M.L. 2014, Chp. 226, Sec. 2, Subd. 04e-1 **Project Abstract**
For the Period Ending June 30, 2017

PROJECT TITLE: Mountain pine beetle: Invasive threat to Minnesota's pines
PROJECT MANAGER: Brian Aukema
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2014, Chp. 226, Sec. 2, Subd. 04e-1

APPROPRIATION AMOUNT: $175,000
AMOUNT SPENT: $175,000
AMOUNT REMAINING: $0

Overall Project Outcomes and Results

Native to the western United States and Canada, mountain pine beetle is the most devastating forest insect in North America, impacting almost 125 million acres of western mature pine forests to date. Mountain pine beetle reproduces under the bark in the water conducting tissues of many species of pines. During outbreaks, mountain pine beetles *must* kill their trees in order to reproduce and prefer live, vigorous, large-diameter trees. Minnesota is at risk of invasion from mountain pine beetle via two different routes. First, populations reproducing in Alberta, Canada could spread through a corridor of jack pine stretching across Canada's boreal forest into northern Minnesota. Second, green pine logs imported from western states could inadvertently bring this insect to the Midwest.

This project, in partnership with the Minnesota Department of Agriculture, had two objectives. First, pine stands in several areas of the state were surveyed for the presence of this insect. No populations were detected to date (see MDA update). Second, we exposed logs of pine species common in Minnesota, such as red pine, jack pine, white pine, and Scots pine, to the nearest known mountain pine beetle populations in the Black Hills of South Dakota, to gain baseline data on the risk to Minnesota's species of pines.

We found that mountain pine beetles were able to tunnel into cut logs of Minnesota's pines, attract mates, and lay eggs. The eggs were fertile, and insects could complete their development. The insects were cold hardy and the data suggest they could survive Minnesota's winters if established here. Development times in Minnesota's pines were slightly faster than those in historical western pine hosts, which was surprising. These results indicate that we should continue to take the threat of range expansion of mountain pine beetle seriously.

Project Results Use and Dissemination

During the course of this project, the MDA enacted an exterior state quarantine for pine logs with bark on them from western states, and the project manager met with DNR officials to discuss management/silvicultural responses to mountain pine beetle should the insect arrive in the state. This project fostered collaborations with five partner state and federal agencies, three universities, trained a PhD student who received a faculty position, and engaged several dozens of undergraduate university students by incorporating this project into classroom education such as redesigned laboratory practical exercises. In one instance, we hosted an undergraduate student from a different state who flew to Minnesota to conduct her internship on this project (at no cost to the project). If you are a student seeking to help with one of the most serious pending challenges in North America, the state of

Minnesota is a great place to come! This research project has resulted in five peer-reviewed publications to date, with others currently in review, along with several presentations at various scientific conferences.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Final Report

Date of Final Report: November 13, 2017

Date of Work Plan Approval: June 4, 2014

Project Completion Date: June 30, 2017

Does this submission include an amendment request? Y

PROJECT TITLE: Mountain Pine Beetle Invasive Threat to Minnesota's Pines (UMN Activities 2 & 3)

Project Manager: Brian Aukema

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Location: Statewide (survey Activity 1); with insect work undertaken both in the Quarantine Lab at the University of Minnesota as well as out-of-state in the Black Hills of South Dakota to avoid unintentional introduction of this pest to Minnesota

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$175,000**
	Amount Spent:	**$175,000**
	Balance:	**$0**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 04e-1

Appropriation Language:
$175,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota and $75,000 the second year is from the trust fund to the commissioner of agriculture to survey for the presence and characterize the potential risk of the invasive mountain pine beetle to Minnesota's pine forests to inform early detection and rapid response. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Mountain Pine Beetle Invasive Threat to Minnesota's Pines (UMN Activities 2 & 3)

II. PROJECT STATEMENT:

This project focuses on survey and characterization of risk to Minnesota's pines from mountain pine beetle. Native to the western United States and Canada, mountain pine beetle is the most devastating forest insect in North America. In the fall of 2012, mountain pine beetle was found in a shipment of logs to Minnesota. Fortunately, the insect was dead, but live insects may be here already.

Mountain pine beetle reproduces in almost all species of pines. It breeds in the water-conducting tissues of the tree, just underneath the bark, much like emerald ash borer. During outbreaks, mountain pine beetle *must* kill their tree in order to reproduce. The insect can only breed in trees larger than 5" diameter, so prefers healthy, larger diameter trees. US Forest Service data from 2011 indicates that Minnesota has 191,000,000 red, jack, and white pines large enough for mountain pine beetle to attack. Our pine forests create valuable wildlife habitat, regulate water runoff, and promote recreational opportunities. To date, mountain pine beetle has impacted almost 125 million acres of mature pine forests in western North America.

This project is being initiated due to two high-priority routes of entry to Minnesota (see graphic page):

1. **Through import of green logs into the state from proximate western states with the insect.** Interstate movement of logs is not regulated, so it is challenging to quantify the extent of this risk. The Minnesota Department of Agriculture (MDA) recently formed an expert task force on mountain pine beetle. Early investigation revealed one supplier in Montana who indicated they distribute wood to 900 builders, including "hundreds" in Minnesota and Wisconsin. Minnesota Department of Agriculture attempted contact with 79 business potentially receiving wood from western sources. Seventeen businesses were interviewed and 5 did state importing pine from western areas in the past. One site visit was made to a business as a result and dead mountain pine beetle were found in lodgepole pine logs from Montana. Raw wood imports brought Douglas fir beetle, a kissing cousin of mountain pine beetle, to Grand Rapids,MN, a few years ago. For unknown reasons, those insects died after being established from 2002-2006. The state was very fortunate, and needs to learn from that experience. This project implements critically-needed statewide monitoring and should be continued until evidence suggests the beetle could not establish here.

2. **From the northwest through a corridor of jack pine stretching across Canada's boreal forest into northern Minnesota.** Currently, an ongoing outbreak of mountain pine beetle in western Canada totals 45 million acres in size, making it the world's largest outbreak of any forest insect. The insect is typically kept in check by cold winter temperatures, but recent warming trends have unleashed the beetle over the Rocky Mountains on a path to Minnesota's pines. In a "good" year, the insects can disperse up to 500 miles (even visible on Doppler radar). Minnesota is 500 miles from the Black Hills of South Dakota, but there is little pine forest in between. We are twice this distance from the approaching front in Canada, but there is contiguous pine in between. Estimating the approaching front is difficult, as monitoring is an imperfect science: much like emerald ash borer, we know where trees have died, not how much closer the beetle is now.

This project uses a collaborative multi-agency team to undertake two objectives. The Minnesota Department of Agriculture will assume Objective 1 (Activity 1), while the University of Minnesota will undertake Objective 2 (Activities 2 & 3).

Objective 1. Survey state locations for presence of mountain pine beetle. If low numbers of insects have been introduced, they may persist for a number of years before exploding (similar to emerald ash borer).

Unlike emerald ash borer, there *is* an effective trap and lure. Management of isolated, endemic populations may not be impossible – *if* we know they are there first.

Objective 2. Characterize the risk to Minnesota's pine species. Studies by Canadian researchers indicate that jack pine is an excellent food source for the insect. We will characterize development and winter survival in red, white, and Scots pines to inform and direct rapid response management for Minnesota's pine species.

III. PROJECT STATUS UPDATES:

Amendment Approved by the LCCMR 10-24-2014: We are seeking permission to rebudget $4,000 from "salary" to "services." In addition to three University of Minnesota student helpers, we were able to partner with two WCSS students to help with fieldwork in the Black Hills of South Dakota studying colonization of mountain pine beetle on pines brought from Minnesota. Because the WCSS students are not U Minnesota students, we could not engage in traditional undergraduate employment but instead seek to offer honoraria for their help. According to the university, this qualification falls under "compensation for services rendered" not strict "employment." The budget and scope of work does not change.

Project Status as of November 15, 2014: This project has started well. A highly talented graduate student was recruited and we were able to deploy pines harvested from Minnesota to beetle populations in the Black Hills of South Dakota immediately after appropriation of funds from LCCMR. The timing worked well, as beetle flight occurred in the temporal window expected. Because beetles reproduce once per year, results related to reproduction and winter cold tolerance will not be available until late 2015. Details on the attraction study are provided below. No changes to project direction or scope are anticipated or required at this time.

Project Status as of May 15, 2015: This project continues to progress well. A trip to the Black Hills in April revealed that the beetles are developing in the logs. The logs were placed in emergence tubes for anticipated emergence late this coming summer. We were able to involved several undergraduates in sorting the survey samples from the MDA (detailed below). No changes to project direction or scope are anticipated or required at this time.

Project Status as of November 15, 2015: In June insects started to emerge from material in the Black Hills. We were able to hire three people this summer (in addition to the graduate student) to help with collections of beetles that emerged from the material in the Black Hills. These data form the basis of the first comparisons of insects emerging from different species of pine hosts present in the Great Lakes region. Because of the unprecedented range expansion of this insect, the topic continues to garner international attention. We presented an update on this work at an international forestry conference in Argentina in August (although no project funds were used for travel).

Amendment [Requested November 24, 2015, Approved December 8, 2015]: We are requesting small shifts in allocations of funds among Activities 1 and 2. We would like to add $800 to supplies for Activity 1 because it was necessary to purchase a small freezer for sample storage, as the science station did not have an available freezer. We also purchased a large number of vials and Eppendorf tubes to store insects for Activity 1, although many of these are being used for Activity 2 following collection. As such, we would like to decrease the supply budget for Activity 2 by $500. We would like to add $100 for printing to Activity 1 given the ongoing requests for scientific presentations and decrease travel for Activity 2 by $400 given less travel than anticipated in the Black Hils (logs for Activity 2 are held at a central location). The net change in budget to the project after reallocations is $0.

With this amendment we are also correcting a typo in the approved work plan to allocations listed under section IV. Project Activities and Outcomes so the amounts match Appendix 1. Previously, the amounts listed in the workplan summed to $173,200 instead of the project appropriation of $175,000.

Project Status as of May 15, 2016: The work continues to go extremely well. In November, work was presented by both the graduate student and an undergraduate student on this project at the national meeting of the Entomological Society of America. Both of them won President's Prizes (first place) in their respective divisions. The likelihood of both students winnering is literally 1 in 100, and reflects some superb work on their part and the high profile nature of this potential invasion event that could decimate pines in eastern North America. Moreover, the first scientific publication from this project that was submitted just prior to the last progress report has been accepted for publication at an international peer-reviewed journal.

Project Status as of November 15, 2016: This past six months saw two peer-reviewed publications come out on this work. The first (mentioned above) is now available from the international journal *Entomologia Experimentalis et Applicata* and details a new method to determine the sex of mountain pine beetles. This is important because females attack the trees and attract males; this publication lays a useful methodological framework as we publish the remaining research from this project. The second publication details how we have involved undergraduates from the university in the survey work from the MDA. Many universities continue to look for ways to keep students engaged and motivated in classes; we involved students in Entomology 4251 (Forest & Shade Tree Entomology) to learn how to sort and identify insect predators attracted to the survey traps. Students appreciated the laboratory activity as it is contributing to an important real-world resource management challenge.

Retroactive Amendment Request 9/28/17

In Activity 2, we request permission to move the $1,000 remaining in "professional contracts" back to "personnel." Previous approved amendment requested reallocation from personnel to contracts. This was strictly to satisfy internal UMN HR classifications when employing students at the Science Station in the Black Hills. In final project year, all students came from UMN so contract was not necessary and this amendment simply reverses the first. We also request permission to reallocate $787 savings from travel in MN (we were able to find suitable trees at Cloquet in the second year) to $640 research supplies (cost increase in chemicals used to attract and trap mountain pine beetles for this research) and $147 personnel. We would like to reallocate $33 unspent in printing (posters for research result dissemination to scientific community) to $25 personnel and $8 communications (tax on $100 SIM card purchase). Finally, we would like to allocate a remaining $107 in travel outside of MN to personnel to zero all categories; these small increases in personnel reflect changing benefits rates through the life of the project.

In Activity 3, with some effort we were able to complete cold tolerance work outside of the BSL-2 quarantine lab (but with an abundance of precautions and appropriate permit). We request reallocation of the BSL-2 rental savings ($4500), $1000 from supplies (thermocouples), $300 from printing (oral presentations instead of posters), and $714 from travel (shared with Activity 2) for total reallocation of $6686 to personnel ,as technicians spent more hours than expected painstakingly extracting these insects from underneath the bark for cold tolerance assays.

Overall Project Outcomes and Results:

Native to the western United States and Canada, mountain pine beetle is the most devastating forest insect in North America, impacting almost 125 million acres of western mature pine forests to date. Mountain pine beetle reproduces under the bark in the water conducting tissues of many species of pines. During outbreaks, mountain pine beetles *must* kill their trees in order to reproduce and prefer live, vigorous, large-diameter trees. Minnesota is at risk of invasion from mountain pine beetle via two different routes. First, populations reproducing in Alberta, Canada could spread through a corridor of jack pine stretching across Canada's boreal forest into northern Minnesota. Second, green pine logs imported from western states could inadvertently bring this insect to the Midwest.

This project, in partnership with the Minnesota Department of Agriculture, had two objectives. First, pine stands in several areas of the state were surveyed for the presence of this insect. No populations were detected to date (see MDA update). Second, we exposed logs of pine species common in Minnesota, such as red pine, jack pine, white pine, and Scots pine, to the nearest known mountain pine beetle populations in the Black Hills of South Dakota, to gain baseline data on the risk to Minnesota's species of pines.

We found that mountain pine beetles were able to tunnel into cut logs of Minnesota's pines, attract mates, and lay eggs. The eggs were fertile, and insects could complete their development. The insects were cold hardy and the data suggest they could survive Minnesota's winters if established here. Development times in Minnesota's pines were slightly faster than those in historical western pine hosts, which was surprising. These results indicate that we should continue to take the threat of range expansion of mountain pine beetle seriously.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1 (MDA): Survey Minnesota pine forests for mountain pine beetle

(Note: This description is copied from the separate workplan for MDA for project coherence. For Budget and Outcomes, please see MDA workplan.)

Description:
MDA will survey pine locations during the timeframe of potential MPB flight period (July – September) throughout Minnesota for three years. Sites will be selected based on known or suspected importation routes of green timber. MDA will identify trap contents for mountain pine beetle, related species and natural enemies. We anticipate that we will be able to maintain a total of approximately 100 traps. These traps will be divided across sites to optimize the number of sites trapped and the trapping coverage at each site. We expect that there will be approximately 25 targeted sites with 4 traps surrounding each site, however the actual number of sites trapped each year may vary based on the discovery of new sites or the determination that previously trapped sites do not justify additional survey.

ACTIVITY 2 (UMN): Determine attractiveness and developmental rate in Minnesota's pines

Description:
Beetles will develop faster, slower, or not at all in "new" tree species. Initial Canadian data suggests that mountain pine beetle can easily kill and reproduce in jack pine. A graduate student will characterize development of mountain pine beetle in logs of red, jack, white, and Scots pine. We will do this by harvesting logs of these species in Minnesota and driving them immediately to the Black Hills of South Dakota where there are active populations of mountain pine beetle. *Note: we will conduct this work outside of the state of Minnesota, as we have no desire to inadvertently introduce this insect to Minnesota.* We will use the Wheaton College Science Station just outside of Rapid City, South Dakota as a home base for summer work. This location is in the middle of several excellent field sites.

Mountain pine beetles will be collected from flight traps in the Black Hills and then introduced to the Minnesota logs in the WCSS laboratory. Mountain pine beetle will readily infest fresh material when they are confined in a small gel capsule over a small nick through the surface of the bark. We will also infest local South Dakota logs harvested from lodgepole and Ponderosa pine. This will allow us to determine attraction/reproduction relative to usual western hosts. Logs of all species will be deployed from the Science Station to the field and the number of flying mountain pine beetles attracted to the infested logs and captured in flight traps will be counted. We will aim for 12 field sites, but that number may be adjusted due to populations of beetles and travel distance from the WCSS.

A second subset of logs will be infested and then screened to prevent escape or additional invasion. The logs will be stored outdoors in South Dakota. Some of these infested logs will be transported to back to Minnesota in the winter directly to the Quarantine Laboratory at the University of Minnesota (see Activity 3,

below). There, cold hardiness in Minnesota's pines and western hosts will be tested. The remaining logs will be preserved in South Dakota until the following summer to count emerging progeny and determine reproductive rates. These experiments will be repeated twice.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 124,800
Amount Spent: $ 124,800
Balance: $ - 0

Activity Completion Date: June 30, 2017

Outcome	Completion Date	Budget
1. *Comparison of Minnesota's pines for attractiveness to flying beetles*	06/30/2016	$56,850
2. *Comparison of development times in Minnesota's pines*	06/30/2016	$56,850
3. *Comparison to western pine hosts and final results reported*	06/30/2017	$12,000

Activity Status as of November 15, 2014:

Logs of red, jack, white, and Scots pine were harvested from the Cloquet Forestry Center and driven to the Black Hills of South Dakota in late July after the project was initiated. Before transport, the ends were sealed with molten wax to reduce dessication. At the same time, logs of Ponderosa and lodgepole pine were harvested and retrieved from South Dakota and Wyoming, respectively. All logs were sectioned into bolts before introduction of female mountain pine beetles using a gel cap method described above. After infestation, the logs were screened to prevent infestation of additional beetles and transported to the field. We were successful in setting up twelve sites for the experiments. Each site had one of the logs above with a funnel trap placed to capture beetles arriving to the logs. Similar to the MDA trapping results, we are now sorting through the trap catches during the flight period of mountain pine beetle and analyzing numbers of mountain pine beetles arriving to each host species.

Activity Status as of May 15, 2015: A trip to our research sites in April indicated that the insects appeared to be surviving the winter. The logs were placed in emergence containers for anticipated emergence of the insects later this summer.

While waiting for the insects to develop (i.e., only one generation per year) we have been sorting the MDA samples. We incorporated this into a laboratory activity that the graduate student Derek Rosenberger led for an Invertebrate Zoology class at Bethel College. Derek and Angie Ambourn from the MDA gave a presentation to the class about the threat of mountain pine beetle to Minnesota's pines. The students had learned about taxonomic classification of insects and were provided some of the summer survey samples to sort into "bark beetles" and "other." We feel the exercise went very well, as it gave the class experience in identification of insects and some degree of personal fulfillment knowing that their efforts were helping confront a serious "real-life" challenge. We have been following up identifying the student-sorted specimens, and to date no mountain pine beetles have been detected.

Activity Status as of November 15, 2015:

This summer the insects began emerging from the logs, indicating that mountain pine beetles are able to complete development in cut logs of Minnesota's pines. Analyses of these data continue. We were surprised to find differences in emergence times between hosts that were a little faster than the western species of pines. If beetles develop too quickly, they risk colonizing trees earlier in the summer and developing to life stages by late fall that are not cold hardy. So, our initial results suggest that some species of pines may be *too* good for the beetles, but more analysis is needed. We are now conducting chemical analyses to understand the chemical differences between the trees, so we can put together a complete picture of how tree chemistry affects the attraction and reproduction of mountain pine beetle in Minnesota's pines.

One unexpected result from working with these insects this summer was discovering a way to exploit the 'stress' response of beetles when they are being handled to determine their sex. With mountain pine beetle (and many tree-killing *Dendroctonus* spp.), the females are the host-selecting sex that bore through the bark. They emit chemicals called pheromones and attract mates, which then overwhelm the host tree they are trying

to colonize. As such, when conducting experiments involving colonization, mate-attraction, and/or reproduction, it is necessary to determine the sex of the beetle. There are two ways to distinguish the sex of the insects: morphological examination of the tergites on the 7th abdominal segment, which is tedious and can injure live insects, and listening to male 'chirps.' These insects will audibly stridulate if you hold them up to your ear; however, it is well known that not all males will stridulate. We discovered that sequential handling of the same cohort of insects will uncover previously silent males in as little as three careful manipulations. We have submitted this observation to a peer-reviewed scientific journal as a note where it is currently under review. We hope this observation will improve future experiments with initial accuracy of sex determination approaching 100%.

Activity Status as of May 15, 2016: We are now wrapping up chemical analyses of the trees. We are finding that our novel eastern pines (red, jack, eastern white, and Scots pine) have very similar amounts of alpha-pinene to the insect's historic hosts in the western part of North America. Alpha-pinene is important to the insects because they use this chemical to make their aggregation pheromone that helps them attract mates and attack and kill trees. Alpha-pinene is only one type of monoterpenoid chemical. We are also finding that Minnesota's pines, although exhibiting similar levels of alpha-pinene, contain much lower amounts of other monoterpenes. Minnesota's pine exhibit, on average, up to 10X less monoterpenes per gram of tree tissue than western species of pines. These chemicals are often used in tree defense, which suggests that our native pines could have reduced capacity to defend themselves if this insect was introduced to Minnesota. It is important to note however, that these are samples taken immediately upon harvest. All live trees have the capacity to produce more chemical upon "challenge." That said, our data do show thus far that the initial baseline is *not* even.

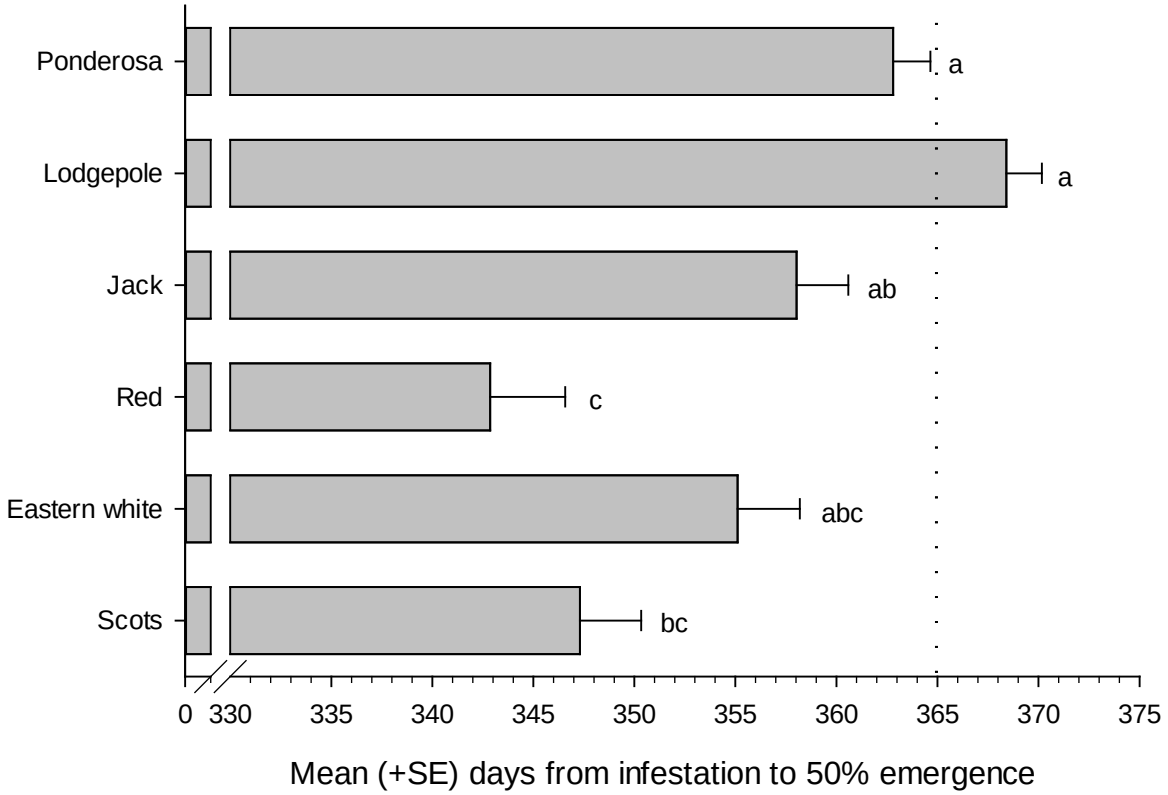
The manuscript on distinguishing sexes of mountain pine beetle has now been accepted for publication in the international peer-reviewed journal, *Entomologia Experimentalis et Applicata*. It will appear in print later this fall.

Activity Status as of November 15, 2016: The manuscript referenced above is now out in print. We are concluding chemical analyses of trees. In the previous status report, we were focusing on alpha-pinene which is a major component of the tree resin. This chemical is an important chemical because that is what the insects use to make their aggregation pheromones that attract mates to the trees. In the past six months, we have also been investigating the trace chemicals found in the resin and attempting to correlate field attraction studies with the chemicals in the phloem tissue in which the beetles tunnel when colonizing a tree. We are finding trace amounts of a phenylpropanoid chemical known as 4-allylanisole, for example, which typically repels flying beetles. Interestingly, we find this compound in the highest amounts in western pines where mountain pine beetle has existed for hundreds of years. Our native pines in Minnesota do not have very much of this compound, likely because trees have never experienced natural selection of these tree-killing bark beetles. Again, this does not bode well for Minnesota's pines if mountain pine beetle were to arrive in the state.

Final Report Summary: The colonization components of this work were published in the peer-reviewed journal PLoS ONE | https://doi.org/10.1371/journal.pone.0176269. A portion of the abstract is reproduced below:

We studied how beetle behavior differed among the various stages of colonization on newly cut logs of four novel potential pine host species; jack (*P. banksiana*), red (*P. resinosa* Ait.), eastern white (*P. strobus* L.) and Scots (*P. sylvestris* L.) pines, as well as two historical hosts, ponderosa (*P. ponderosa* Dougl. ex. Laws. var. *scopulorum* Engelm.) and lodgepole (*P. contorta* Dougl. var. *latifolia* Engelm.) pines. Overall, we found that beetle colonization behaviors at each stage in the colonization process differ between pine hosts, likely due to differing chemical and physical bark traits. Pines without co-evolved constitutive defenses against mountain pine beetle exhibited reduced amounts of defensive monoterpenoid chemicals; however, such patterns also reduced beetle attraction and colonization. Neither chemical nor physical defenses fully defended trees against the various stages of host procurement that can result in tree colonization and death.

The reproductive work is currently in review at a different peer-reviewed journal. Mountain pine beetle could reproduce in cut logs of all of our species of pines – and in many cases developed *faster* than the expected one-year life cycle. Below we reproduce a graph of successful reproduction of mountain pine beetle in Minnesota's pines:



Caption: Effect of pine species on time to 50% emergence of mountain pine beetles in Black Hills, SD ($F_{5,42} = 8.6$, $P < 0.0001$). Data represent both years. Means followed by the same letter are not significantly different from each other. n=15-16 logs per species for each annual replication.

ACTIVITY 3 (UMN): Characterize cold tolerance in Minnesota's pines

In western pines, cold tolerance differs depending on species of pine. The same graduate student and an undergraduate summer worker will characterize the effects of freezing temperatures on beetle mortality levels in logs of red, jack, white, and Scots pine under quarantine conditions at the U of M to inform risk maps.

Freshly cut pines will be infested with adult mountain pine beetle and screened as per Activity 2. Beetles will be allowed to reproduce and offspring to develop until late December or early January. This approach provides adequate time and conditions for mountain pine beetle to naturally acclimate to cold. Preliminary observations (D. Rosenberger, U of MN, data not shown) indicate that mountain pine beetle from cut logs are as cold hardy as from standing trees of the same host (i.e., ponderosa pine).

We use artificial infestation because the pine species of interest do not occur with the current range of mountain pine beetle. Also, mountain pine beetle prefers to colonize large diameter trees so transplanting eastern species is not a feasible option.

In December/January, infested logs will be secured in triple containment (i.e., three independent means to prevent the escape of the insects) and returned to Minnesota. Under secure conditions, infested logs will be peeled and the distribution of life stages noted. Cold hardiness of recovered insects will be measured in three ways. We will measure the supercooling points of overwintering life stages. The supercooling point is the

temperature at which insects begin to freeze. Mountain pine beetle uses a freeze-avoidant strategy to survive the winter on western pines because individuals will die if they freeze. The insect produces cryoprotectants and is able to prevent freezing until temperatures approach -35°C. However, we recognize that the overwintering strategy might be different on new pine species. So, we will also measure the lower lethal temperature of the insect. For these measurements, insects are cooled to randomly-selected temperatures between 0 and -40°C. Insects are immediately removed upon reaching these temperatures. Survival (as demonstrated by normal behavior of the insect) will be recorded at 24, 48, and 72 hours after cold exposure. These studies will allow us to determine if some individuals might die before or upon freezing or if some fraction of the population can survive freezing. Lastly, if we can obtain enough insects, we will measure lower lethal time. For these measures, insects will be held at sub-zero temperature for up to 160 days. Batches of insects will be removed at regular intervals and survivorship assessed. At the conclusion of experiments, material will be returned to South Dakota.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 50,200
Amount Spent: $ 50,200
Balance: $ 0

Activity Completion Date: June 30, 2017

Outcome	Completion Date	Budget
1. *Determination of lower lethal temperature in Minnesota's pines*	06/30/2017	50,200

Activity Status as of November 15, 2014: At the same time that logs were infested in Activity 2, a subset of logs was infested and remains in South Dakota. The beetles laid eggs which hatched, and the larvae began tunneling until their activity slowed into the winter. Overwintering beetles will be tested for cold tolerance later this winter.

Activity Status as of May 15, 2015: The graduate student conducted initial cold tolerance testing of developing beetles in each of the six hosts. We have found qualitative differences in the supercooling points of the insects among hosts, which was a bit surprising, and suggests that the insects may find "refuges" in some of our native pines vs. others. Full analysis is ongoing to detect quantitative differences.

Activity Status as of November 15, 2015: We have conducted additional runs to determine supercooling points of insects within different hosts. There seem to be year to year differences that we are trying to tease apart. The rankings among trees appear to be similar, but the magnitude of the responses differs. What is clear is that beetles emerging out of red pine consistently appear to be the most cold tolerant. None of the insects are cold tolerant beyond what they experience in their historic range (-40F).

We are now trying to determine whether there are unique chemistries or fungi that may be responsible for host-specific differences. Mountain pine beetles, like many bark beetles, are not sterile and have cuticular structures that vector fungi into the trees they attack. The fungi serve a variety of function s for the insects, such as serving as nutritional sources for the developing brood and potentially making the insects more (or less) cold hardy. An undergraduate, Jonah Widmer, began exploring whether there are differences in the presence of one fungus, *Ophiostoma montium,* between species of pines in an undergraduate research project mentored by the project lead, the graduate student, and Prof. Robert Blanchette's laboratory in Plant Pathology. Insects collected in Activity one were collected into individual microcentrifuge tubes using sterile technique and frozen until extraction. The beetles were crushed before their DNA was extracted, and then the solution with species-specific primers was run through PCR. The products were observed with gel electrophoresis. Jonah's undergraduate project continues in the data analysis stage, where he is working to determine the proportion of beetles carrying this fungus. We are not observing that the beetles emerging from red pine carry the highest proportions of this fungus, although he has successfully recovered *O. montium* from insects emerging from all of our native pines tested.

Activity Status as of May 15, 2016: Undergraduate Jonah Widmer presented the results of his independent study at the Entomological Society of America, and won first place in the President's Prize competition! To summarize, he has demonstrated that *Ophiostoma montium*, an important fungal associate of mountain pine beetle, can develop in novel eastern pine hosts and be vectored by emerging beetles. This is the first time this has been demonstrated, and could be related to the differences among supercooling points. A copy of his poster is attached to the end of this file.

In addition, we hosted a second undergraduate who worked with us at the Wheaton College Science Station in Rapid City on Activity 2 this past summer. Hannah needed to complete a two-credit research experience course at Wheaton College, so continued working on an aspect of mountain pine beetle ecology this semester. She flew up from Wheaton College to the University of Minnesota twice this past semester (no travel charges to project). She worked to determine whether the staining left in logs colonized by the beetles varied between species of pines tested. We found that white pine had the highest amount of staining overall. Staining can be a problem in recovery of timber for various wood products. We were a little surprised to find that white pine had more staining than red pine, which yields beetles that appear to be the most cold tolerant. We were pleased that Hannah wanted to continue her involvement in this work, even though she is not a student at the University of Minnesota!

Activity Status as of November 15, 2016: We are finished collecting cold tolerance data in the laboratory, and are now working to correlate the number of insects reared out of logs of different species of pine with the field temperatures recorded each winter. We have developed developmental indices for each log based on the distributions of life stages of mountain pine beetle going into each winter. We have found that insects in red pine develop the most rapidly compared to all species – and these insects appeared to be hit the hardest in the cold winter of 2013-2014. So, while red pine might be the best for mountain pine beetles, the insects risk developing to cold sensitive life stages from late summer into fall. Of course, if winters continue to warm, this will not affect the insects at all.

Final Report Summary: This work was published in a peer-reviewed journal as Rosenberger, Aukema, and Venette (2017) Cold tolerance of mountain pine beetle among novel eastern pines: A potential for trade-offs in an invaded range? *Forest Ecology & Management* 400: 28-37. The abstract is reproduced below:

Novel hosts may have unforeseen impacts on herbivore life history traits. The mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is a tree-killing bark beetle native to western North America but constrained by cold temperatures in the northern limits of its distribution. In recent years, this insect has spread north and east of its historical range, and continued expansion, or accidental introduction, could result in the mountain pine beetle becoming invasive in eastern North America. The limiting effect of cold temperatures among novel host pines is unknown, yet crucial for understanding the risk posed to northeastern North American forests. We report the susceptibility of mountain pine beetle to cold temperatures while overwintering in six different pine species. Brood developed in two western pine hosts (*Pinus contorta* Dougl. var. *latifolia* Engelm. and *P. ponderosa* Dougl. ex. Laws. var. *scopulorum* Engelm.) as well as four eastern pines (*P. banksiana* Lamb., *P. resinosa* Ait., *P. strobus* L. and *P. sylvestris* L.) novel to this insect. The cold tolerance and cold tolerance strategy of the most common overwintering stage varied by host and year. Models describing lower lethal temperatures more accurately predicted observed field mortality of overwintering larvae than models based on temperatures at which larvae froze. Rapid development to less cold tolerant pupal and adult stages by brood in novel hosts prior to winter may constitute a trade-off between increased host suitability and winter mortality. We demonstrate that overwintering survival of mountain pine beetles in novel hosts depends on a match between the climate and ecophysiological effects of pine species. These results have implications for risk assessment models and management planning for eastern forests as mountain pine beetle continues to expand its range.

V. DISSEMINATION:

Description:

This work will be shared with relevant stakeholders through meetings and presentations (e.g., Upper Midwest Invasive Species Council, MN Forest Resource/Stewardship Council, North Central Forest Pest Workshop, etc.). Presentations have already been given on this important topic for groups such as the Great Lakes Log Crafters Association. We will be available for media requests, as well. This insect is well known in the western United States and Canada and western media outlets periodically request interviews from personnel in states at risk of introduction or invasion to find out about preparedness levels.

Status as of November 15, 2014:

The potential expansion of mountain pine beetle to pine forests of eastern North America is one of the most serious forest health threats today. As such, we have received a number of invitations to present ongoing work on risk assessment at several venues. This LCCMR project was highlighted at several meetings over the past five months:

July 22, 2014	Southern Forest Insect Work Conference	Charleston, SC
Sept 8, 2014	North Central Forest Pest Workshop	Chariton, IA
Oct 6, 2014	International Union of Forestry Research Organizations World Congress	Salt Lake City, UT
Oct 22, 2014	Upper Midwest Invasive Species Meeting	Duluth, MN
Nov 11, 2014	Bethel College Tri-Beta Undergraduate Biology Honors Banquet	Arden Hills, MN

In addition, we contribute a short article updating the rate of spread through the Canadian boreal forest towards Minnesota:

Aukema, B.H., McKee, F.R., and D.W. Rosenberger. Update on mountain pine beetle, a potentially devastating threat. Pp. 14-15, in *Tree Farming for Better Forests*, Summer 2014

Status as of May 15, 2015:

We were interviewed by National Geographic cartographers for details about how range expansion of mountain pine beetle could affect the forest resource of the Midwest. We received an acknowledgement in the resulting article (see cartography section, http://ngm.nationalgeographic.com/2015/04/pine-beetles/rosner-text, "Pine Beetle Epidemic: the Bug that's Eating the Woods" April 2015).

Status as of November 15, 2015: Presentations on this work were given at the North Central Forest Pest Workshop at Mosinee Indian Reservation in Keshena, WI Sept 24-27 and the International Union of Forest Research Organizations joint working party meeting "Population dynamics of bark and wood-boring beetles" and "Invasive insects and international trade" in Bariloche, Argentina, Aug 31 – 3 Sept. Travel funds were not used outside of the state of Minnesota even though we continue to receive such external requests for updates on this high-profile project.

The lead PI also met with officials at the DNR on November 3 to discuss this project and management/silvicultural responses to MPB should the insect arrive in the state.

Status as of May 15, 2016:

Two presentations were given at the national meeting of the Entomological Society of America, November 15-18 at the convention center in Minneapolis. Each student received a First Place President's Prize in their division:

- **Widmer, J.**, Rosenberger, D.W., Blanchette, R., Held, B., Venette, R.C., and B.H. Aukema. The suitability of novel hosts for *Grosmannia clavigera* and *Ophiostoma montium*, two common fungal associates ofmountain pine beetle (Coleoptera: Curculionidae)

- **Rosenberger, D.W.**, Aukema, B.H., and R.C. Venette. How climate change and host-specific cold tolerance may mediate invasion potential of mountain pine beetle, *Dendroctonus ponderosae*, in eastern pine forests

Status as of November 15, 2016:

Three presentations were given since the last update. One presentation was given at the North American Forest Insect Work Conference, which is a national gathering of forest health professionals that meets every five years. The 2016 meeting was in Washington, DC, from May 31-June 3. There, we were also able to meet with colleagues from Alberta, Canada involved in spread control of mountain pine beetle as we work to understand factors that may slow potential arrival in the Lake states region. Another presentation was given at the International Congress of Entomology in October, which met in Orlando, Florida. This meeting meets every four years, and provided another opportunity to share lessons with others involved in controlling outbreaks of bark beetles. Finally, Brian Aukema gave an invited department seminar at UW-Madison at the end of September on mountain pine beetle. This provided a valuable opportunity to share research with Wisconsin colleagues, who have also been trapping the state for potential arrival of mountain pine beetle.

Final Report Summary:

During the course of this project, the MDA enacted an exterior state quarantine for pine logs with bark on them from western states, and the project manager met with DNR officials to discuss management/silvicultural responses to mountain pine beetle should the insect arrive in the state. This project fostered collaborations with five partner state and federal agencies, three universities, trained a PhD student who received a faculty position, and engaged several dozens of undergraduate university students by incorporating this project into classroom education such as redesigned laboratory practical exercises. In one instance, we hosted an undergraduate student from a different state who flew to Minnesota to conduct her internship on this project (at no cost to the project). If you are an undergraduate looking to help on one of the most serious pending challenges in North America, the state of Minnesota is a great place to come!

This research project has resulted in five peer-reviewed publications to date, with others currently in review:

Rosenberger, D.W., R.C. Venette, Maddox, M.P., and B.H. Aukema. (2017) Colonization behaviours of mountain pine beetle on novel hosts: implications for range expansion into eastern North America. *PLoS ONE* https://doi.org/10.1371/journal.pone.0176269

Rosenberger, D.W., Aukema, B.H., and R.C. Venette. (2017) Cold tolerance of mountain pine beetle among novel eastern pines: A potential for trade-offs in an invaded range? *Forest Ecology & Management* 400: 28-37

Rosenberger, D.W. and B.H. Aukema. (2016) Stimulating curiosity and engagement with insects beyond the college classroom through citizen science. *American Entomologist* 62: 120-122. (*this paper summarized an invited symposium talk at a national scientific conference, where we highlighted how we involved undergraduate students at the University of Minnesota to sort through MDA survey samples in Forest Entomology 4251. Students enjoyed the enhancement of classroom learning with hands-on tackling a serious, real life ecological challenge!).

Rosenberger, D.W., Venette, R.C., and B.H. Aukema. (2016) Sex determination of live mountain pine beetles (Coleoptera: Curclionidae): refinement of a behavioural method for *Dendroctonus* spp. *Entomologia Experimentalis et Applicata*. 160: 195-199.

There are two other scientific papers pending.

Our project results were also shared at several academic and stakeholder venues. Because of the high profile nature of this work and continent-wide implications for this native insect expanding its range, we received several international invitations to share progress reports. Venues included the University of Wisconsin-Madison, IUFRO World Forestry Congress, the Western Forest Insect Work Conference, the Upper Midwest Invasive Species Conference, the International Congress of Entomology, the North Central Forest Pest Workshop, the Ecological Society of America, the Entomological Society of America, and the Walker Northern Silviculture Workshop to list a few. Many of these presentations were undertaken without cost to the project through external travel scholarships to students.

One of the highlights of this project was the receipt of *two* President's Prizes for student presentations at the national meetings of the Entomological Society of America in the fall of 2015.

We are pleased with the quality and quantity of research that was facilitated, the benefits of student training, and how quickly we were able to disseminate results. We thank the LCCMR commission for their investment in this important natural resource issue.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview (UMN Activities 2 & 3 only):

Budget Category	$ Amount	Explanation
Personnel:	~~$ 140,000~~ $147,965	One graduate student at 50%FTE for 2 years, one undergraduate summer student at 30% FTE each of 3 years, 1 summer faculty time at ~~15%~~ 5% FTE for 3 years Summer faculty pay was voluntarily substituted to recruit and pay postdoc Dr. Kevin Chase who joined this project for six months training in advance of MPB Phase II (MITPPC, 2016-2020).
Professional/Technical Contracts	~~$4,000~~ $3,000	Two undergraduates research honoraria in lieu of salary as based at Wheaton College Science Station outside of Minnesota for field coordination help.
Equipment/Tools/Supplies:	~~$4,500~~ $4,140	Lab and field supplies Increase in price of chemical reagents and lures; we erred on side of being able to attract enough insects for research
Printing:	~~$700~~ $367	Printing/poster charges for dissemination of results
Travel Expenses in MN:	~~$2000~~ $1,213	$1,000 each of two years collecting pine material to transport to Black Hills (est. 2 day truck rental plus 750 miles at $0.39/mile plus one night lodging x 2 trips each year) July & Aug for Activity 2
Other:	~~$23,800~~ $18,315	• Travel to, from, among field sites in Black Hills of South Dakota ~~($19,100)~~ ($18,300) • Rental of UMN Quarantine Facility 3 years ~~($4,500)~~ ($0) • Cellular air time prepaid 2 years for safety in case of field emergencies ($200). Proposed as cheaper than ACR

		ResQLink+ Personal locator beacon ($289, REI) or SPOT tracker ($100+$100 subscription). We have used satelite phones (Iridium) in past research, but cell reception is acceptable at WCSS so propose this as least expensive route; if unallowable will pursue more expensive option.
TOTAL ENRTF BUDGET:	**$175,000**	

Explanation of Use of Classified Staff:

Explanation of Capital Expenditures Greater Than $5,000:

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 2.35

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Canada: NSERC TRIA-Net $3M Cdn (in kind)	$0	$	Because Canadian grant funds cannot be spent outside of Canada, these funds cannot support work in Minnesota. However, we will be in touch with Canadian workers on their projects (invasion pathway through the Canadian boreal forest) and their ongoing spread control work
State			
Waived indirect costs of 52% U of M $91,000	$0	$	
TOTAL OTHER FUNDS:	**$0**	**$**	

VII. PROJECT STRATEGY:

A. Project Team/Partners

Similar to the ongoing EAB projects on biological control, detection, and monitoring, this proposal is a joint partnership with the MDA, USDA Forest Service, and the University of Minnesota.

Receiving funds: The MDA (Abrahamson) will lead the survey efforts (Activity 1). The U of M and the Forest Service (Aukema/Venette) will lead the characterization of risk to Minnesota's pines through studies of reproduction and cold tolerance (Activities 2/3).

Not receiving funds: The Forest Service will not receive funds. All institutions will provide in-kind equipment, facilities, intellectual input, and GIS/technical support, and we will collaborate with the DNR and other federal agencies, including Canadian. As stated above, a collaborative Canadian research team was recently awarded $3M from their federal authorities to study the approaching eastward invasion front. Our proposal complements their and does not overlap.

B. Project Impact and Long-term Strategy:

This project has immediate impact for Minnesota by surveying whether the insect has established in the state, given that dead insects were found on imported pine logs in the fall of 2012 with a random inspection. Mountain pine beetle can exist for years at "endemic" levels where it reproduces in but does not kill trees.

When environmental conditions permit, the insect suddenly erupts and begins killing trees until either 1) it runs out of trees to kill or 2) unfavorable winter temperatures kill a significant portion of the insects.

A longer-term strategy has already begun here and elsewhere. In Minnesota, the threat of mountain pine beetle has prompted convening of an expert task force through the Minnesota Department of Agriculture. Several outreach presentations have been given to relevant stakeholder groups highlighting the necessity to reduce likelihood of transporting the insect – or any of its associates – to the state.

In the event that mountain pine beetle is found or arrives in the near future, the work on risk assessment in various pine species and cold tolerance will inform rapid response strategies. We will know within a few years which tree species produce the most beetles, and what level of cold might be needed to kill populations in the winter.

LCCMR has not spent any funds on the emerging mountain pine beetle problem to date. Over the past 10 years, Canada has spent $1.5B on spread control and mitigation of ecologic consequences. This figure does not include $285,000 earmarked this year by provinces such as Ontario that share a border with MN. Wisconsin has already deployed sentinel traps in five locations for early detection.

C. Spending History:

Funding Source	**M.L. 2008 or FY09**	**M.L. 2009 or FY10**	**M.L. 2010 or FY11**	**M.L. 2011 or FY12-13**	**M.L. 2013 or FY14**
U of M Graduate School Fellowship for PhD Student to recruit Derek Rosenberger			$42,0000		

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): See shared MDA – UMN graphic

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: N/A

XII. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than 11/15/2014, 5/15/2015, 11/15/2015, 5/15/2016 and 11/15/2016. A final report and associated products will be submitted between June 30 and August 15, 2017.

Jonah's winning poster: presented at the national meeting of the Entomological Society of America to a national audience of insect research and management experts.

Ophiostoma montium, a fungal associate of mountain pine beetle, can grow in and be transferred from logs of novel eastern pine hosts

Jonah R. Widmer [1], Derek W. Rosenberger[1], Robert A. Blanchette[2], Benjamin W. Held[2], Robert C. Venette[3], Aubree M. Wilke[1], & Brian H. Aukema[1]

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[2]Dept. of Plant Pathology, University of Minnesota, St. Paul, MN
[3]USDA Forest Service, Northern Research Station, St. Paul


Ophiostoma montium

Introduction

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is a native insect that can kill lodgepole (*P. contorta*) and ponderosa (*P. ponderosa*) pine when at outbreak levels in western North America.[1]

Recent eastward range expansion resulted in interactions with a novel host, jack pine (*P. banksiana*)[2] and further eastward movement could result in contact with red (*P. resinosa*) eastern white (*P. strobus*) and Scots (*P. sylvestris*) pines.

While mountain pine beetle has attacked these species in off-site plantings the past, it is unknown whether fungal associates of the beetle, vital to nutrition and development of offspring[3], are able to colonize these novel hosts.

Here we used a species specific primer[4] to test for the presence of the phoretic blue stain fungal associate, *Ophiostoma montium,* on beetles emerging from logs of native and novel pine species.

Research Questions

- Can species specific-primers detect *O. montium* on emerged beetles?
- Can *O. montium* grow in novel hosts and be transferred by emerging beetles?

Methods – Beetle Collection

- Trees of each species were cut in Minnesota, Wyoming and South Dakota and infested with mountain pine beetles caught in August, 2013.
- Logs overwintered in natural common garden conditions then were placed in emergence tubes in an unheated laboratory for spring and summer.
- Upon emergence in July and August 2014 beetles were collected into individual microcentrifuge tubes using sterile techniques and frozen until extraction.

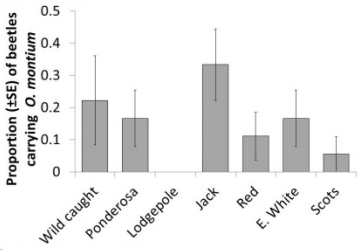
Methods - Fungal extraction and detection


Beetles crushed and DNA extracted


DNA solution with species-specific primers run through PCR


PCR products visualized with gel electrophoresis

Results



- *O. montium* was found on beetles emerging from logs of each novel pine species.
- Proportions of beetles vectoring fungi from ponderosa logs were similar to wild beetles emerging from naturally colonized ponderosa pine in the Black Hills.

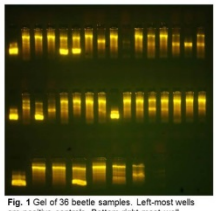


Fig. 1 Gel of 36 beetle samples. Left-most wells are positive controls. Bottom right-most well (bottom row, well 8) is negative control.

Discussion

- Our results indicate that *Ophiostoma montium,* an important fungal associate of mountain pine beetle, can develop in novel eastern pine hosts and be vectored by emerging beetles.
- While *O. montium* was not recovered from beetles emerging from lodgepole pine logs in this study, the fungus has been recovered from this tree species in previous studies.
- One limitation to this study was that while fungi were exposed to constitutive defenses in logs, they were not exposed to induced defenses of the living tree, which can further limit fungal growth.

Acknowledgments

This research was made possible by a University of Minnesota Graduate Fellowship to DWR, the Minnesota Department of Natural Resources and a grant from the Minnesota Environment and Natural Resources Trust Fund.

Contact Information

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Brian Aukema: bhaukema@umn.edu
Robert Blanchett: robertb@umn.edu

References

1. **Safranyik, L., and A. L. Carroll. 2006.** The biology and epidemiology of the mountain pine beetle in Lodgepole Pine forests., pp. 3–66. *In* Safranyik, L., Wilson, B. (eds.), The mountain pine beetle: A synthesis of biology, management and impacts on lodgepole pine. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC.
2. **Cullingham, C. I., J. E. K. Cooke, S. Dang, C. S. Davis, B. J. Cooke, and D. W. Coltman. 2011.** Mountain pine beetle host-range expansion threatens the boreal forest. Mol. Ecol. 20: 2157–71.
3. **Bentz, B. J., and D. L. Six. 2006.** Ergosterol content of fungi associated with *Dendroctonus ponderosae* and *Dendroctonus rufipennis* (Coleoptera: Curculionidae, Scolytinae). Ann. Entomol. Soc. Am. 99: 189–194.
4. **Khadempour, L., S. Massoumi Alamouti, R. Hamelin, J. Bohlmann, and C. Breuil. 2010.** Target-specific PCR primers can detect and differentiate ophiostomatoid fungi from microbial communities associated with the mountain pine beetle *Dendroctonus ponderosae*. Fungal Biol. 114: 825–33.

Environment and Natural Resources Trust Fund
M.L. 2014 Project Budget - FINAL REPORT

Project Title: Mountain Pine Beetle Invasive Threat to Minnesota's Pines (UMN Activities 2 & 3)
Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 04e-1
Project Manager: Brian Aukema
Organization: University of Minnesota
M.L. 2014 ENRTF Appropriation: $175,000
Project Length and Completion Date: 3 year project, to be completed June 30, 2017
Date of Report: September 28, 2017

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Revised Activity 2 Budget 09/28/17	Amount Spent	Activity 2 Balance	Activity 3 Budget	Revised Activity 3 Budget 09/28/17	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL REVISED BUDGET 9/28/17	TOTAL SPENT	TOTAL BALANCE
BUDGET ITEM	**Survey (See MDA budget)**			**Attractiveness and development in Minnesota's pines**				**Determine cold tolerance**							
Personnel (Wages and Benefits)				$98,000	$99,279	$99,279	$0	$42,000	$48,686	$48,686	$0	$140,000	$147,965	$147,965	$0
1 Graduate Research Assistant: $41,500 in year 1, $42,500 in Year 2, evenly shared between Activities 2 & 3, 50% FTE for 2 years															
1 Undergraduate Research Assistant or Technician: $8,000 each of ~~3~~ 2 years and $4,000 one year (92% salary, 8% benefits), approximately 40 hours/week in summers Activity 2 (may be three different students)															
U of M: One 3 year PTE faculty $12,000/year (80% salary, 20% fringe) for method development Activity 2															
Professional/Technical Contracts															
Two undergraduates research honoraria in lieu of salary if based at WCSS outside of Minnesota for field coordination help				$4,000	$3,000	$3,000	$0					$4,000	$3,000	$3,000	$0
Equipment/Tools/Supplies															
Lures, ethanol for storing collected insects, screening, staples, rope, misc. field supplies for Activity 2				$3,500	$4,140	$4,140	$0					$3,500	$4,140	$4,140	$0
Syringes and thermocouples for Activity 3								$1,000	$0	$0	$0	$1,000	$0	$0	$0
Printing															
Scientific posters for dissemination results ($200/year) splite between Activities 2 & 3				$400	$367	$367	$0	$300	$0	$0	$0	$700	$367	$367	$0
Travel expenses in Minnesota $1,000 each of two years collecting pine material to transport to Black Hills (est. 2 day truck rental plus 750 miles at $0.39/mile plus one night lodging x 2 trips each year) July & Aug for Activity 2				$2,000	$1,213	$1,213	$0					$2,000	$1,213	$1,213	$0
Other															
Travel expenses outside of Minnesota: Activity 2: $7,600/year for first two years. Work will be conducted in Black Hills of SD to avoid introduction of MPB to MN. Flight season typically mid-July through August or early Sept, approx. 60 days. Expenses include pickup truck rental 2 x 2 mo rental of 3/4 ton trucks at $800/mo, plus est. 3600 miles/year gas at $0.39/mi, total $4,600 year; includes deploying trap lines to collect MPB, procuring lodgepole pine from Big Horn Mtns, WY, deploying MN and western pines to field sites in Black Hills, checking attraction every 3d from base station. Travel includes $1,500 lodging for team inclusive of research base space at Wheaton College Science Station in South Dakota (storage of logs from MN, use of upper classrooms to infest material to deploy to field). Budget also allows two overnight trips to fetch material for Activity 3 approx October, Jan two years in trucks for return to UMN Quarantine Facilities (est. $1,400; 2 trips x 2 trips x $100 truck rental x 1200 miles at $0.39 + hotel). $1.5K each of three years also budgeted for travel to meet with MPB specialists to share findings and stay abreast of management strategies and progress slowing spread from Canada.				$16,700	$16,593	$16,593	$0	$2,400	$1,514	$1,514	$0	$19,100	$18,107	$18,106	$1
Cell phone airtime: $100/year for 2 years pay-as-you-go for safety emergencies in the field on Activity 2. Proposed as cheaper than ACR ResQLink+ Personal locator beacon ($289, REI) or SPOT tracker ($100+$100 subscription). We have used satelite phones (Iridium) in past, but cell reception is acceptable at WCSS so propose this as least expensive route.				$200	$208	$208	$0					$200	$208	$208	$0
UMN Quarantine Facility rental for Activty 3								$4,500	$0	$0	$0	$4,500	$0	$0	$0
COLUMN TOTAL				**$124,800**	**$124,800**	**$124,800**	**$0**	**$50,200**	**$50,200**	**$50,200**	**$0**	**$175,000**	**$175,000**	**$175,000**	**$0**

Mountain Pine Beetle:
Invasive Threat to Minnesota's Pines

Has it reached us yet?

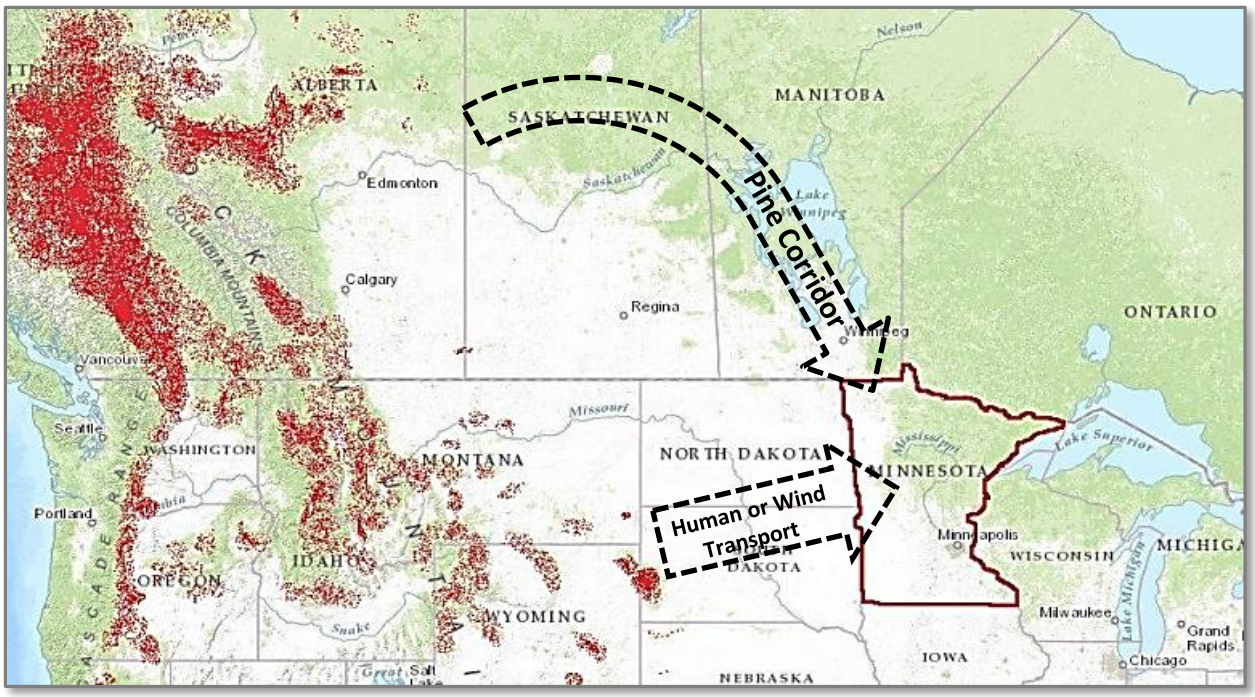
This beetle was imported into Dodge County in fall 2012. Fortunately, this mountain pine beetle was dead. MDA surveyed, but did not detect any new insects.

Can it reproduce in our pines?

We found the insect can attract mates, lay eggs, develop, and emerge from cut logs of our native pines – sometimes faster than in their historic western range.

Conclusion

This insect remains a serious invasive threat



Shaded areas indicate conifer forest. Dark areas on the left indicate the current extent of forests with high mortality due to mountain pine beetle. Routes to Minnesota from current epidemic populations are shown.

MINNESOTA DEPARTMENT OF AGRICULTURE

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

UNIVERSITY OF MINNESOTA