larvae collected from black ash logs froze at -32.3°C (-26.1°F) while larvae from green ash logs froze at -32.9°C (-27.2°F), but more than half of the larvae from black ash froze between -23°C (-9.4°F) and -32.3°C and from green ash between -15 (+5°F) and -32.9°C. The proportion of insects that died after brief exposure to cold did not consistently differ from the room temperature controls until temperatures reached -35°C (-31°F). Exposure to this temperature killed approximately 85% of larvae from black ash and 40% of larvae from green ash, after correcting for mortality that occurred in the room-temperature control. These results suggest that EAB from black ash are more sensitive to cold than larvae from green ash. This result also reaffirms considerable variation from year to year in the cold tolerance of EAB. These differences seem to depend on conditions during the previous fall.

January 15, 2014

We completed the second year of post-harvest vegetation measurements across all of the study sites on the Chippewa National Forest. Analyses of two-year trends in survival of planted seedlings indicate that American elm, swamp white oak, and hackberry have had the greatest levels of survival out of the 11 non-ash species planted (> 80% survival for all three species). Survival of planted lowland conifer species, including northern white cedar and black spruce, has been greatest in areas where an ash canopy is still present, namely the group selection and EAB-mortality treatments (girdled plots) highlighting the negative impacts clearcutting may have on our ability to establish non-host species in these areas. The second season of post-harvest hydrological measurements was completed and water table dynamics were similar to the first growing season with clearcut treatments containing flooded conditions that persisted six to eight weeks longer than in no-harvest and group selection areas. Girdle treatments also experienced considerable ash dieback and mortality in the second season and water table dynamics were reflective of this with flooded conditions similar to clearcut

treatments. These results indicate that EAB-induced mortality will cause dramatic shifts in groundwater dynamics that could limit the effectiveness of planting non-host species once EAB is affecting an area. Results from the three seasons of EAB larvae winter survival have been integrated into models predicting EAB spread under different winter temperature scenarios.

July 17, 2014

We have completed two-thirds of the third year of post-harvest vegetation and hydrological measurements across all of the study sites on the Chippewa National Forest, with the remainder scheduled to be completed by the fall. Analyses of two-year trends of the impacts of ash mortality on understory plant communities indicate that pre-emptive clearcutting of black ash in response to EAB may result in dramatic shifts of understory plant communities towards strong dominance by lake sedge and other graminoids. Changes in understory plant communities in response to ash mortality due to simulated EAB have been less dramatic, likely due to the slower rates of tree mortality on these sites relative to clearcut areas. Shifts in plant communities in the clearcut harvested treatments are reflective of the increased saturated conditions in these areas, as many plants now dominating these sites are obligate wetland species. Estimates of the contribution of black ash trees to the overall water budget of black ash swamps indicate that transpiration by black ash accounts for 40-80% of the total evapotranspiration for black ash wetlands. Although this contribution is lower than documented for other forest trees, the loss of this water use by black ash due to EAB is significant enough to push hydrologic regimes towards conditions no longer supporting arboreal vegetation. Results of models predicting EAB spread under different winter temperature scenarios suggest that cold winter temperatures (< -30° F) may slow rates of tree mortality, but will not prevent EAB from infesting a given the ability of populations to rebound after experiencing severe periods of cold. This reflects that not all individuals are killed by these temperatures and are able to return to high population levels in one to two years.

February 21, 2015

We have completed the third year of post-harvest vegetation and hydrological measurements across all of the study sites on the Chippewa National Forest. Analyses of three-year trends in survival of planted seedlings indicate that American elm, swamp white oak, and hackberry remain the species with the greatest levels of survival out of the 11 non-ash species planted (> 80% survival for all three species in non-clearcut plots). Survival of all planted species continues to be lowest in clearcut areas, suggesting this practice may create challenging conditions for establishing non-ash species. The three conifer species planted in the experiment, black spruce, northern white cedar, and tamarack, have low survival rates (< 20%), likely due to herbivory and unfavorable hydrologic dynamics. The third season of post-harvest hydrological measurements was completed and water table dynamics were similar to the second growing season with clearcut and girdle (EAB mortality) treatments experiencing flooded conditions that persisted six to eight weeks longer than in no-harvest and group selection areas. These flooded conditions suggest that the increase in herbaceous and shrub species observed following ash mortality is not great enough to counterbalance

the contribution of ash transpiration in regulating hydrology of these areas. As such, it is expected that the loss of ash to EAB and preemptive clearcutting will cause significant shifts in water table conditions towards greater flooding and loss of tree cover in these areas.

Overall Project Outcomes and Results

The Emerald Ash Borer (EAB) has been decimating ash throughout the Lake States and is currently threatening the future of the ash forests that occur across much of Minnesota. Of particular concern is the impact of EAB on black ash swamps, which cover over one million acres. This project was designed to increase our understanding of the impacts of EAB through the establishment of a network of research sites in black ash forests. Treatments simulating EAB-induced mortality (all trees girdled in 4-acre areas) and associated management responses (i.e., clearcutting and group selection harvests) were implemented at eight, large-scale (20 acre) research sites on the Chippewa National Forest. Each treatment included two levels of planting (planting or no planting) to evaluate the potential for planting non-host species to increase the resilience of these areas to EAB. Planted seedlings included American elm, white cedar, yellow birch, tamarack, and swamp white oak. Results from this project indicate that loss of black ash will have significant impacts on the hydrology of these areas with clearcut and girdled (EAB mortality) plots experiencing flooded conditions that extended six to eight weeks longer than other areas. Estimates of black ash's contribution to the water budget indicated it accounts for 40-80% of total evapotranspiration, reinforcing the important role it plays in ash swamp hydrology. Three-year survival of planted seedlings also reflect its hydrologic influence, with lowest overall survival rates in clearcuts due to flooded, marsh-like conditions in these areas. Swamp white oak, hackberry, and American elm had the greatest survival rates of planted species (>80% in non-clearcut areas) with the lowest rates observed for black spruce, northern white cedar, and tamarack (<20%). Collectively, these results underscore the importance of maintaining black ash canopies in these areas to increase the success of plantings aimed at reducing vulnerability to EAB.

IV. Outline of Project Results:

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

Description: We will locate and establish 8 study sites within black ash forests in northern Minnesota. Experimental treatments at each site will include three levels of ash loss (retain all ash, simulated EAB mortality by girdling all ash, or harvest all ash) and two levels of planting (planting or no planting). Each experimental ash-loss treatment will be a minimum of 20 acres to allow for assessment of hydrological impacts of EAB.

Summary Budget Information for Result 1:	**ENRTF Budget:**	**$ 172,491**
	Amount Spent:	**$ 172,491**
	Balance:	**$ 0**

Deliverable	Completion Date	Budget
1. Work with MNDNR, USFS, and counties to identify black ash forest sites	October, 2010	$25,500
2. Conduct pre-harvest measurements of forest conditions	November, 2010	$116,376
3. Implement treatments (carry out timber sales and girdle trees)	March, 2012	$30,615

Result Completion Date: March 2012

Result Status as of February 27, 2011: We have located and established the black ash study sites for this project within the Chippewa National Forest in northern Minnesota (Deliverable 1). Within each site, we have randomly assigned four experimental treatments: retain all ash, simulated emerald ash borer (EAB) mortality by girdling all ash, harvest all ash, and group selection harvests (removal of 0.1 acre groups of ash). Each site is 20 acres in size and contains 4, 4-acre stands that will serve as experimental units (total of 8 stands). Plots and monitoring wells have been established in all 8 stands and will continue to be measured for pre-harvest assessments of ecological and hydrologic conditions this spring/summer. In addition, timber sales are currently being set up for experimental treatments and will be conducted in winter 2011/2012. We are on schedule to meet all proposed completion dates for deliverables under Result 1.

Result Status as of July 27, 2011: We have completed pre-harvest measurements of vegetation across 4 of the 8 study sites within black ash forests on the Chippewa National Forest in northern Minnesota and will complete measurements on the remaining 4 sites by September 2011. In addition, baseline hydrological measurements have been collected across all 8 study areas and indicate that hydrologic regimes are similar across sites allowing for a broad assessment of EAB impacts on the hydrology of black ash forests. Timber sales have been set up for experimental treatments on these areas and will be conducted in winter 2011/2012. We are on schedule to meet all proposed completion dates for deliverables under Result 1.

Result Status as of January 26, 2012: We have completed pre-harvest measurements across all of the study sites within black ash forests on the Chippewa National Forest in northern Minnesota (Deliverable 2). Timber sales for implementing the experimental treatments have begun and are scheduled to be completed by March. Girdling treatments will begin in February and will also be completed by March. We are on schedule to meet all proposed completion dates for deliverables under Result 1.

Result Status as of August 3, 2012: We have completed the establishment of the research sites and all deliverables under Result 1.

Result Status as of January 31, 2013: We have completed all deliverables under Result 1.

Result Status as of September 3, 2013: We have completed all deliverables under Result 1.

Result Status as of January 15, 2014: We have completed all deliverables under Result 1.

Result Status as of July 2014: We have completed all deliverables under Result 1.

Result Status as of February 21, 2015: We have completed all deliverables under Result 1.

Final Report Summary: Eight, large-scale black ash study sites were established on the Chippewa National Forest in northern Minnesota in 2010-2011. Within each site, we randomly assigned four experimental treatments: retain all ash, simulated emerald ash borer (EAB) mortality by girdling all ash, harvest all ash, and group selection harvests (removal of 0.1 acre groups of ash). Each site is 20 acres in size and contains 4, 4-acre stands that serve as experimental units (total of 8 stands). In the spring/summer of 2011, we established vegetation plots and monitoring wells across all of these areas to develop pretreatment baseline conditions and used these plots and wells in subsequent field seasons (2012-2014) to assess the impacts of each treatment on plant communities and site hydrology. The experimental treatments were implemented via timber harvests occurring in January 2011-February 2012, as well as hand girdling of all ash stems in simulated EAB mortality plots in February 2012. Girdling was reapplied in June-July 2012 to ensure wounding was deep enough to kill overstory black ash. The establishment of these study sites has provided a powerful experimental setting to continue to monitor both the influence of EAB and forest harvesting on black ash forest ecosystems, as well as to evaluate potential adaptive management strategies for reducing the impacts of this introduced insect. In addition, the close proximity of several replicates of this experiment to Third River Road within the Chippewa National Forest has allowed for several field tours of these areas as part of workshops and trainings related to sustaining black ash forests in the face of EAB.

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

Description: To assess the impacts of EAB on native plants, tree regeneration, invasive species, and hydrology, we will plant seedlings and monitor their survival and growth, characterize the abundance of native and invasive plant species in unplanted areas, and assess changes in hydrology following ash mortality. Seedlings will consist of a mix of species adapted to lowland forest conditions, allowing us to address questions related to appropriate species for increasing the resiliency of ash swamps to EAB. Results concerning the impacts of ash mortality on native plant communities, tree regeneration, and hydrology will be summarized in public project reports and conveyed to managers through outreach activities.

Summary Budget Information for Result 2: **ENRTF Budget: $ 397,188**
Amount Spent: $ 397,188
Balance: $ 0

Deliverable	Completion Date	Budget
1. Plant seedlings and conduct post-harvest measurements	October, 2011	$99,260
2. Assess plant communities, planted seedlings, and hydrology for 4 years	October, 2014	$279,919
3. Develop and publish project summaries aimed at resource managers working with black ash swamps within the state	June, 2015	$18,009

Result Completion Date: June 2015

Result Status as of February 27, 2011: We have established monitoring wells and vegetation sampling plots within all 8 black ash stands. In addition, seedlings representing 11 different species have been ordered and will be planted in fall 2011 and spring 2012. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of July 27, 2011: Seedling plots have been laid out with the study areas and half of the seedlings will be planted this September. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of January 26, 2012: We have completed planting seedlings for the fall planting portion of the experiment and have ordered the remaining seedlings for planting this spring. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of August 3, 2012: We have completed planting seedlings for the spring planting portion of the experiment and have completed sampling 4 of the 8 research areas for the first year of post-harvest measurements. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of January 31, 2013: We have completed planting seedlings (Deliverable 1) and the first year of post-harvest measurements. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Amendment request July 2, 2013: Amendment is requested to rebudget $18,000 from personnel to Non-capital equipment/tools and $10,200 from personnel to Travel expenses. This amendment is being requested to support the purchase of level loggers

and soil moisture meters for monitoring groundwater table responses across black ash wetlands and to support the high amount of travel required to measure and monitor these research areas (Activities 1 and 2). The purchase of this equipment will allow for a more robust estimate of the impact of black ash mortality from EAB on local and regional hydrology. **Amendment approved by LCCMR on July 9, 2013.**

Result Status as of September 3, 2013: We have completed the second year of post-harvest measurements for 5 of the 8 research areas and will complete the remainder of measurements by September 30. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of January 15, 2014: We have completed the second year of post-harvest vegetation and hydrologic measurements. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of July 2014: We have completed sampling vegetation and planted seedlings in 5 of the 8 research areas for the third year of post-harvest measurements with measurements expected to be completed in the remaining areas by mid-August. We are also 2/3rds through our third season measuring groundwater table dynamics post-treatment. We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Result Status as of February 20, 2015: We have completed the third year of post-harvest vegetation and hydrologic measurements for a total of four years measurements in these areas (Deliverable 2). We are on schedule to meet all proposed completion dates for deliverables under Result 2.

Final Report Summary: The impacts of EAB and associated management strategies on native plant communities, seedlings of potential replacement tree species, spread of invasive species, and hydrologic patterns were monitored for four years (2011-2014) across the eight study sites. Examination of the development of the plant communities in these areas following EAB mortality and harvesting indicated that clearcut harvesting quickly shifted the dominance of these communities towards marsh-like vegetation, with lake sedge and other obligate wetlands species becoming dominant. The slower progression of mortality in the EAB mortality plots resulted in less dramatic shifts over the four years of monitoring; however, by the final year of measurement these areas also contained a greater abundance of obligate wetlands species. We did not detect any significant impact of EAB mortality on the spread of invasive species over the duration of this project. A total of 134,168 seedlings representing 11 potential replacement species (384 reps per species per treatment) were planted across each treatment in fall 2011 and spring 2012 (half in each season). The species of seedlings were northern white cedar, yellow birch, tamarack, red maple, hackberry, swamp white oak, black spruce, quaking aspen, cottonwood, balsam poplar, American elm (resistant variety, local seed source crossed with Valley Forge cultivar), and Manchurian ash. Seedlings were either containerized or bare-root planting stock. Given the higher overall survival rates of species that were bare-root planting stock (e.g., swamp white oak and American elm), future work looking at adaptive strategies for addressing EAB should include explicit within-species tests on how stock type influences overall species

survival in these areas. Also, the 11 species chosen were determined based on general consensus among the project PIs and therefore did not include all potential replacement species for black ash. Future work should include additional species, such as bur oak and silver maple, which may also do well in these ecosystems.

Detailed hydrological data were collected from our research areas from 2011-2014 allowing us to characterize both the baseline hydrologic conditions in these ecosystems, as well as to document the impacts of ash mortality on water table dynamics, flooding, and soil moisture regimes. Given the extensive size of our treatment areas and the level of instrumentation needed to fully characterize hydrologic dynamics in these swamps, equipment costs for this portion of the project exceeded our original estimate (see Amendment request above). These expenditures and our experimental design allowed us to both demonstrate the profound influence black ash has on the water budget in black ash wetlands (50-80% of total evapotranspiration) and document the impacts of losing black ash trees on increased levels of flooding in these areas. Both the long-term monitoring wells and vegetation plots continue to be maintained and measured and will allow for important insights on the long-term impacts of EAB and forest management on these ecosystems.

RESULT 3: Determine potential for spread of EAB into northern Minnesota
Description: The potential for EAB to impact black ash communities in Minnesota hinges on the cold tolerance of this insect. We will conduct laboratory experiments investigating the tolerance of EAB larvae to winter temperatures commonly occurring in northern Minnesota. Findings from these experiments will be integrated into models predicting the potential spread of EAB throughout the state. Results concerning the cold tolerance and potential spread of EAB strategies will be summarized in public project reports and conveyed to managers through outreach activities.

Summary Budget Information for Result 3:	**ENRTF Budget:**	**$ 66,321**
	Amount Spent:	**$ 66,321**
	Balance:	**$ 0**

Deliverable	**Completion Date**	**Budget**
1. Determine the cold tolerance of EAB	November, 2012	$34,200
2. Incorporate results into models of EAB spread	November, 2013	$25,326
3. Publish project summaries aimed at resource managers working with black ash swamps within the state	June, 2014	$6,795

Result Completion Date: June 2014

Result Status as of February 27, 2011: Initial assessments of the survival of EAB larvae exposed to winter temperatures representative of northern Minnesota have been conducted. In particular, the survival of EAB larvae within ash logs subjected to winter

temperatures in Grand Rapids, MN has been assessed. This work suggests that under 10% of EAB larvae can survive winter temperatures typically found in the Grand Rapids region. Additional monitoring of survival in winter 2010/2011 will be used to inform estimates of EAB cold tolerance. We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of July 27, 2011: As a follow-up to our initial assessments of the survival of EAB larvae exposed to winter temperatures, we have collected logs of black ash and green ash from northern Minnesota for additional evaluations of larvae survival. These evaluations will occur in winter 2010/2011 and will be used to inform estimates of EAB cold tolerance. We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of January 26, 2012: EAB larvae were collected from green ash and black logs originating from the Pike Bay Experimental Forest in northern Minnesota in early November 2011. Mortality of larvae was high; only a total of nine larvae were recovered from all logs. Weight and supercooling point were measured for each larva and cold tolerance determined (Deliverable 1). We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of August 3, 2012: We have completed two years of winter survival measurements and are currently incorporating these results into models of EAB spread. In addition, the factors affecting different levels of EAB survival between winter 2009-2010 and 2010-2011 are being investigated. We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of January 31, 2013: Analyses of the factors affecting EAB survival have been completed and are currently being integrated into models of EAB spread. We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of September 3, 2013: We have completed three years of winter survival measurements and have determined the primary factors affecting the variability in different levels of EAB survival between winter 2009-2010, 2010-2011, and 2011-2012. We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of January 15, 2014: Winter survival measurements have been integrated into models determining the probability of EAB spread across northern MN based on various future projected winter temperature regimes. We are on schedule to meet all proposed completion dates for deliverables under Result 3.

Result Status as of July 2014: We have completed all deliverables under Result 3.

Result Status as of February 21, 2015: We have completed all deliverables under Result 3.

Final Report Summary: Green and black ash logs were collected from near the experimental areas established under Result 1 and used for rearing EAB larvae to

evaluate the cold tolerance of this species to enable predictions of potential spread into northern Minnesota. Winter survival of larvae were examined by exposing logs to winter temperatures in Grand Rapids, MN during the winters of 2009-2010, 2010-2011, and 2011-2012. Integration of winter survival measurements with models determining spread of EAB in MN suggest areas with annual low temperatures < -30°F are likely to have high rates of winter mortality of EAB larvae in most years. Although these temperatures may slow rates of tree mortality they will not prevent EAB from infesting a given area due to the ability of populations to rebound after experiencing severe periods of cold. This reflects that not all individuals are killed by these temperatures and are able to return to high population levels in one to two years. Funding from the Minnesota Department of Agriculture to Co-PI Rob Venette was leveraged to increase the number of years that cold tolerance was monitored for this portion of the study.

V. TOTAL ENRTF PROJECT BUDGET:

Personnel: $589,000. These funds will be used to support salary and fringe for two graduate students; one for four years and the other for 2 years. Graduate fringe is budgeted at 0.7694 of salary load and includes tuition for the academic year, health care for the fiscal year, and social security and Medicare for 6.5 pay periods (summer). One of these graduate students will be responsible for collecting and analyzing vegetation data associated with Results 1 and 2, whereas the other graduate student will be responsible for Result 3. These funds are also for supporting salary and fringe (0.1812) for a post-doctoral research associate for four years. This post-doctoral research associate will be responsible for ecohydrological analyses and measurements associated with Results 1 and 2. Salary and fringe (0.3230) for a research associate for three years (0.5 FTE) is also budgeted. This research associate will be responsible for identifying field sites, overseeing treatment implementation, and coordinating field research crews. Finally, salary and fringe (0.0743) for two summer students is budgeted for four years to assist with field measurements associated with Results 1 and 2. Note ENRTF are not being used to pay any PI salaries.

Contracts: $ 0

Equipment/Tools/Supplies: $40,500. These funds will be used for buying equipment associated with Results 1 and 2. Equipment includes rebar for permanently marking plot centers ($550), supplies for constructing wells for monitoring hydrology at each site ($31,100), soil moisture meters for monitoring groundwater responses to EAB ($3,000), Haglof distance measuring equipment ($700), stake whiskers for marking subplots ($110), calipers for measuring seedling growth ($320), supplies for constructing frames for measuring understory vegetation ($150), draw knives and pruning saws for girdling trees ($1000), gloves for field crews girdling trees ($60), diameter tapes for measuring overstory trees ($150), and data loggers for micrometeorological measurements ($3460)

Acquisition (Fee Title or Permanent Easements): $ 0

Travel: $35,200. Due to the high number of study sites and logistics associated with establishing the harvest treatments and baseline data collection, $35,200 is budgeted for domestic travel within Minnesota. This money will be used to pay for mileage (75%) and lodging (25%) for researchers, the field technician, post-doc, graduate students, and undergraduate students. Mileage includes regular trips from UMN St. Paul campus to 12 field sites located across northern Minnesota throughout the year.

Additional Budget Items: $ 0

TOTAL ENRTF PROJECT BUDGET: $636,000

Explanation of Capital Expenditures Greater Than $3,500: NA

VI. PROJECT STRATEGY:

A. Project Partners: In addition to the Project Manager, other project team members are noted below.

Peter Reich
Department of Forest Resources
University of Minnesota
St. Paul, MN

Alan Ek
Department of Forest Resources
University of Minnesota
St. Paul, MN

Grant Domke
Department of Forest Resources
University of Minnesota
St. Paul, MN

Robert Slesak
Minnesota Forest Resources Council
St. Paul, MN

Brian Palik
USDA Forest Service
Northern Research Station
Grand Rapids, MN

Rob Venette
USDA Forest Service
Northern Research Station
St. Paul, MN

B. Project Impact and Long-term Strategy:

Due to the large component of Minnesota's forested landbase dominated by black ash systems, there is a critical need for research that can assess the potential impacts of EAB on our ash forests, as well as generate management strategies for maintaining the functioning of these systems, even after EAB has arrived. This project is intended to be a 5-year study. This time period is necessary to allow for research site identification, treatment implementation, and 4 years of post-treatment measurements. Importantly, having multiple measurement years to assess tree seedling survival and hydrological changes following ash mortality will be critical for generating well-informed management and conservation strategies aimed at minimizing the impacts of EAB on black ash swamps. This proposed project will build upon an existing project examining the decline of black ash within northern Minnesota established with $160,000 in grants from the USDA Forest Service (USFS). Project participants are committed to long-term maintenance and monitoring of sites established in this proposed project. Although we anticipate subsequent proposals to LCCMR, we are also seeking additional funds from the USDA, US Forest Service Forest Health Monitoring Program, and the National Science Foundation

C. Other Funds Proposed to be Spent during the Project Period: University of Minnesota and US Forest Service North Central Research Station will provide in-kind support of 0.25 FTE for a grand total of $107,000. In addition, $160,000 of grants from the USDA Forest Service will be used towards Result 1.

D. Spending History: $636,000

VII. DISSEMINATION:

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

Final Report Summary

The results of this project have been shared on numerous occasions with resource professionals, policy makers, citizens, and scientists over the past five years in efforts to inform forest conservation decisions regarding the impacts of emerald ash borer on black ash forests in Minnesota. These dissemination activities have included the development of a fact sheet for LCCMR members that was distributed on the LCCMR

tour of Itasca State Park on July 18, 2013. In addition, we have shared the results from this project with private forest landowners, and county, state, tribal and federal natural resource managers on multiple occasions, including at the Aitkin County Land Department Ash Workshop on March 9, 2012, Forest Health Workshop in Walker, MN on February 12, 2013, and North Central Forest Pest Workshop in Frontenac, MN on September 24, 2013. We organized and led a Black Ash Field Day at our research sites on August 21, 2013 for 38 field foresters, loggers, and landowners and also included several stops at our research sites as part of a Climate-Informed Forest Management field tour of the Chippewa National Forest on May 8, 2014 for 100 participants. We have developed a "silviculture case study" of the five-year results of this project that will posted online on the "Great Lakes Silviculture Prescription Library" website this fall. Result of the project have also been presented at the Midwest-Great Lakes Society for Ecological Restoration Chapter Meeting in St. Paul, MN on March 28, 2014, Midwest Invasive Species Conference in Duluth, MN on October 22, 2014, Black Ash Symposium in Orono, ME on November 4, 2014, and Sustainable Forests Education Cooperative Wildlife and Forest Research Review in Cloquet, MN on February 24, 2015. Finally, the project PI has served on the Minnesota DNR black ash management guideline committee since the inception of this project and has shared project results to influence the current recommendations for managing MN black ash forests in the face of EAB. Publications resulting from this work are available for download from the Department of Forest Resources web site (www.forestry.umn.edu). Additional publications from this work that are currently in development will also be posted on this site and shared with LCCMR staff for dissemination.

VIII. REPORTING REQUIREMENTS: Periodic workprogram progress reports will be submitted not later than January 2011, July 2011, January 2012, July 2012, January 2013, July 2013, January 2014, July 2014, and January 2015. A final work program report and associated products will be submitted between June 30 and August 1, 2015, as requested by the LCCMR.

IX. RESEARCH PROJECTS: See attached addendum.

Final Attachment A: Budget Detail for M.L. 2010, Chp. 362, Sec. 2, Subd. 6b

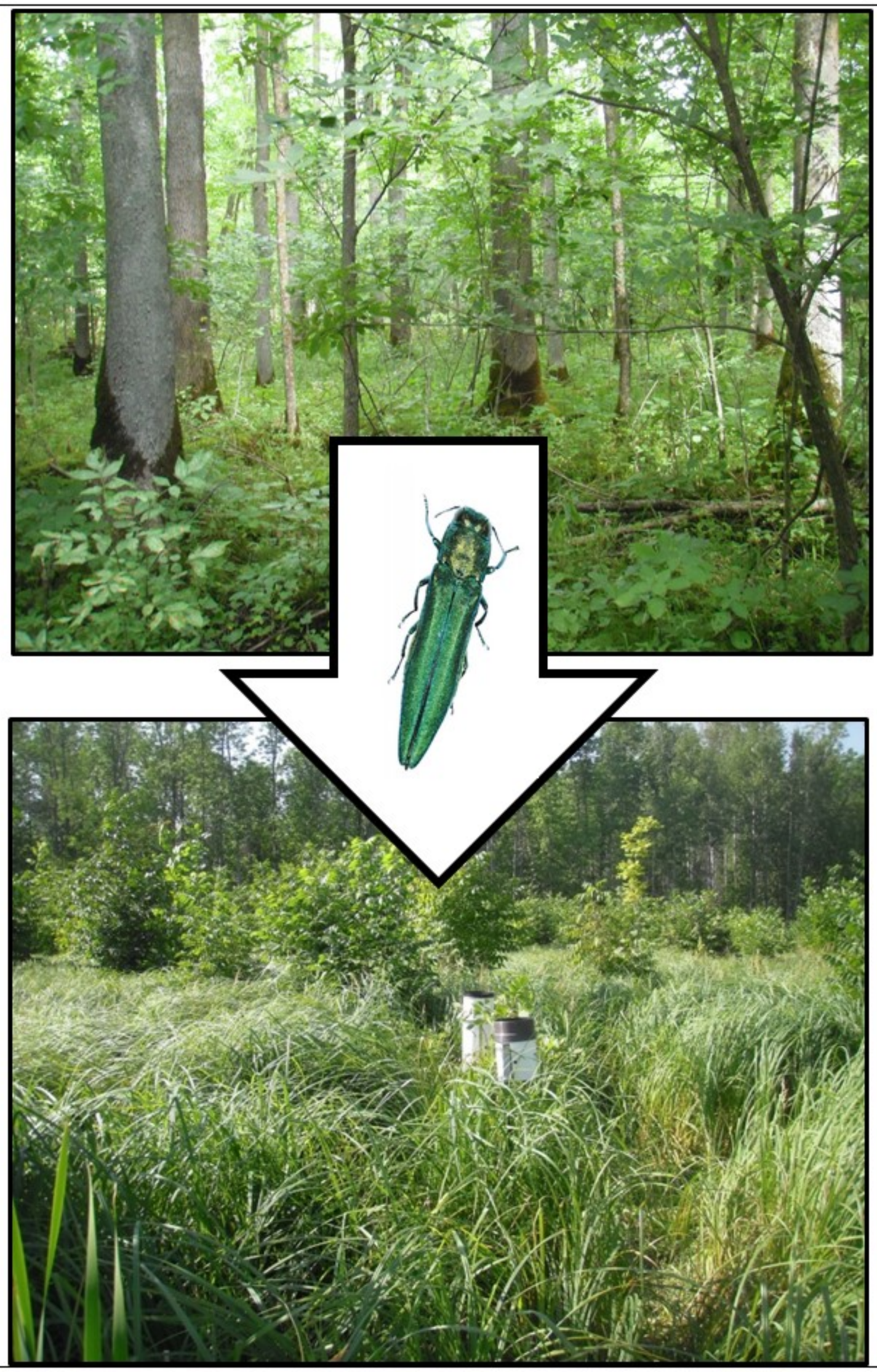
Project Title: Ecological and Hydrological Impacts of Emerald Ash Borer

Project Manager Name: Anthony D'Amato

Trust Fund Appropriation: $636,000

2010 Trust Fund Budget	**Result 1 Budget:**	**Amount Spent** *(date)*	**Balance** *(date)*	**Result 2 Budget:**	**Amount Spent** *(date)*	**Balance** *(date)*	**Result 3 Budget:**	**Amount Spent** *(date)*	**Balance** *(date)*	**TOTAL BUDGET**	**TOTAL BALANCE**
	Develop a network of research sites within black ash forests to assess impacts of EAB on biodiversity and productivity	2/21/2015	2/21/2015	**Determine the impacts of ash mortality from EAB on native plant communities, survival and growth of possible replacement tree species, spread of invasive species, and hydrologic patterns**	2/21/2015	2/21/2015	**Determine potential for spread of EAB into northern Minnesota**	2/21/2015	2/21/2015		
BUDGET ITEM											
PERSONNEL: wages and benefits Salary and fringe for two graduate students; one for four years and the other for 2 years. Graduate fringe is budgeted at 0.7694 of salary load and includes tuition for the academic year, health care for the fiscal year, and social security and Medicare for 6.5 pay periods (summer)	35,100	35,100	0	77,904	77,904	0	66,321	66,321	0	179,325	0
Salary and fringe (0.1812) for a post-doctoral research associate for four years.	75,239	75,239	0	150,478	150,478	0				225,717	0
Salary and fringe (0.3230) for a research associate for three years (0.5 FTE)	39,348	39,348	0	78,696	78,696	0				118,044	0
Salary and fringe (0.0743) for two summer students for four years	9,304	9,304	0	27,910	27,910	0				37,214	0
Non-capital Equipment / Tools Equipment includes rebar for permanently marking plot centers ($550), supplies for constructing wells for monitoring hydrology at each site ($15500),Haglof distance measuring equipment ($700), stake whiskers for marking subplots ($110), calipers for measuring seedling growth ($320), supplies for constructing frames for measuring understory vegetation ($150), draw knives and pruning saws for girdling trees ($1000), gloves for field crew girdling trees ($60), diameter tapes for measuring overstory trees ($150), data loggers for micrometeorological measurements ($3460)	6,000	6,000	0	34,500	34,500	0				40,500	0
Travel expenses in MinnesotaDue to the high number of study sites and logistics associated with establishing the harvest treatments and baseline data collection, $25,000 is budgeted for domestic travel within Minnesota. This money will be used to pay for mileage (75%) and lodging (25%) for researchers, the field technician, post-doc, graduate students, and undergraduate students. Mileage includes trips from UMN St. Paul campus to 15 field sites located across northern Minnesota.	7,500	7,500	0	27,700	27,700	0				35,200	0
COLUMN TOTAL	**$172,491**	**$172,491**	**$0**	**$397,188**	**$397,188**	**$0**	**$66,321**	**$66,321**	**$0**	636,000	0

Minnesota's black ash forests support the highest level of plant diversity of all forests and provide critical hydrologic functions, including flood regulation



We found that loss of black ash due to Emerald Ash Borer or preemptive clearcutting can shift forested wetlands to grass and sedge-dominated ecosystems and lead to greater amounts of flooding. Maintenance of black ash overstory trees will be critical to facilitate planting efforts aimed at increasing the resilience of these areas.