**TITLE:** White pine decline in the Great Lakes Region

**LOCATION:** Northern lower peninsula (LP) and upper peninsula (UP) of Michigan

**DATE:** September 2013

**DURATION:** Year 1 of a 2-year project  **FUNDING SOURCE:** Base EM

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**FHP SPONSOR/CONTACT:** Dr. Joseph O’Brien; USFS Northern Research Station, St. Paul, MN

**PROJECT OBJECTIVES:** The key overall objective of the proposed project is to mechanistically explain the etiology of white pine decline (*Pinus strobus*) in the Great Lakes region of Michigan by examining the interactive effects of climatic stress, fungal pathogens (e.g., *Diplodia* spp.), pine spittlebug (*Aphrophora parallela*), and other biotic factors (lichens and stand- and tree-level attributes). This study will contribute to a disease and insect risk decline model that integrates the influence of predisposing abiotic and biotic factors responsible for the white pine decline. The specific questions that will be addressed in this project include:

- Is drought stress the sole abiotic factor that predisposes pine stands to white pine decline or do other climatic factors such as summer heat stress play an important role as well?
- What is the mechanistic etiology of white pine decline in terms of parceling out the relative influence of fungal pathogens, pine spittlebug, and lichen species composition?
- To what degree do stand-level attributes (e.g., stand density) and tree-level physical (e.g., bark texture) and chemical properties (e.g., bark pH) influence the microhabitat of populations of fungal pathogens, pine spittlebug, and lichen species?
- How will future regional climate change influence the growth and mortality of white pine to this decline syndrome?

**JUSTIFICATION:**

a. **Linkage to FHM Detection Monitoring** – According to the Michigan Forest Health Highlights (MDNR 2008-2012), white pine decline was first detected in 2006 in the Au Sable and Manistee river corridors located in the north-central Lower Peninsula region of Michigan. In 2012 (MDNR 2012), this white pine decline syndrome has advanced northwards into the Upper Peninsula region where it is has now been reported in the Munising District of Hiawatha National Forest. White pine decline has been primarily associated with stem and branch cankers induced by fungal pathogens (primarily *Diplodia* spp.), pine spittlebug, and presence of cankers is commonly found under lichens.

b. **Significance in Terms of the Geographic Scale** – Although the proposed study will be conducted in Michigan in the focal areas affected by this decline (MDNR 2008-2012), the tools and results developed in this study will help inform attempts to manage the effects of white pine decline in other areas of the eastern United States. The impact of the fungal pathogen *Diplodia* is widespread geographically in the United States occurring in 30 eastern and central states plus California and Hawaii and impacts more than 20 pine species (Peterson 1997). Spittlebug affects many pine plantations and forests throughout eastern North America and its distribution corresponds to its host range (Wilson 1991). Epiphytic lichens are a common component of tree crowns and boles of many forest communities in the United States and globally (Ellis 2012).

c. **Biological Impact and/or Political Importance of the Issue** – Eastern white pine is a dominant tree in conifer and mixed conifer forests of eastern North America and is a major timber species that was harvested extensively in the late 19th and early 20th centuries in the Great Lakes Region (Wendel and Smith 1990). White pine is important for reforestation and bioenergy, the Christmas tree and landscaping industry, wildlife habitat, and is also used for furniture construction. The Michigan state tree is white pine. The white pine forest resources in this region are potentially vulnerable to future climate change which may in turn increase the susceptibility and incidences of white pine decline in this region.

d. **Scientific Basis/Feasibility** – The key approach involves conducting tree-ring analyses (dendrochronology) to characterize the etiological components of white pine decline. Dendrochronology is a powerful approach to compare annually resolved growth and mortality patterns with corresponding annual climatic records. For instance, dendrochronology has been instrumental to identify establishment of emerald ash borer 10 years before external symptoms are readily perceptible in trees (Siegert et al. 2010). White pine has also shown great potential in dendroclimatic and dendroecological studies (e.g., Chhin et al. 2013). The study will also characterize the physical and chemical properties of the microenvironment of trees, especially bark characteristics (e.g., Levia et al. 2006; Berg et al. 2012).
2013), which in turn can have a pronounced effect on the populations of fungal, insect, and lichen species (e.g., Ellis 2012).

e. **Priority Issues Addressed from Request for Proposals.** The proposed study will address four of the priority issues of the EM Base program: 1) climate change, 2) drought, 3) filling data gaps in disease and insect risk models, and 4) tree mortality.

**DESCRIPTION:**

**a. Background:** The instrumental climatic record has indicated that global average surface temperatures have increased by 0.7°C over 1906-2005 (IPCC 2007). Projections of future climate change based on general circulation models and different emission scenarios of greenhouse gases indicate a further warming of 1.1°C–6.4°C by the end of the 21st century (2090-2099) relative to 1980-1999 (IPCC 2007). Regional climate forecasts for the state of Michigan and the Great Lakes Region indicate that average temperatures will rise 3-11°C in the summer and 3-7°C in the winter (Kling et al. 2003). While little change is expected in annual average precipitation, higher temperatures are expected to lead to increased rates of evapotranspiration in plants. Climate is generally considered an important factor in predisposing trees to be susceptible to secondary factors (insects and fungal diseases) leading to forest decline (Manion 1991).

Drought and intraspecific competition in high density pine stands have been implicated as predisposing factors for increased white pine decline in Michigan (Manion 2008-2012; Griesmer and Adams 2012). Predisposed trees are more likely to be affected and subsequently form cankers on stems and branches caused by fungal pathogens; to date *Diplodia* and *Therria* spp. have so far been implicated (Smith and Stanosz 1995; Griesmer and Adams 2012; MIDNR 2012; Solheim et al. 2013). Entry and growth of fungal pathogens in trees is promoted by the pine spittlebug which is a sap-feeding pest of white pine in the Great Lakes. Furthermore, cankers are commonly associated under dark green colored lichens but the exact mechanism of the relationships between lichen and cankers is not known (MIDNR 2012). It is known that lichens can modify bark pH and bark moisture relations (e.g., Gauslaa and Goward 2012) and this change in bark chemistry may potentially modify the growth environment of fungal pathogens. Lichens have been used as biomonitors of environmental change and are sensitive to pollution and climatic change (Ellis 2013).

The influence of drought, other abiotic factors (e.g., heat stress), and biotic factors (lichens, stand- and tree-level attributes) has not been mechanistically related to disease and insect risk and the net influence of all factors has not been systematically related to growth and mortality rates in white pine forests experiencing decline (Desprez-Loustau et al. 2006; Manion 1997). This study will incorporate a dendrochronological approach that allows the retrospective examination of past annual diameter growth rates and dates of tree mortality and allows relating these parameters to meteorological records of the study region, and to assess the potential impacts of future climate change. Overall, this research will help limit potential economic losses in the white pine resources in the Great Lakes region due to climate change and the complex suite of biotic factors (i.e., fungal pathogens, insect, lichens, stand- and tree-level attributes).

**b. Methods:** White pine stands (pole sized, 30-60 years old) will be selected along a latitudinal climate gradient from the northern lower peninsula (LP) to the upper peninsula (UP) of Michigan. Field site selection and sampling in the first year of the project will be conducted in Huron National Forest in the LP through which the Au Sable river corridor is located and where white pine decline has been previously detected. In the second year, field sampling will be conducted in Hiawatha National Forest in the UP where white pine has been recently detected in 2012. In each study region (LP and UP), 12 forest stands will be selected, leading to a total of 24 stands sampled. The forest stands will be distributed across contrasting levels of two main factors: stand density (low (<400 stems per acre) versus high (>800 stems per acre)) and pine spittlebug presence (low versus high). Presence of pine spittlebug will be determined primarily by examining 1-year-old shoots for feeding wounds and scars; furthermore, eggs, nymphs and adult stages will be surveyed on shoot tips and trunks (Wilson 1991). In each region, 2 stands will be selected with low stand density and low spittlebug presence, and 2 stands will be selected with low stand density and high spittlebug presence. Similarly, 4 stands will be selected across possible pairs of high stand density and spittlebug presence. The remaining 4 stands in each region will serve as controls and will be selected from low and high density stands unaffected by pine spittlebug.

In each selected stand, a circular plot (24-ft radius) will be established. Stand-level attributes that will be measured include stand density and stand basal area. In terms of tree-level attributes, 4 living and 4 dead trees will be randomly selected and their diameter at breast height (DBH), total height, and height to live crown will be recorded in each plot. Two increment cores will be obtained per tree at breast height to determine stand age and quantify past growth history. Ecophysiological and microclimatic measurements will also be recorded for these randomly selected trees including: light intensity, soil moisture, and bark texture and bark pH of the main stem. For each selected tree, two randomly selected branches will be sampled from the connection point with the main stem up to 6 feet in length. Each selected branch will characterized in terms of branch diameter, branch height, branch orientation, branch surface area, bark texture, bark pH, and bark water storage capacity (Levia and Wubbena 2006; Berg et al. 2013). The branch surface will also be quantified in terms of % coverage of species of lichens and fungal pathogens, and canker size will be noted. Lichens will be identified according to Brodo (2001) and classified into different functional forms (i.e., foliose, crustose, fruticose) and reproductive strategy (i.e., sexual spores versus asexual spores (isidia and soredia)) (Ellis 2012). Difficult lichen specimens will be sent to the MSU Beal Herbarium for identification. Bark will be removed from above the cankers and diseased cambium will be cultured on
mycological agar medium. Fungal hyphae will be harvested from cultured media and DNA will be extracted and sequenced using a standard PCR reaction (Griesmer and Adams, 2012). The fungal pathogen responsible for causing each branch canker will be identified by cross-referencing DNA regions with the GenBank database (Griesmer and Adams 2012). This DNA analysis will be conducted in a molecular genetics laboratory in the Department of Forestry at MSU.

All wood samples will be processed using standard dendrochronological techniques in Dr. Chhin’s tree-ring laboratory at MSU (Chhin et al. 2013). For each tree core, annual ring width will be measured using an image analysis software-based system (CooRecorder: Cypis Elektronik & Data AB), and samples with extremely narrow rings will be measured with a binocular microscope and a stage micrometer (Velmax). Climate data (temperature and precipitation) will be obtained from the meteorological stations nearest to the study areas from the U.S. National Climate Data Center (NCDC). Relationships between annual ring-width and past climate records will be assessed using correlation and multiple linear regression techniques (Chhin et al. 2013) to quantify the role of climatic predisposition to white pine decline. Branch canker coverage will be compared between the control stands and two levels of stand density and two levels of pine spittle bug presence using analysis of variance (ANOVA). Branch canker cover will also be related to tree-level microenvironmental attributes (e.g., bark texture and pH), and other biotic factors (lichen species cover) using correlation, regression, and multivariate analyses. Furthermore, logistic regression analysis will also be applied to potentially detect which climatic factors and biotic factors (i.e., fungal pathogens, insect, lichens, stand- and tree-level attributes) may have predisposed white pine to mortality. Different scenarios of future climate change based on different emission scenarios of greenhouse gases will be obtained from the NCDC. Growth and mortality patterns in the white pine trees will be projected into the 21st century under these climate change scenarios.

c. Products: Two peer-reviewed journal articles are expected from this proposed research. One paper will focus on elaborating on the general etiology of white decline and growth patterns in the Great Lakes region, while the second paper will focus on the interactive effects of climate, disease, insects, and other biotic factors (e.g., lichens) on mortality rates of white pine. Project findings will also be presented at a conference (e.g., North Central Forest Pest Workshop).

d. Schedule of Activities: The proposed project is expected to last for two years commencing in August 2014 and ending in August 2016. Key project phases and their respective starting dates (mm/yyyy) are listed below:

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Budget Justification: Salary: Salary of PI for 0.5 month in each year: yr 1 $3,186; yr 2 $3,249. An undergraduate research assistant will be hired full-time in the summer of yr 1 ($4,500) and yr 2 ($4,635) to assist primarily with field work. One technical aide will be hired in yr 1 ($20,000) and yr 2 ($20,600) to carry out both the field and laboratory work. Fringe Benefits: Fringe rate for PI is: yr 1 $853; yr 2 $887. Fringe rates for summer undergraduate research assistant (yr 1 $344; yr
2 $355) and technical aide (yr 1 $1,530; yr 2 $1,576) is 7.65%. **Contributed Costs:** 1.5 month of salary (yr 1 $9,572; yr 2 $9,764) and fringe (yr 1 $2,564; yr 2 $2,665) for PI in all 2 years. MSU overhead rate is 53.5% of modified total direct costs (TDC) (modified TDC = TDC – tuition and fees) (yr 1 $6,493; yr 2 $6,650). Overhead also includes unrecovered indirect costs calculated based on 53.5% of modified TDC of requested funding (yr 1 $20,551; yr 2 $22,096). **Supply Costs:** In all years, the cost to purchase general field and laboratory supplies is $4,000.

**LITERATURE CITED:**


Solheim, H., Torp, T.B., and Hietala, A.M. 2013. Characterization of the ascomycetes *Therrya fuckelii* and *T. pinii* fruiting on Scots pine branches in Nordic countries. Mycological Progress, 12: 37-44.
