ML 2015 Project Abstract

PROJECT TITLE: MITPPC Sub-project #9 Characterizing dispersal of larval gypsy moth to improve quarantine regulations
PROJECT MANAGER: Brian Aukema
AFFILIATION: University of Minnesota, MITPPC
MAILING ADDRESS: 1992 Folwell
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: ML 2015, Ch. 76m Sec. 2, Subd. 6a
APPROPRIATION AMOUNT: $35,000

Overall Project Outcomes and Results
The European gypsy moth is an invasive insect that feeds on over 300 species of trees and shrubs. Management guidelines within a national quarantine recommend that wood products, such as timber being harvested and moved from the forest, are staged within a buffer zone area devoid of any host vegetation during harvesting operations. This buffer zone reduces the likelihood that late instar gypsy moth larvae will pupate nearby, emerge as adults, mate, and lay eggs on the wood. In practice, this buffer zone is 100 feet in radius, but this distance was established with limited understanding of the movement ecology of gypsy moth larvae. We conducted laboratory experiments at the University of Minnesota to determine how host type and food deprivation affected movement of gypsy moth caterpillars. During outbreaks, food can become scarce as larvae strip trees of foliage. Larvae were raised on one of five foods: oak, tamarack, Norway maple, sugar maple, or artificial diet. Subsets of larvae were also deprived of food for zero, 24, or 48 hours. After the food deprivation period, late instar larvae were placed on the servosphere. Larvae raised on oak, a preferred host, were unlikely to move unless starved. They moved farther and faster the longer they were starved. In contrast, when larvae were raised on less preferred hosts, they were more likely to move without prior starvation. These results suggest that feeding on optimal hosts provides gypsy moth larvae with the energy and nutritional requirements to move more quickly to more food when there is none immediately available. Thus, risks of larvae crossing a regulatory buffer zone may increase where an outbreak results in complete defoliation of preferred hosts. Results from this laboratory study were integrated with a federally-funded field study to inform best management practices of this invasive species in Minnesota.

Project Results Use and Dissemination
This work has been shared with national regulatory officials at USDA APHIS who are revising the national gypsy moth management handbook at a time when the insect continues to invade Minnesota. This work was also been presented at two conferences with resource managers and other research staff:


One scientific journal article has been submitted:

Date of Final Report: March 25, 2019
Date of Sub-Project Work Plan Approval: June 7, 2017
Project Completion Date: Aug 31, 2018

SUB-PROJECT TITLE: MITPPC #9: Characterizing dispersal of larval gypsy moth to improve quarantine regulations

Sub-Project Manager: Brian Aukema
Organization: University of Minnesota, Department of Entomology
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Telephone Number: (612) 612-1847
Email Address: BrianAukema@umn.edu
Web Address: http://www.forest-insects.umn.edu

Location: Lake and Cook counties

Total ENRTF Project Budget: $35,000
ENRTF Appropriation: $35,000
Amount Spent: $35,000
Balance: $0

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 6a

Appropriation Language:
$5,000,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Invasive Terrestrial Plants and Pests Center established in Laws 2014, chapter 312, article 13, section 44, to conduct research to prevent, minimize, and mitigate the threats and impacts posed by invasive plants, pathogens, and pests to the state's prairies, forests, wetlands, and agricultural resources. This appropriation is available until June 30, 2023, by which time the project must be completed and final products delivered.
I. SUB-PROJECT TITLE: MITPPC #9: Characterizing dispersal of larval gypsy moth to improve quarantine regulations

II. SUB-PROJECT STATEMENT:
The most ideal regulatory and mitigation measures for invasive species will contain the pest but not adversely affect commerce. Balancing these objectives can pose unique challenges, however. For example, state and federal regulations against the European gypsy moth *Lymantria dispar* (Lepidoptera: Erebidae) restrict movement of regulated articles such as logs and firewood. This situation is a major problem for pulp and lumber mills and firewood producers that reside outside regulated areas in Minnesota and Wisconsin but receive wood harvested from areas inside the quarantine zones. When “clean” piles are staged in infested areas at any point in the supply chain, they risk acquiring late instar larvae that move from proximate host trees in search of pupation sites. Adults emerging from pupal cases can crawl onto the logs, mate, and oviposit fresh egg masses - thus spreading the insect to previously “clean” areas.

Hence, an isolation or buffer zone is commonly employed around log decks. Identifying the most appropriate size of a buffer zone around a pile as a mitigation measure depends on defining the movement potential for larval gypsy moths in the field. Current practice utilizes a buffer distance of 100 feet, but the origin of this guideline is unclear. Typically, larvae do not move far from their host trees, as they pupate in the soil directly below the tree in which they were feeding. In outbreak situations, however, caterpillars can crawl farther to find food.

The United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA-APHIS), has provided $133,000 to determine how feeding status and age affect gypsy moth dispersal, and what cues affect movement. The hypothesis is that late instar larvae in outbreak situations, where defoliation of surrounding vegetation is occurring, will be more prone to moving in search of food or pupation sites. USDA-APHIS is funding the mark-resight experiments to track movement and navigation, including distance, wandering of the larvae, ground temperature, and wind speed. These field studies will use harmonic radar to locate the insects. To date, we have found that late instars can move more than 100 feet in search of food or shelter in less than 12 hours, but the angle of incident light strongly affects dispersal patterns.

Laboratory studies are not included in the USDA-APHIS grant and are essential to complete the research protocol. The scope of work described here will complete the research project and provide the data necessary to fully understand larvae movement. Our goal is to provide improved science-based guidelines to restrict movement of gypsy moths without restricting commerce. This work will benefit the forest industry – especially loggers and firewood producers - in Minnesota and Wisconsin.

III. OVERALL SUB-PROJECT STATUS UPDATES:

Sub-Project Status as of June 30, 2017: The servosphere has been ordered.

Sub-Project Status as of December 31, 2017: The equipment has arrived at the University of Minnesota. The equipment took a long time to manufacture, configure, and ship because each unit is custom-manufactured by Syntech International. We are ready to start experimentation.

Overall Sub-Project Outcomes and Results:

The European gypsy moth is an invasive insect that feeds on over 300 species of trees and shrubs. Management guidelines within a national quarantine recommend that wood products, such as timber being harvested and moved from the forest, are staged within a buffer zone area devoid of any host vegetation during harvesting operations. This buffer zone reduces the likelihood that late instar gypsy moth larvae will pupate nearby, emerge as adults, mate, and lay eggs on the wood. In practice, this buffer zone is 100 feet in radius, but this
distance was established with limited understanding of the movement ecology of gypsy moth larvae. We conducted laboratory experiments at the University of Minnesota to determine how host type and food deprivation affected movement of gypsy moth caterpillars. During outbreaks, food can become scarce as larvae strip trees of foliage. Larvae were raised on one of five foods: oak, tamarack, Norway maple, sugar maple, or artificial diet. Subsets of larvae were also deprived of food for zero, 24, or 48 hours. After the food deprivation period, late instar larvae were placed on the servosphere. Larvae raised on oak, a preferred host, were unlikely to move unless starved. They moved farther and faster the longer they were starved. In contrast, when larvae were raised on less preferred hosts, they were more likely to move without prior starvation. These results suggest that feeding on optimal hosts provides gypsy moth larvae with the energy and nutritional requirements to move more quickly to more food when there is none immediately available. Thus, risks of larvae crossing a regulatory buffer zone may increase where an outbreak results in complete defoliation of preferred hosts. Results from this laboratory study were integrated with a federally-funded field study to inform best management practices of this invasive species in Minnesota.

IV. SUB-PROJECT ACTIVITIES AND OUTCOMES:

**ACTIVITY 1: Lab-based studies of dispersal ability of gypsy moth larvae**

**Description:** Field studies will determine the effect of age on walking behavior of gypsy moth larvae using harmonic radar. However, movement of larvae prior to 5th instar is likely to be impeded by harmonic radar tags. Hence, we will use a servosphere, also known as a locomotory compensator, to quantify the amount and type of movement of third – sixth instar larvae. A servosphere is a specialized piece of equipment that is designed to measure the walking behavior of insects. The servosphere has four primary parts: (i) a low-friction, spherical walking surface; (ii) a digital video recording camera to record orientation; (iii) a sensory stimulus source; and (iv) a dedicated microcomputer to electronically capture insect behavior. The stimulus can be a visual or chemical cue. When placed on the servosphere, insects begin to walk towards or away from the stimulus. In our studies, larval movement will be recorded for an hour at a time, and we will record total distance, straight line distance (initial point to final point), and tortuosity (a ratio of these two measures, which provides an estimate of “wandering” behavior). We will examine effects of developmental stage, feeding status, and light stimuli on behavior. We will use this information to identify “worst case” conditions, i.e., the set of circumstance that lead to the farthest distance walked. Behaviors of 5th and 6th instars in the laboratory will be compared with behaviors measured in the field.

The servosphere is a critical piece of equipment because it allows researchers to study mid- to long-distance locomotion of small to mid-size insects in confined spaces. This activity would be done in the quarantine lab. Gypsy moth is an insect under federal quarantine, which imposes strict limitations on the locations and types of experiments that can be conducted. The approach ensures that no insects will escape as can occur during field studies with multiple individuals. Further, our preliminary studies on the walking behavior of gypsy moth larvae in Wisconsin showed that even large individuals (2-2 ½ inches long) can be difficult to track over time. So, recovery and observation of third instars (approximately ½ inch long) or fourth instars (slightly less than 1 inch long) is not reliable nor practical in the field.

**Summary Budget Information for Activity 1:**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Determine effects of developmental stage, feeding status, and environmental stimuli on larval movement to determine “worst case” conditions</td>
<td>December 31, 2017</td>
</tr>
<tr>
<td>2. Determine the maximum and expected distances that gypsy moth larvae can move as a foundation for a new recommendation for isolation zones around commercial log decks</td>
<td>April 31, 2018</td>
</tr>
</tbody>
</table>

| ENRTF Budget: | $ 35,000 |
| Amount Spent: | $ 35,000 |
| Balance: | $ 0 |

The ENRTF Budget and Amount Spent are the same, indicating no funds were spent as of the completion date.
Sub-Project Status as of June 30, 2017: Due to health issues at Syntech, manufacturing and shipping took longer than anticipated. We have spent the month of December setting up the base unit, configuring the software, and testing it with non-quarantine insects like Madagascar hissing cockroaches. We have built a custom enclosure that allows us to conduct more nuanced experiments. The first larvae of gypsy moth are scheduled to hatch in the last week of December in the quarantine facility, and we look forward to conducting our first experiments.

Budget reflects payment for receipt of servosphere. Computer hardware payment is still pending.

Sub-Project Status as of December 31, 2017 Hardware has been received, ready to start experimentation.

Final Report Summary:
Overall, 358 gypsy moth larvae were placed on the servosphere, with 244 individuals providing useful behavioral data. For each insect we measured total distance moved, net displacement, tortuosity, mean velocity, mean number of stops, and mean length of stops. Net displacement was calculated mathematically as the change in distance between the “start location” of larvae and their “ending location” (recognizing that the servosphere, much like a tread mill, keeps each larva in the same position). Tortuosity is a unitless ratio of net displacement to total distance moved and is used as a measure of path straightness: a value of one indicates a perfectly straight path.

In summary, larvae raised on *Quercus macrocarpa* (bur oak), a preferred host, were unlikely to move unless starved. They moved farther and faster the longer they were starved. In contrast, when larvae were raised on less preferred hosts, like eastern larch or silver maple, they were more likely to move without prior starvation. These results suggest that feeding on optimal hosts provides gypsy moth larvae with the energy and nutritional requirements to move more quickly to more food when there is none immediately available.

The rates of movement measured in this study indicate that late-instar gypsy moth larvae are physically capable of traversing a 100 ft vegetation free barrier, potentially in as little as an hour. However, for this result to occur in the field, larvae would need to be modestly starved and to move in a straight line in the proper direction. These results are consistent with observed patterns of larval movement in the field. Collectively, these results suggest that larvae are capable of walking farther distances than previously appreciated.

Full results are already in peer-review at a scientific journal; we look forward to sharing the full publication as soon as it is published.

V. DISSEMINATION:
Description: We will share our findings with Minnesota agencies and citizen groups so that public information and decision making is based on the best available science. We will submit updates of our progress through the University of Minnesota, College of Food, Agricultural, and Natural Resource Sciences, and College of Biological Sciences via websites, social media, and publications. We will use social media and other news outlets to communicate our research when warranted. Additionally, we will present our findings national and international conferences. Peer-reviewed publications will be disseminated at the earliest possible date.

Sub-Project Status as of June 30, 2017: None. We are acquiring the equipment.
Sub-Project Status as of December 31, 2017: None. We are installing the equipment.
Final Report Summary:
This work has been shared with national regulatory officials at USDA APHIS who are revising the national gypsy moth management handbook at a time when the insect continues to invade Minnesota. This work was also been presented at two conferences with resource managers and other research staff:


We have submitted a scientific journal article:


We will send the article to MITPPC when published.

VI. SUB-PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

<table>
<thead>
<tr>
<th>Budget Category</th>
<th>$ Amount</th>
<th>Overview Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment/Tools/Supplies:</td>
<td>$33,500</td>
<td>$33,500 for servosphere and data acquisition system</td>
</tr>
<tr>
<td>Other:</td>
<td>$1,500</td>
<td>BSL-2 quarantine facility rent, shipping to receive egg masses</td>
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<tr>
<td><strong>TOTAL ENRTF BUDGET:</strong></td>
<td><strong>$35,000</strong></td>
<td></td>
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</table>

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: A servosphere is necessary for controlled experimentation with a federally quarantined insect in order to measure movement and dispersal of the insect.

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

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

<table>
<thead>
<tr>
<th>Source of Funds</th>
<th>$ Amount Proposed</th>
<th>$ Amount Spent</th>
<th>Use of Other Funds</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGK, Inc. Fellowship</td>
<td>$45,000</td>
<td>$35,000</td>
<td>Graduate research assistant (salary &amp; fringe)</td>
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<tr>
<td>US Department of Agriculture, Animal &amp; Plant Health Inspection Service</td>
<td>$72,000</td>
<td>$0</td>
<td>Graduate research assistant (salary &amp; fringe), supplies, &amp; travel</td>
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<td>UMN Indirect rate 52%</td>
<td>$18,200</td>
<td>$0</td>
<td>Indirect costs associated with implementation of project</td>
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<td><strong>TOTAL OTHER FUNDS:</strong></td>
<td><strong>$135,200</strong></td>
<td><strong>$35,000</strong></td>
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</table>

VII. PROJECT STRATEGY:

A. Project Partners: Scott Myers and Paul Chaloux (USDA-APHIS) will continue to consult on the proposed experiments. They provided partial funding for the first two years of preliminary data collection as we seek to improve quarantine practices that will not adversely affect forest product movement. Kimberly Theilen-Cremers
and Marissa Streifel (Minnesota Department of Agriculture) and Brian Kuhn (Wisconsin Department of Agriculture, Trade and Consumer Protection) also provide regulatory advice and feedback.

B. Project Impact and Long-term Strategy: The total funding secured from non-MITPPC sources to date through the projected completion of Mr. Wittman’s degree is $178,000. Full project support for all salary and field study commitments has been provided by the USDA APHIS Gypsy Moth Program with in-kind support from WI-DATCP and MDA. We are in the final year of study. A University of Minnesota’s McLaughlin Gormley King Fellowship to Mr. Wittman is currently supporting this work to spring 2017.

The regulatory manual for USDA APHIS is currently undergoing revision and we hope that project results will reduce risk of movement for gypsy moth while not restricting trade.

C. Funding History:

<table>
<thead>
<tr>
<th>Funding Source and Use of Funds</th>
<th>Funding Timeframe</th>
<th>$ Amount</th>
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<tr>
<td>USDA APHIS, Methods development and proof of concept for larval movement</td>
<td>2014-2016</td>
<td>$61,000</td>
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IX. VISUAL COMPONENT or MAP(S): N/A

X. RESEARCH ADDENDUM: A research addendum was developed after a panel of researchers from the University of Minnesota provided competitive reviews of a pre-proposal of this work. The addendum was distributed to relevant experts outside the University of Minnesota and reviewed for scientific novelty, appropriateness of methods, qualifications of the research team, and potential impact on invasive species management. The research addendum was modified as necessary in response to comments received during the peer-review process. The final document provides a technically detailed description of the research to be completed under this sub-project work plan. The research addendum is on file with the Minnesota Invasive Terrestrial Plant and Pest Center.

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted in December and June of each year. A final report and associated products will be submitted between August 31, 2018 and Nov 30, 2018.
**Sub-Project Title:** MITPPC #9: Characterizing dispersal of larval gypsy moth to improve quarantine regulations  
**Legal Citation:** ML 2015, Ch. 76, Art. 2, Sec. 6a  
**Sub-Project Manager:** Brian Aukema  
**Organization:** University of Minnesota  
**Sub-Project Budget:** $35,000  
**Sub-Project Length and Completion Date:** 1.5 years, Aug 31, 2018  
**Date of Report:** March 25, 2019

<table>
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<th>ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET</th>
<th>Activity 1 Budget</th>
<th>Activity 1 Amount Spent</th>
<th>Activity 1 Balance</th>
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