Agreement # 12-PA-11091900-022

A Collaborative Approach to Prioritizing High Allegheny Hemlock for Conservation in Light of Impending Impact by Hemlock Woolly Adelgid

S. Johnson[1], S. Bearer[1], A. Hille[2], R. Turcotte[2], S. Stout[2]

[1] – The Nature Conservancy

[2] – The United States Forest Service

High Allegheny Plateau Hemlock Conservation Project

Final Report to the USFS

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Abstract

Eastern hemlock (*Tsuga canadensis* (L.) Carrière) is a valuable component of Allegheny Plateau forests in northwestern Pennsylvania and western New York, providing critical ecological and economic value. Yet, since the 1950s, hemlock forests throughout the Central Appalachians have been under threat from a non-native forest pest, the hemlock woolly adelgid (*Adelges tsugae* Annand). In late 2012, in order to address this threat at the most meaningful scale, the US Forest Service and The Nature Conservancy organized a partnership of land owners and managers, interested groups and organizations, and academic institutions to develop a strategy for conservation of the hemlock resource on the High Allegheny Unglaciated Plateau. The first step in this prioritization was identifying hemlock on the landscape across ownerships; for this we obtained the 30 meter resolution Forest Service Forest Health Technology Enterprise Team (FHTET) model of hemlock basal area (square feet per acre). This model underwent a field validation during the summer of 2013 using both field-collected point data and stand polygon data obtained from collaborators. We then convened a Steering Committee which included representatives from a variety of collaborating groups to review, discuss and identify the most important ecological, social, and economic values that hemlock forests provide. Then, GIS data representing these values, along with expert knowledge, were used to choose and rank the important hemlock forests of the High Allegheny Plateau as priorities for protection from the threat of the adelgid. We have learned that in-person contact is very important for this type of collaborative effort, which was facilitated by the Steering Committee, three workshops, and direct contact through field trips and conference calls. The priority hemlock conservation areas that were identified by this partnership provide a guide for focusing limited resources, with the goal of protecting at least a portion of these areas from the impacts of the adelgid until more long-term management techniques are discovered. We believe the most logical next step to protect the important hemlock forests identified in this prioritization is the formation of a Cooperative Pest Management Area to continue this important collaboration, allocate scarce resources across the pest management area, and allow private partners access to funding for protection of priority hemlock on their lands.

Table of Contents

List of Figures

List of Tables

Introduction

Eastern hemlock (*Tsuga canadensis* (L.) Carrière) was a dominant tree species in the presettlement forests of the eastern United States (Lutz 1930, Whitney 1990), and covers an extensive range in the present day (Figure 1). It is a very important component of present-day eastern temperate forests, serving as a keystone species, especially in riparian zones (Mladenoff 1987, Quimby 1996, Ellison et al. 2005). Hemlock is the main conifer component in many existing old growth forests of Pennsylvania and New York (Bjorkbom and Larson 1977, Abrams et al. 2001, Nowacki and Abrams 1994) and provides critical habitat for many species in both riparian and upland areas (Burns and Honkala 1990, Tingley et al. 2002, Ross et al. 2004, Turcotte 2008, Allen et al. 2009, Matthewson 2009). Hemlock trees in a forest directly and indirectly affect water volume and chemistry (Ford and Vose 2007, Cessna and Nielsen 2012, Brantley et al. 2013), and soil nitrogen cycling (Jenkins et al. 1999). Hemlock forests also provide many social values including aesthetic, spiritual, discovery and teaching value (Dale Luthringer, Environmental Education Specialist at Cook Forest State Park, PA, personal communication).

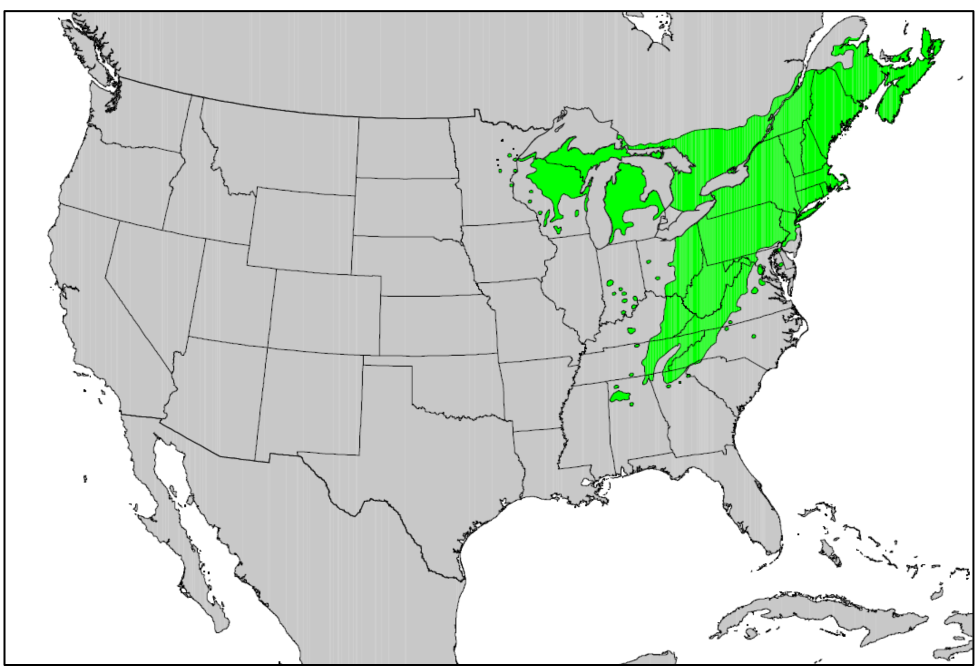

Figure 1. Range map of eastern hemlock (Little 1971; http://esp.cr.usgs.gov/data/little/).

Eastern hemlock as well as Carolina hemlock (*T. caroliniana* Engelm) are being negatively affected by an introduced forest pest, the hemlock woolly adelgid (*Adelges tsugae* Annand) (abbreviated as adelgid or HWA). The adelgid is native to Japan, where it feeds on two species of hemlock, *T. sieboldii* Carrière, and *T. diversifolia* (Maxim.) Masters (Havill et al. 2006). In 1951, HWA was discovered in the eastern United States, near Richmond, Virginia (USDA Forest Service 2005). The adelgid has spread from this introduction point, infesting new areas each year, and has had a significant impact on hemlock health and abundance throughout the ranges of both eastern and Carolina hemlock (Orwig and Foster 1998, Evans 2002, Eschtruth et al. 2006). As of 2012, about half of the entire range of eastern hemlock was infested, including the majority of counties in Pennsylvania, and a little over a third of the counties in New York (Figure 2).

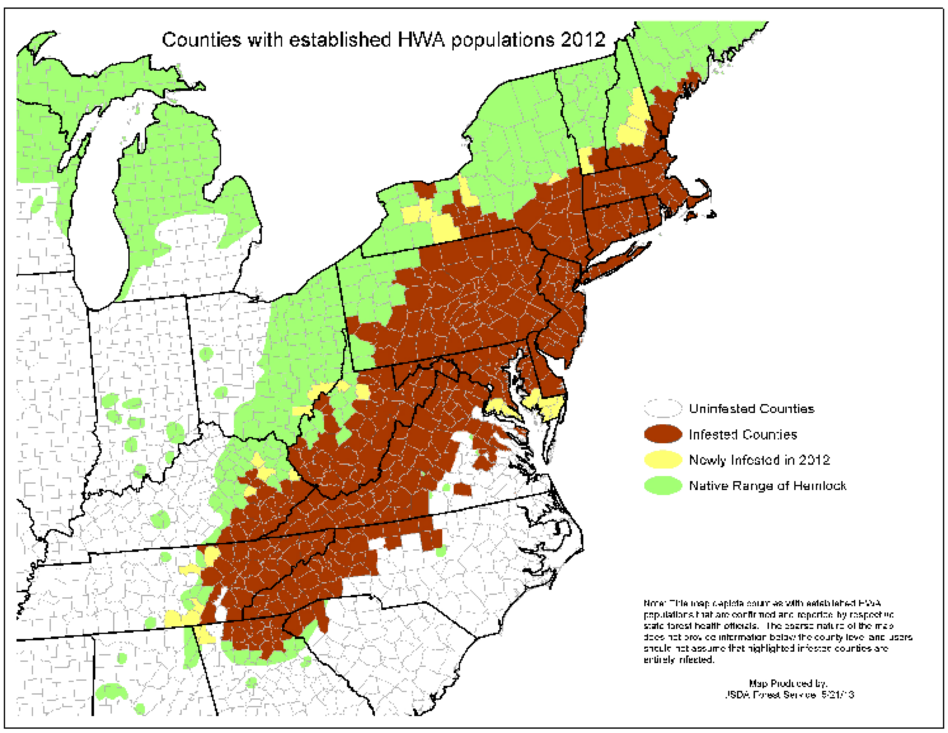

Figure 2. US Forest Service 2012 range map of HWA, shown by infested counties in the eastern United States.

The adelgid spreads by many means, including animals, wind, and humans through transport of infested nursery stock, and direct contact with and transport of crawlers and eggs on vehicles and clothing (McClure 1990, Ouellette 2002). Rates of spread are difficult to predict, but scientists have postulated anywhere from 12 to 18 kilometers per year on average, however this rate decreases as winter temperatures decrease (Evans and Gregoire 2007, Paradis et al. 2008). New infestations are often difficult to detect, because HWA can be introduced to the upper branches of trees where it is not easily noticed, and egg sacs, while relatively easy to identify, are very small. The adult adelgids are even smaller and harder to locate with the naked eye than the egg sacs (McClure 1987). Survey and detection protocols are effective (Costa and Onken 2006), however the capacity to implement them across larger spatial scales is many times lacking, especially on private lands.

Adelgids are aphid-like insects with piercing and sucking mouthparts (Figure 3; USDA 2005). They feed exclusively on conifers, and each female can lay from 50 to 300 eggs (Figure 4; McClure 1987). The hemlock woolly adelgid is aggressive in its non-native range in the eastern United States, where eastern hemlock has shown minimal resistance (Montgomery et al. 2009). HWA feeds mainly on areas of new growth, and causes depletion of the tree's food reserves leading to needle loss, bud mortality, a general cycle of decline (depending on weather; Trotter and Shields 2009), and mortality in 5 to 10 years (Orwig and Foster 1998, Orwig et al. 2002, Eschtruth et al. 2006) or longer (Escthruth et al. 2013).

Figures 3 & 4. Hemlock woolly adelgid adults (left, USDA 2005) and egg sacs on eastern hemlock branch (right; Chris Evans, The University of Georgia, http://www.forestryimages.org/).

Hemlock woolly adelgid can affect large tracts of forestland across the landscape, and its ability to disperse across large areas of unsuitable habitat allows it to infest areas that might otherwise be considered isolated. Although chemical treatments can save individuals and groups of hemlocks, conserving the important ecosystem functions and values that hemlock provides, such treatments are expensive. Biological controls (several predatory beetle species that feed on adelgid) are available; however winter temperatures limit survival in some areas (Onken and Reardon 2011). Despite the limitations of these available options, conservation of important hemlock resources is within reason, through the use of regional, integrated and collaborative strategies. Some invasive insects, such as emerald ash borer, cause nearly complete mortality very quickly (Poland and McCullough 2006, Smitley et al. 2008), leaving much more limited options for conservation. Many hemlock trees are able to survive HWA infestation for years (Eschtruth et al. 2013), providing opportunities for planning and coordination of efforts, and future potential for advances in HWA treatment and control technology. To combat the potentially devastating ecosystem effects of this introduced forest pest and address the conservation of an important keystone tree species, landscape level collaborative approaches may be the best option. We decided to initiate and test a collaborative, interagency and multi-landowner effort to plan for hemlock conservation in the High Allegheny Unglaciated Plateau subecoregion of northwestern Pennsylvania and western New York. Our hope is that this collaborative prioritization process can be used as a model for HWA or other forest pest efforts across the northeast.

Study Area

The focal landscape of this work is the unglaciated section of the Allegheny High Plateau (Figure 5, EPA ecoregion 212Ga). The land in this ecoregion was mainly bought by timber companies around the early to mid-1800s (Whitney and DeCant 2003), and this ownership pattern as well as glaciated soils may have limited agriculture land use. In this landscape hemlock was originally a large component, as much as 40% of the forest (Lutz 1930, Whitney 1990, Abrams and Orwig 1996). Today, although much of the forested cover remains intact (the ecoregion is 80% forested according to the National Land Cover Dataset of 2006; Fry et al. 2011), hemlock has declined in overall importance, due to heavy logging in many areas for the tanbark and other industries around the late 1800s and early 1900s (Whitney 1990). The fact that much of this landscape is both forested and in large ownership blocks both public and private is relatively rare in the eastern United States, providing a unique opportunity for collaboration and an ecosystem-based, all lands approach to hemlock conservation (Figure 6). At the outset of this project, HWA was not known to be present in the High Allegheny Unglaciated Plateau subecoregion. However, during the spring of 2013 several infestations were located within the subecoregion, on state and federal public land.

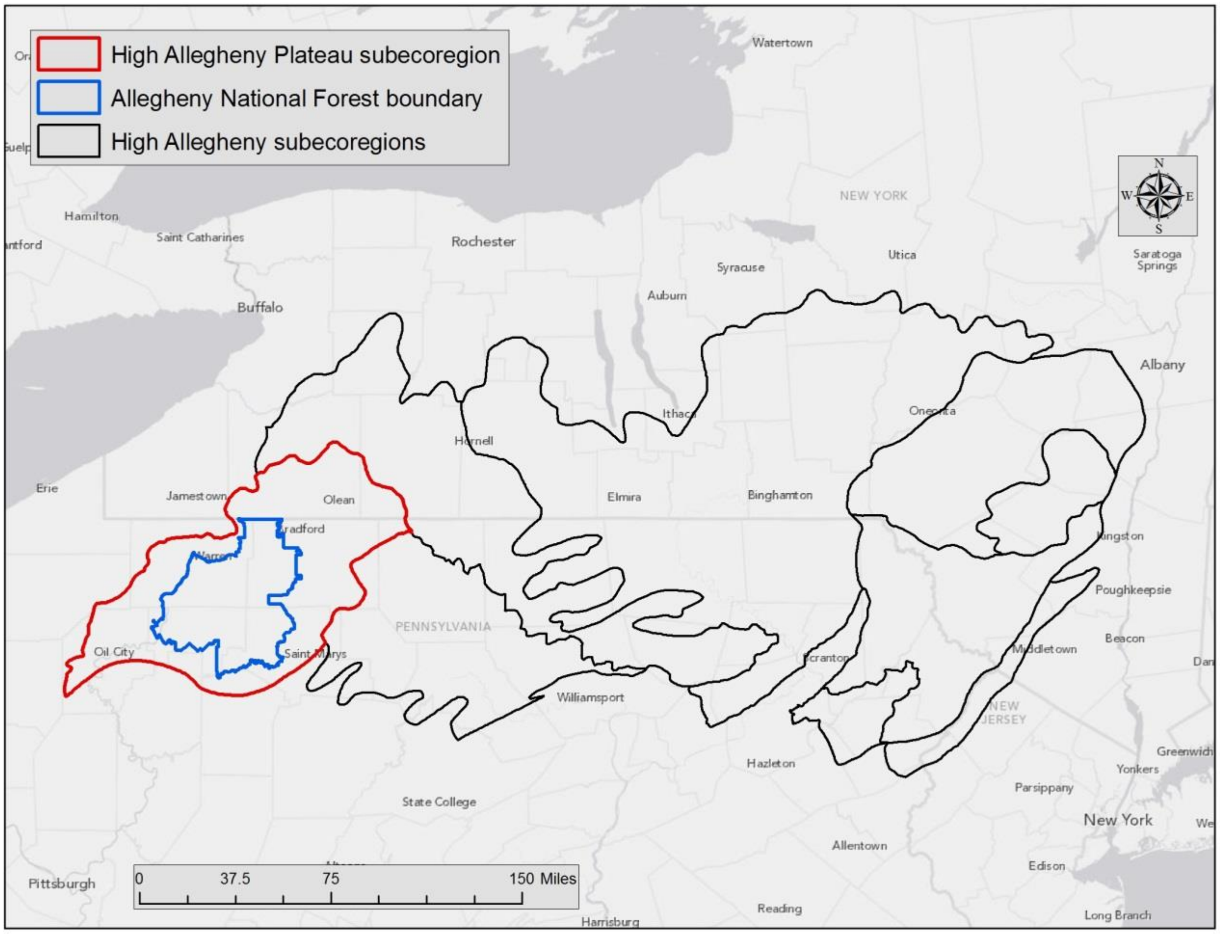

Figure 5. The High Allegheny Unglaciated Plateau subecoregion of northwestern Pennsylvania and western New York.

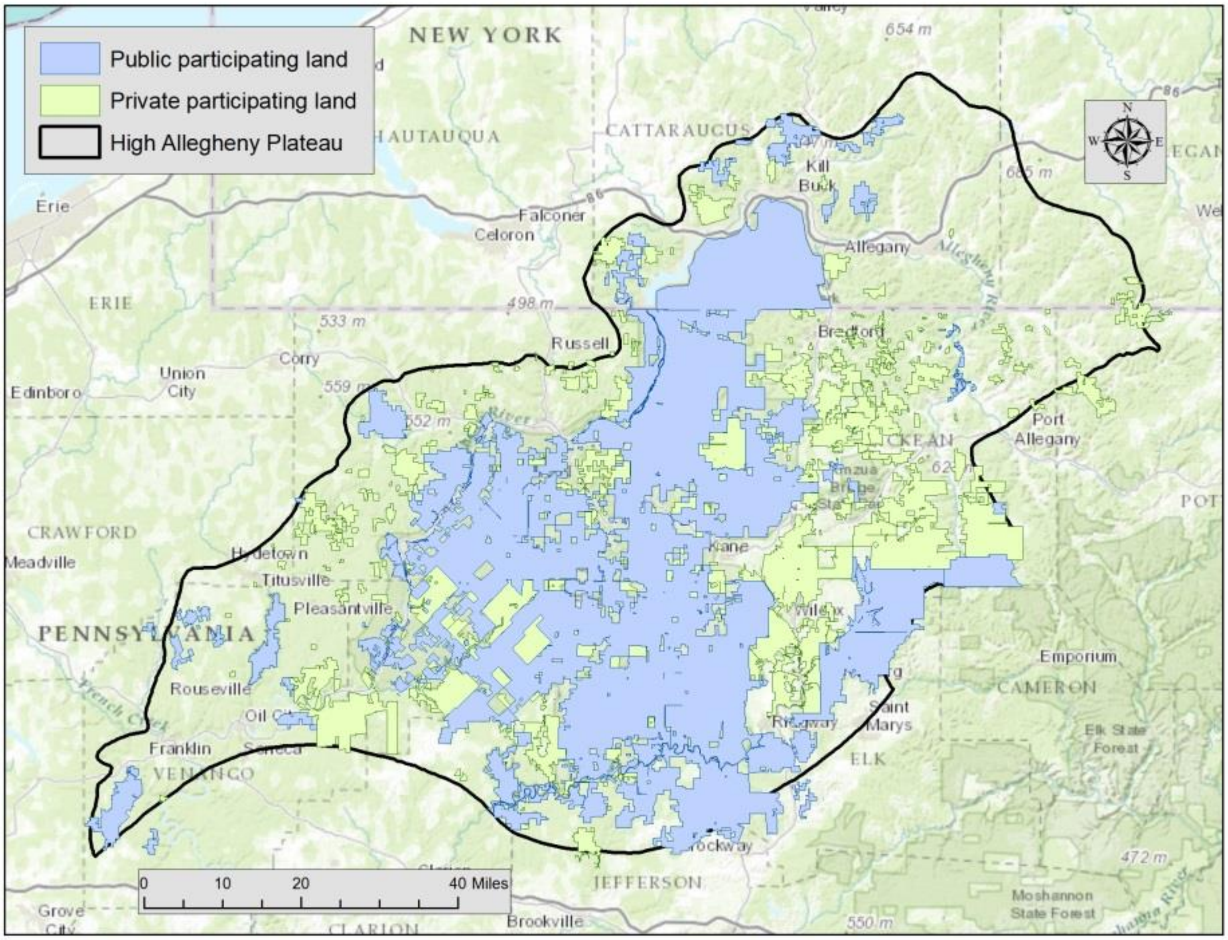

Figure 6. Public and private participating land ownership and management within the High Allegheny Unglaciated Plateau.

The United States Forest Service (USFS), Allegheny National Forest (ANF) comprises the largest public ownership within the subecoregion. The Forest Service, concerned about the impending impacts of HWA, wanted to prepare in advance of infestation by addressing this forest pest from a landscape perspective in collaboration with both public and private landowners. The goal of this work is to develop a plan for prioritizing locations and actions to best allocate limited resources. Achieving this goal ideally will result in retaining a component of hemlock on the landscape, protecting important places, and maintaining ecosystem function through the oncoming wave of adelgid infestation. The Nature Conservancy (TNC) and the USFS joined together late in 2012 to address these goals through development of a strategy to initiate collaboration among landowners, identify the hemlock resource in spatially explicit models, and prioritize this resource through scientific information and a collaborative process.

We were informed at the outset by two efforts undertaken by Forest Service staff in Pennsylvania and West Virginia. In 2010, The USFS Northern Research Station, Yale University, and Allegheny National Forest sponsored an intern to complete an assessment of eastern hemlock and risk of HWA on the Allegheny National Forest. This assessment included predicting hemlock occurrence and mapping hemlock throughout the Forest, then assessing and mapping risk to the hemlock resource (susceptibility to infestation and vulnerability to insect-caused mortality; Moore, unpublished, 2011). This initial spatial risk assessment was used to prioritize monitoring locations for HWA, and was the basis for the larger, landscape level approach to hemlock conservation. At about the same time, another cross-boundary effort was getting underway in West Virginia, led by USFS and National Park Service (NPS) personnel. This effort prioritized hemlock in the Monongahela National Forest and surrounding State and National Parks for protection by chemical and biological control of the adelgid, and provided a useful framework for the development of our strategy.

The Collaboration

Beginning in August, 2012, an announcement was distributed via electronic mail to organizations, agencies, a tribal government, academic partners and conservation groups by The Nature Conservancy (the one-page announcement produced by Bearer and Hille is contained in the files provided to the Forest Service). Starting in November 2012, representatives of potential collaborating groups were contacted individually about this project, to invite their cooperation and input for the greater benefit of all who have a stake and interest in the conservation of hemlock in northwestern Pennsylvania and western New York. Representatives of almost 50 groups, agencies, organizations, and institutions responded with interest in joining this collaboration in some way and most remained active throughout the project (Table 1). Combined acreage of partner ownerships encompassed a large portion of the land area of the High Allegheny Unglaciated Plateau subecoregion (Figure 5). Collaboration was maintained through this communication network, via email, phone, and in-person contact through workshops, meetings, and trainings. This network expanded throughout 2013, and our hope is the network will continue to evolve and expand in the coming years.

Table 1. Participating groups, organizations, agencies, and companies including the three groups spearheading the effort, followed by all collaborators in alphabetical order.

Participant	Notes on participation	Steering Committee representation
USFS Allegheny National Forest	Lead	Yes
USFS State and Private Forestry	Lead	Yes
USFS Northern Research Station	Lead	Yes
The Nature Conservancy, Pennsylvania Chapter	Lead	Yes
Adirondack Mountain Club	Recent addition (active)	
Clarion University	Active	
Congressman Glenn Thompson (representative)	Workshop 1	
Elk County Commissioners	In communication	
FORECON, Inc.	Provided data	
Forest Investment Associates (FIA)	Active	
Foundation for Sustainable Forests	In communication	
Friends of Allegheny Wilderness	Active	Yes
Generations Forestry, Inc.	In communication	
Hancock Forest Management	Active	Yes
Industrial Timber and Lumber (ITL)	In communication	
Kane Hardwoods, Collins Pine Co.	Active	Yes
Kinzua Fish & Wildlife Association	Workshop 2 and follow-up	
LandVest	Active	Yes
McKean County Commissioners	Workshop 2 and follow-up	
McKean County Conservation District	Active	
National Wild Turkey Federation	Workshop 2 and follow-up	
NY DEC; State Forests	Active	
NYS Office of Parks, Recreation, and Historic Preservation	Active	Yes (new)
PA Association of Consulting Foresters	Workshop 1 and follow-up	
PA DCNR Bureau of Forestry	Active	Yes
PA DCNR State Parks	Active	Yes
PA DEP	Provided data	
PA Natural Heritage Program	Provided data	
PA PGC	Active	Yes
PA Sustainable Forest Initiative	Workshop 1 and follow-up	
Penn State Extension	Active	
Pennsylvania Audubon	Recent addition (active)	
Pennsylvania Kinzua Pathways	In communication	
Save the Ancients Campaign (Gateway Lodge)	In communication	
Seneca Nation of Indians	In communication	
Seneca Resources	Active	
SUNY Jamestown Community College	Recent addition (active)	
The Forestland Group	Provided data	
The Nature Conservancy, Western New York Chapter	Workshop 2 and follow-up	
Trout Unlimited	In communication	
University of Pittsburgh at Bradford	Recent addition (active)	
Warren County Commissioners	In communication	
Western NY PRISM	Workshop 2 and follow-up	
Western PA Conservancy	Active	

Workshops & Steering Committee Formation

From February through November, 2013, we held three open-participation workshops to gather collaborators together, facilitate discussion, gain insight from collaborators on hemlock forest valuation and perform the initial round of the prioritization of hemlock within the project area.

Workshop 1, February 14th, 2013

Workshop 1 provided an introduction to the values of eastern hemlock, the emerging threat of HWA infestation across the region, and the proposed USFS/TNC prioritization strategy through a series of presentations (presentations provided in a zip file contained in the files provided to the Forest Service). Input was garnered from all present (Workshop attendance in files provided to the Forest Service; represented partners in attendance at Workshops 1, 2, and 3) on the proposed strategy.

To focus efforts and enhance efficiency, we then created a Steering Committee of key representatives shortly following the initial February workshop. A series of conference calls and web meetings with Steering Committee members occurred through the months of March to July, 2013. These calls and meetings were geared towards background decision-making for the prioritizing of hemlock for conservation and treatment. Topics of discussion at each meeting were: 1. valuation metrics needed to prioritize hemlock, 2. verification of the geographic data used in assessing hemlock values, 3. risk factors associated with the spread of HWA, and 4. verification of geographic data used in assessing risk. Prior to each call, TNC provided Steering Committee members with lists of potential valuation and risk metrics (calls 1 and 3), and gathered data for the Steering Committee to view and react to (calls 2 and 4). These Steering Committee meetings were crucial to gain fully collaborative input from key partnership participants. The end result of these conversations was clear support from collaborators for the metrics that we would use to evaluate the priority level of various locations with hemlock throughout the High Allegheny Plateau.

The ecological and social values provided by hemlock that were discussed and agreed upon were protection of water quality and riparian zones, presence of rare species and habitats (including old growth, a rare habitat), general habitat provision (such as in unbroken core forest tracts), social values (recreation, aesthetic, spiritual), and connectivity of the hemlock resource. These values were not ranked in hierarchy of importance because the significance of each is dependent upon the landowner's priorities for management and conservation. Using these valuation metrics and considerations discussed on Steering Committee calls and web meetings, we developed maps that included the USFS Forest Health Technology Enterprise Team (FHTET) modeled hemlock basal area and data relevant to the valuation metrics which we deemed important for prioritizing hemlock (see next section, page 23; maps and supporting information included in the files provided to the Forest Service). These maps were printed in large poster format (36 inch x 48 inch) to facilitate selection of priority hemlock areas by participants at Workshop 2. The final valuation categories and relevant mapped datasets are described in Table 2.

Table 2. Hemlock valuation categories agreed upon through Steering Committee discussion, and corresponding Workshop 2 mapped datasets (for more detailed dataset descriptions, see handouts for Workshop 2 participants contained in files provided to the Forest Service).

Value	Datasets
Protection of water quality and riparian zones	PA DEP Designated & Existing Use water quality classification, NY DEC Classification of Waters
Presence of rare, threatened, or endangered species and habitats (including old growth)	Natural Heritage Program data (Element Occurrences and PA Core Biodiversity Areas), Big Basin old growth hemlock community (Allegany State Park, NY)
General habitat provision	TNC Priority Forest Habitat Patches
Social values (recreation, aesthetic, spiritual)	Public land, Forest Game Cooperators (PGC, PA only), trails (foot, bike, water, and snowmobile), NY DEC points of interest, Recommended public fishing sites,
Connectivity of the hemlock resource	FHTET model

Workshop 2, August 8th, 2013

Workshop 2 was crucial to this effort, as the initial prioritization of hemlock areas for conservation efforts was performed by attendees and members of the collaboration (see files provided to the Forest Service attendance at workshop 2). The workshop began with an introductory presentation that recapped the status of the hemlock validation and valuation measures, highlighted the importance of the task at hand, and introduced the proposed next phase of both the hemlock prioritization and conservation strategy as a whole (presentation contained in files provided to the Forest Service). Then, the maps created through Steering Committee discussion were placed on tables and covered with thin sheets of clear plastic to facilitate multiple groups' evaluations of the same map. Groups were assembled at assigned maps, and each group member was allowed to identify a priority area in turn. When each area was identified and drawn on the map, the group member who identified the area rated it according to five different metrics (Table 3, columns 2 through 7). Then, all group members were instructed to give the area a High, Medium, or Low priority ranking by placing their initials in one of these columns (Table 3, columns 8 through 10). Following group prioritization, group representatives provided a short presentation of each map's priorities to the entire workshop. Voting sheets were passed out to all participants, and they were asked to fill out their "Top 3" hemlock priority areas for the High Allegheny Plateau as a whole (Tables 4 and 5). Several of these areas have important old growth and indeed all areas of known significant old growth were chosen at least once in this exercise, including Cook Forest State Park, Heart's Content Scenic and Natural Area, Allegany State Park, and Tionesta Scenic and Research Natural Area. The vast majority of Top 3 sites contain high quality waters, and several include habitat for rare species, including the Chapman Dam State Park area that encompasses state endangered northern flying squirrel habitat (a species dependent on conifer habitat because of lichen hosted by hemlock and spruce that the squirrel uses for food and nest-building; Butchkoski and Turner 2010). The majority of Top 3 areas are also public lands noted for high recreation value, indicating the importance of social values to the partnership. The number of votes each of these areas received in the Top 3 voting exercise was tallied and recorded, and clearly shows several top priority areas overall. However, because of the wide variety of values that collaborators find to be important, the number of votes received was used simply as another tool to allow various partners and landowners to evaluate the priority areas according to their personal needs and values.

Table 3. Top of tally sheet showing the elements of data collection required by group scribes during the Workshop 2 group prioritization.

Map #:	1		Prioritization	1						
Date:	8/8/2013									
Scribe:										
Group Members:										
	Rate 1 through 5; 5 being highest, 1 being lowest									
					Rare Species or	Other (specify	Initials			Comments
Area Number	Recreation	Water Quality	Aesthetic	Habitat	Communities	in Comments)	Top	Medium	Low	
100										
101										
102										
103										
104										
105										
106										
107										
108										
109										
110										
111										
112										
113										
114										
115										

Table 4. The Top 20 general areas that received at least one vote for 'Top 3' at Workshop 2.

Top 20 Priority Area	**No. of votes**
Cook Forest (including Seneca & Ridge Trails and Forest Cathedral)	26
Heart's Content	21
Allegany State Park *(includes 6 delineated areas of old growth)*	9
Minister Creek	7
Tionesta	5
Chapman Dam State Park	5
Oil Creek State Park	5
Clear Creek State Park	4
Kane Experimental Forest	3
Sugar Run	2
Swamp Creek/Crooked Creek	2
Kellettville/Salmon Creek	1
Cornplanter/Hooks Brook	1
Willow Creek/Tracy Run	1
Kinzua Bridge State Park	1
4 Mile Run	1
Cather's Run	1
Potato Creek (403, private land)	1
Little Coon Run/SGL	1
Tracy Roadless Area	1

Table 5. Results of prioritization for the Top 3 voted areas, showing the average group score for each value and total participant scores for ranking the areas as Top, Middle or Low priority. The General Area Description section indicates participant comments many times indicating the important attribute that led to the area's Top 3 designation.

Polygon ID#	General Area Description	Recreation Value	Water Quality Value	Aesthetic Value	Habitat Value	Rare Species Habitat Value	Top Rank	Middle Rank	Low Rank
NY_5	Big Basin old growth; Allegany State Park	5	4	5	5	4	3	3	0
NY_4	Big Basin old growth; Allegany State Park	5	3	5	5	5	5	1	0
NY_6	Big Basin old growth; Allegany State Park and private	4	3	4	4	5	5	1	0
PA_2	combined ownership	5	3	5	5	5	1	0	0
PA_47	combined ownership	5	4	4	5	4	1	2	0
PA_50	Tracy Roadless Area; Allegheny National Forest	5	5	5	5	3	0	4	1
PA_54	Rt.321 corridor; Allegheny National Forest	5	5	4	5	5	1	0	0
PA_54-1	North Country Trail; Allegheny National Forest	5	4	5	5	5	1	1	0
PA_87	Chapman Dam area; combined ownerships	5	5	5	5	5	6	2	0
PA_91	Hearts Content Scenic Area; USFS and others	5	5	5	5	5	8	0	0
PA_97-2	Kelletville area; combined ownerships	5	4	4	5	5	4	0	0
PA_76	Tionesta Scenic Recreation Area; USFS and others	3	4	3	3	NA	0	0	0
PA_94	Minister Creek roadless area; USFS and others	5	5	5	5	4	5	0	0
PA_91-1	Hearts Content area; USFS and some private	NA	4	5	5	5	6	0	0
PA_94-2	Minister Campground; USFS and some private	5	4	5	5	5	6	0	0
PA_18	Coon area; combined ownerships	4	5	4	4	4	4	4	0
PA_19	Cook Forest State Park; PA DCNR and others	5	5	5	5	5	8	0	0
PA_21	Cather's Run; PA DCNR and others	5	4	4	4	4	4	3	0
PA_22	Clear Creek State Park; PA DCNR	5	5	5	4	4	7	0	0
PA_19-1	Clear Creek State Park, Seneca Trail; PA DCNR	5	3	5	4	5	3	0	0
PA_19-2	Clear Creek State Park, Forest Cathedral; PA DCNR	5	3	5	4	5	3	0	0
PA_15	Oil Creek State Park; PA DCNR and others	5	4	5	5	5	3	0	0
PA_36	Burbot area; combined ownerships	4	4	4	4	4	2	0	0
PA_69	Kane Experimental Forest area; USFS and others	3	4	3	3	3	4	0	0
PA_33	combined ownership	2	5	3	5	4	2	2	0
PA_35	Swamp Creek area; private forestland	1	5	3	5	5	8	0	0
PA_39	combined ownership	4	5	5	5	1	1	2	1
PA_81	Mile Run area; combined ownership	0	0	0	0	0	0	0	0
PA_48	Unnamed polygon; USFS	0	0	0	0	0	0	0	0
PA_54-2	Unnamed polygon; USFS and others	0	0	0	0	0	0	0	0
PA_87-2	Chapman State Park; DCNR and others	5	5	5	5	5	0	0	0

US Forest Service staff and other participants not able to attend the Workshop were given copies of the maps prior to August 8th, and delineated priority areas within the boundary of the Allegheny National Forest. We attributed these priority areas with comments indicating why members of the partnership consider them to be priorities. Both the prioritization exercise conducted at Workshop 2 and the detail on priority areas from other participants highlighted the importance of field knowledge for adequate consideration of all potential hemlock priority areas within the geography of interest. The resulting polygons manually drawn from each of these exercises were digitized using ArcGIS software package 10.1 (ESRI 2012). Figure 7 shows both the Workshop 2 participant delineations and USFS and other personnel delineations.

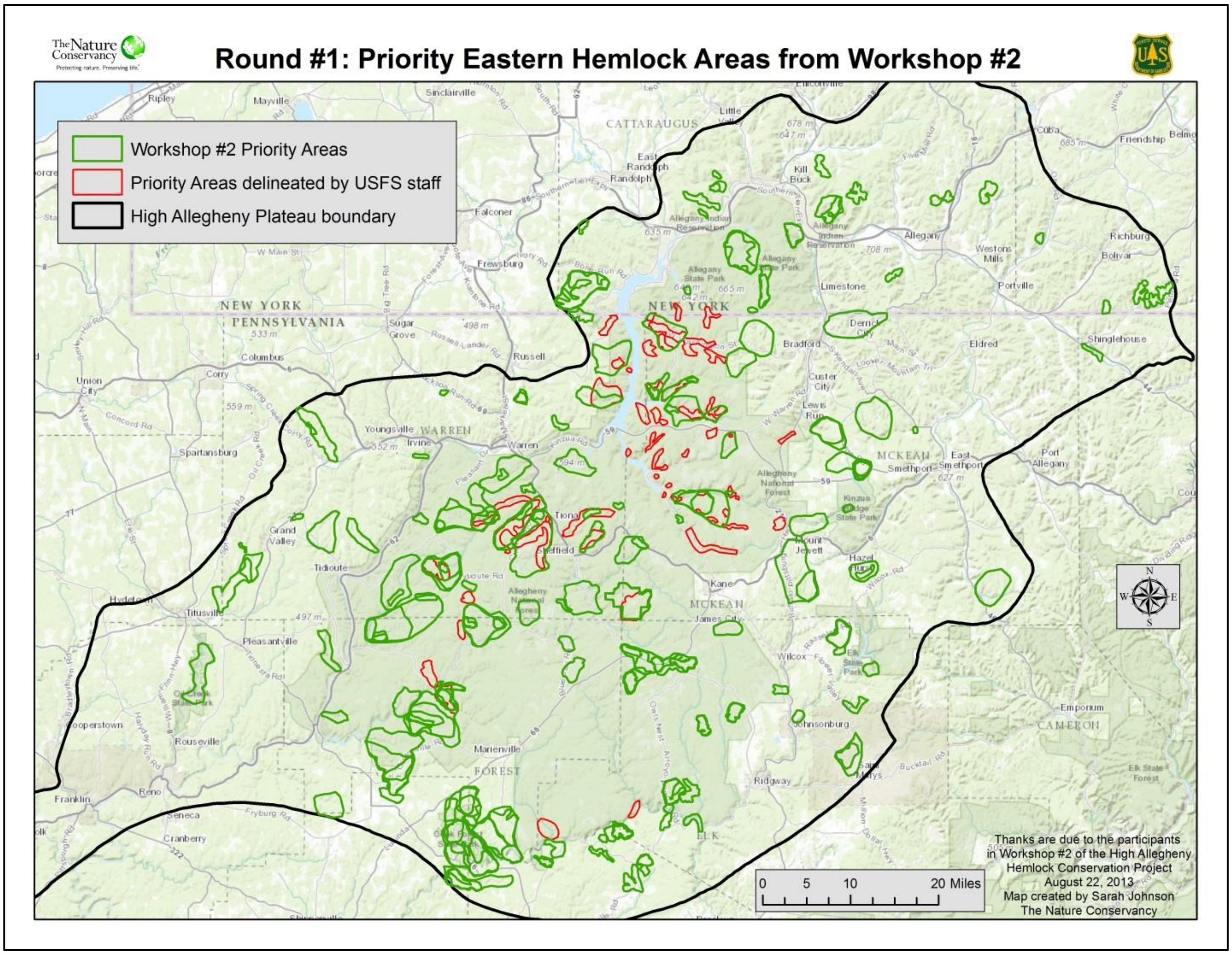

Figure 7. Digitized Round #1 Prioritization results and US Forest Service prioritized areas.

Following the initial prioritization at workshop 2, the designated priority areas underwent a second round of scrutiny by expert reviewers including Steering Committee members, PA DCNR Bureau of Forestry and State Parks staff, NY State Parks staff of Allegany State Park, NY DEC staff, and US Forest Service personnel stationed in other locations and familiar with the effects of HWA. As a result of this expert review, we made several changes to the format of data. Overlapping priority areas were grouped and boundaries finalized, and several priority areas were added from collaborator expertise, particularly in Allegany State Park, New York. Attribute tables for each priority area were formed with data relevant to the conservation priority level, such as water quality rating of associated streams, available recreation areas, presence of old growth, etc. (the priority areas shapefile is contained in the geodatabase provided to the Forest Service). The final prioritization according to two variables relevant to the ranking of each priority area is shown in Figure 8. When we finalized this review, we produced a document to go with the data (a 'Readme' document, contained in the geodatabase provided to the Forest Service), and created a web map application to facilitate public comment on the priority areas. A summary table of all attributes for each priority area designated as a Top 20 area (31 areas total, including 27 large areas and associated smaller focal areas contained within several larger areas), including all attributes listed in the priority areas shapefile, was included in MS Excel spreadsheet format with the files provided to the Forest Service. Reference the "Readme" document provided for descriptions of the attributes contained in the Excel spreadsheet.

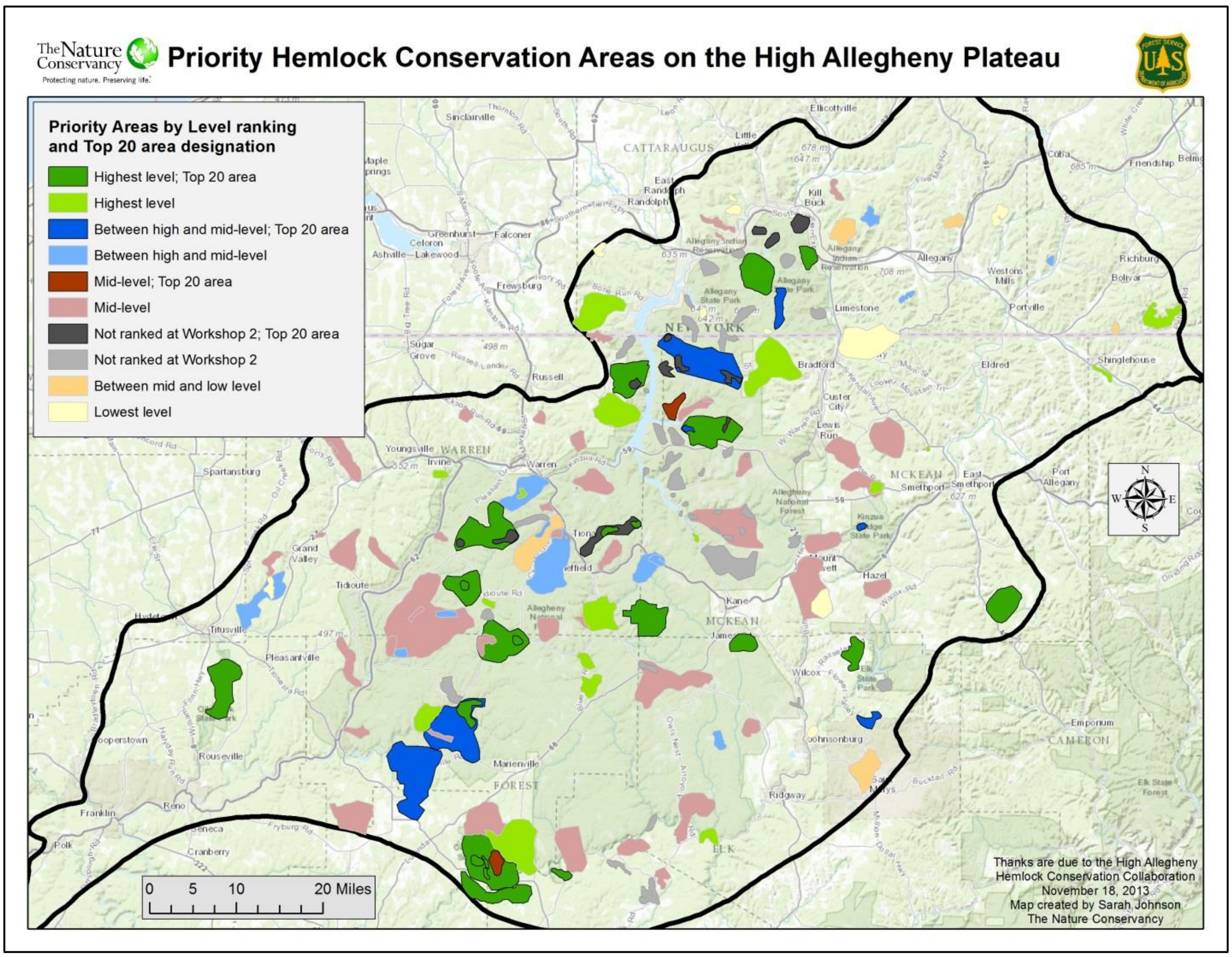

Figure 8. Final prioritization, displayed by Level and Top 20 area designation. The level attribute is derived from the number of participants in Workshop 2 that designated the area as a Top, Middle, or Low priority during group work, and the Top 20 designation is derived from the voting exercise completed after the group work at Workshop 2. The combination of these two

variables provides a more complete picture of the priority ranking of each of these areas than either variable alone.

Workshop 3, November 21st, 2013

Workshop 3 was held as an in-person meeting at the US Forest Service ANF office in North Warren, PA, with an additional webinar component to accommodate collaborators across a wide geography. The goal of the meeting was to provide an overview of the entire first phase of the project (overview presentation contained in the files provided to the Forest Service), go through the available web applications, and discuss the proposed next phase and steps of the collaborative effort. Partners expressed significant support and a need to continue and expand the partnership for a variety of reasons including information exchange, increased efficacy of conservation efforts, and initiation of a Cooperative Management Area to gain funding for cross-boundary work on both public and private lands. The workshop also included a discussion on additional activities that the partnership could undertake, and a plan was made for continuing with this important work.

Workshop 3 provided the opportunity to roll-out the newly developed web-map applications, and describe the best way to access and use the data contained in the sites. The web map (links are listed below) allows a user to view the High Allegheny Priority Hemlock Conservation Areas in full, without the use of any special software. Any member of the public may view the site, and one only needs a web browser program such as Internet Explorer. When in the web map viewer, to open the web map, click the button labeled Open and select 'Open in ArcGIS.com map viewer' to view the web map. Users with ArcGIS 10x on a local computer who would like to open and view the data there should select 'Open in ArcGIS 10 for Desktop'. In the web map, click the button labeled Legend in the upper left to view the symbology. Attributes of each priority will display with a left-click within the boundary of the area. If users would like to save a copy of the Priority Hemlock Areas shapefile directly onto their local computer, follow the second link listed below. To download a shapefile directly to a computer, click the Open button under the graphic. Select 'Open in ArcGIS 10.1 for Desktop'. The webpage will open an ArcMap document and add the shape to it; the shape can then be exported to a local computer or any drive from there. The third link below allows any user access to the 'Readme' document that should accompany the Priority Hemlock Areas shapefile, and should be read prior to viewing priority area attributes. This document provides a description of the data, the process used to create the data, and descriptions of the attributes and their abbreviated headings.

- *Web Map can be accessed through this link*:
- http://tnc.maps.arcgis.com/home/item.html?id=a7dcd307215c4c0fb77ae7c64378d111

- *Priority Areas shapefile can be accessed and downloaded through this link*:
- http://tnc.maps.arcgis.com/home/item.html?id=9a4ade5680df4d01a0f10fc0047d865f

- *The Readme document can be accessed through the Description section of the web map home page, the Description section of the priority areas shapefile home page, or from this link*:
- http://tnc.maps.arcgis.com/home/item.html?id=0a2720cd3fb54f7bb709dea1b1a443e7

Locating Hemlock on the Landscape

Introduction

The USFS Forest Health Technology Enterprise Team (FHTET) develops and delivers forest health technology products to field personnel, including broad-scale host risk maps for various tree species at 1 kilometer resolution for the entire continental United States and Alaska (http://www.fs.fed.us/foresthealth/technology/). Currently, FHTET is generating 30 meter resolution host maps for vulnerable tree species including eastern hemlock (Ellenwood and Krist 2007, Ellenwood and Sapio 2009). The 30 meter resolution FHTET model of eastern hemlock basal area (square feet/acre) was made available to TNC for use with this project, for the area within the boundary of the High Allegheny Unglaciated Plateau (Figure 9). This dataset currently has the highest spatial resolution and most accurate landscape-level basal area prediction capabilities for eastern hemlock. However, to understand how the model performed in our landscape, we needed to test its accuracy across ownership boundaries.

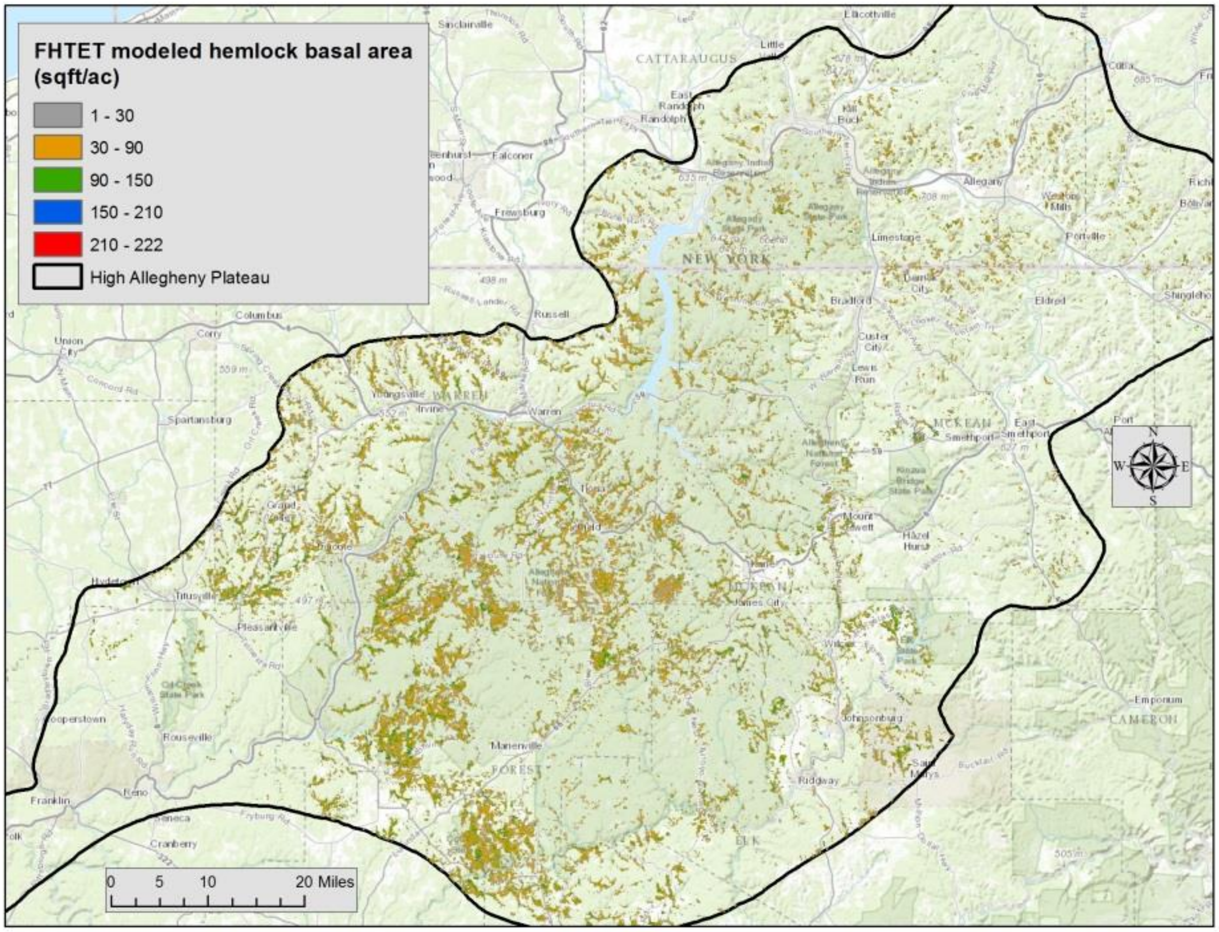

Figure 9. Forest Service Forest Health Technology Enterprise Team (FHTET) model of hemlock basal area, measured in square feet per acre.

Assessment of the model: Methods

The FHTET hemlock basal area model was assessed through field sampling at randomly selected point locations with ½ mile of any road (by USFS and Clarion University field crews), as well as through the use of stand level polygon data from three collaborators. These two independent data sets were used to assess the validity of the FHTET hemlock basal area model. This assessment process was not used to prove if the FHTET model was correct but to see if the model predictions were useful.

Five crews were organized to perform field sampling throughout areas of the High Allegheny Unglaciated Plateau where stand-level data was not available. We used ½ mile from accessible roadways as a constraint because further distances would have significantly reduced our sample size across the region due to travel time, and field crews could access a wide variety of hemlock forests within this distance (i.e. a range of topographic and soil moisture conditions). One crew of two people was organized by the US Forest Service staff of the Allegheny National Forest to complete the sampling at the New York points, and a sub-contract was written to Clarion University (Dr. Suzanne Boyden, Associate Professor of Community and Forest Ecology) for four crews to complete the remainder of the sample points (Figure 10). Stand polygon data were obtained from three collaborators, the Allegheny National Forest, Kane Hardwoods – Collins Pine Company, and Forest Investment Associates (Figure 10). This stand data included average hemlock basal area (measured in square feet/acre) attributes for each stand, including stands where the average hemlock basal area was zero.

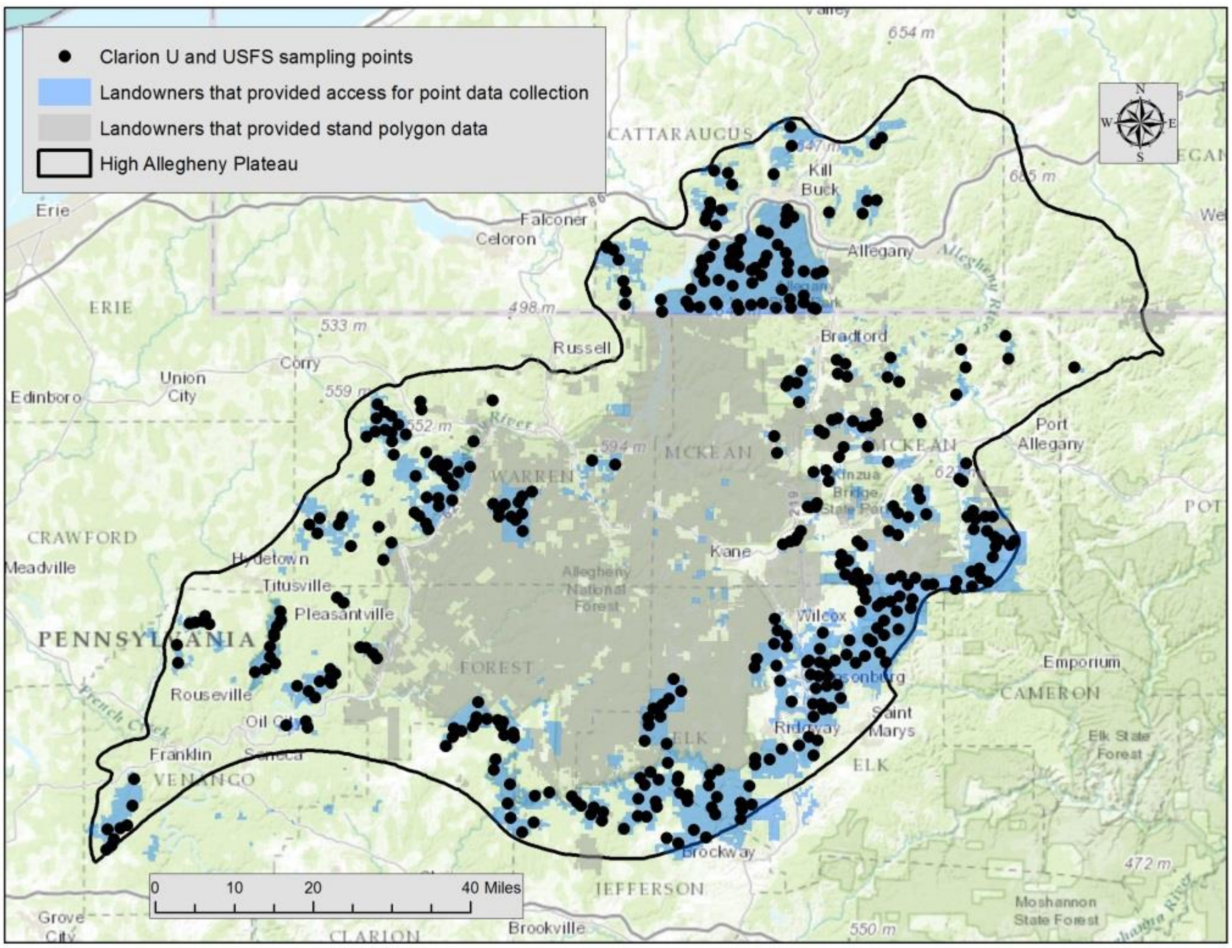

Figure 10. Map of Pennsylvania and New York validation sampling points and landowners that provided stand polygon data.

Validation points were designated as a stratified random sample of areas (within ½ mile of any road) using the Create Random Points tool in ArcGIS 10.1 (ESRI 2012). USFS and Clarion University field crews used a GPS unit to navigate as close as possible to each pre-selected point location. When they arrived on location, a new GPS waypoint was taken with the highest possible accuracy to record the difference between the pre-selected point and the actual data point location. Crews used a 10 BAF prism at each plot center to measure the basal area (square feet/acre) of hemlock at each point. To increase efficiency of data collection, border trees were counted as halves, or 5 square feet of basal area. The crews provided new GPS waypoint locations in text file format, the ID of each new waypoint, and the field-measured basal area of hemlock at the point location. ArcGIS 10.1 (ESRI 2012) tools were used to identify the corresponding modeled hemlock basal area measurement from the FHTET model at each data collection point (full point dataset contained in geodatabase provided to the Forest Service).

Three collaborators provided hemlock basal area data in GIS shapefile polygon format which we then incorporated into the FHTET validation. Each stand polygon was given a unique ID, and attributed with the field-measured average basal area (square feet/acre) of hemlock within the stand. We then identified the modeled average basal area of hemlock from all cells of the FHTET model with cell centers falling within the boundaries of each stand polygon. The final dataset for statistical analysis included the stand ID, field-measured average basal area of hemlock, and FHTET modeled average basal area of hemlock (full dataset contained in the geodatabase provided to the Forest Service, including a data description document and relevant Data Use Agreements). We initially conducted a visual comparison and evaluation, both between the model of hemlock occurrence available for the Allegheny National Forest and the FHTET hemlock model, and between the FHTET model and 0.3 meter resolution aerial imagery (using the ESRI aerial imagery basemap, which is compiled from several sources of best-available aerial imagery).

Statistical analysis

Nonparametric analysis was used on the field sample point and stand polygon datasets because the data did not fit a normal distribution curve following transformation. Paired comparisons between the point field samples, stand data, and the FHTET hemlock basal area model were tested with the Wilcoxon signed-rank test using PROC Univariate (SAS institute Inc. 2011). In addition we also opted for a more parsimonious statistical model by considering the presence of hemlock as a binary response variable (0/1); and used the continuity adjusted Chi-square test in PROC FREQ (SAS institute Inc. 2011) to determine if there was an association between the field point samples, the stand data, and the FHTET hemlock basal area model.

Assessment of the Model: Results

Visual examination of several areas throughout the High Allegheny Unglaciated Plateau revealed a close association between the FHTET model of hemlock basal area and conifer stands noted in aerial imagery. Figures 11 and 12 show comparisons between aerial imagery and the FHTET model for two typical scenarios within the study area. White pine and spruce plantations are potentially confounding factors with spectral modeling similar to FHTET's hemlock model, however through aerial interpretation and ground truthing, it appears that in most cases, the FHTET model distinguishes between conifer species and is able to identify hemlock accurately.

Figure 11. First example area of visual model validation over best-available aerial imagery. Image on the left is leaf-off aerial, and image on the right is the same area overlaid by the FHTET model using the same basal area bins and color scheme as shown in Figure 9. The modeled hemlock basal area appears to closely follow conifer cover while omitting other types of cover that also show up green, however some areas are missed.

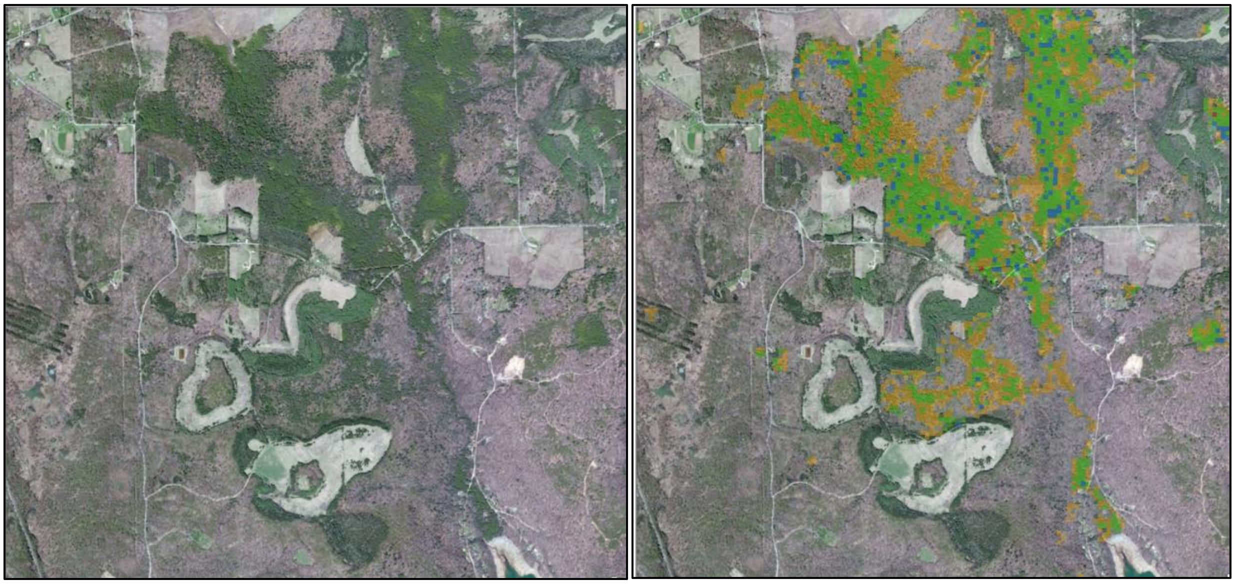

Figure 12. Second example area of visual model validation over best-available aerial imagery. Image on the left is leaf-off aerial, and image on the right is the same area overlaid by the FHTET model using the same basal area bins and color scheme as shown in Figure 9. The modeled hemlock basal area very closely approximates the aerial photography in this area.

A significant difference (Wilcoxon signed-rank test; $P < 0.0001$) in the amount of basal area was found between the field samples and the FHTET hemlock basal area model. Of the 319 survey points, 63% (201) of both the field samples and FHTET hemlock basal area model were found to contain no eastern hemlock. As a result these points were dropped and the data was reassessed to see if differences were present when either one field samples or the FHTET model indicated that hemlock was present. A significant difference (Wilcoxon signed-rank test; $P < 0.0001$) was again found between the basal area in the field samples and the FHTET hemlock basal area model. In looking at the distribution plot for the difference between the field samples and the FHTET hemlock basal area model it appears that the model is under-estimating the basal area more than overestimating (Figure 13). It appears that ~34% of the time it is under-estimating the basal area by about 20-60 square feet, and about ~30% of the time the field sample and FHTET model are within ± 20 square feet of basal area. There also appears to be some observations (~ 8%) in which there is a large difference in basal area between the field samples and the FHTET model (≥ 120 square feet).

A strong association ($\chi^2 = 45.28$, N= 319, $P < 0.001$) in the presence and absence of eastern hemlock was found between the field point samples and the FHTET model. Examination of the cell frequencies showed that about 75% (201 out of 319) of the samples were in agreement for the presence or absence of eastern hemlock. Of these, 63% of the field point samples and FHTET modeled cells were in agreement for the absence of eastern hemlock, while 12% were in agreement for the presence of eastern hemlock. In 19% of the samples, the FHTET model predicted the absence of eastern hemlock while field surveys found hemlock presence. In 5% of the survey sites the opposite was found, with the model predicting hemlock presence where field surveys found hemlock to be absent.

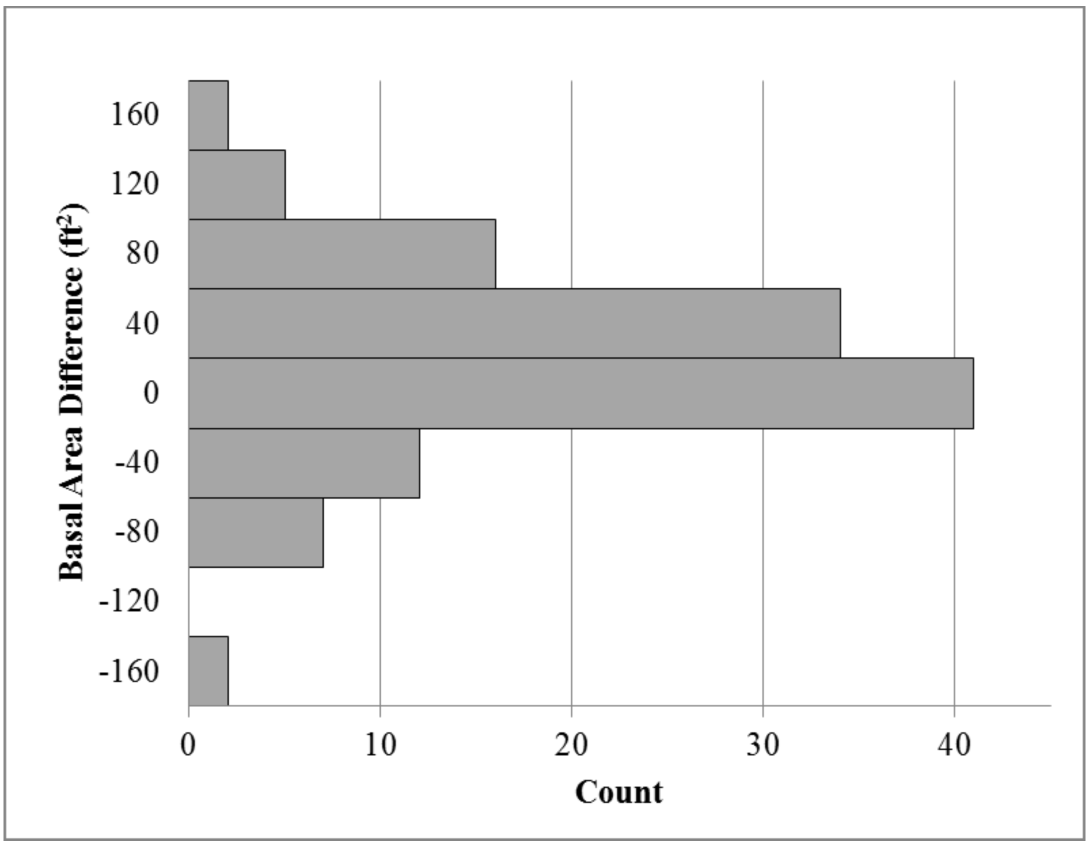

Figure 13. Difference in basal area between field samples and FHTET hemlock basal area model.

Stand polygons ranged in size from 30 m^2 to 3.5 km^2, with an average size of 0.1 ± 0.2 km^2 (~131 cells). A significant difference (Wilcoxon signed-rank test; $P < 0.0001$) in the amount of basal area was found between the stand data and the FHTET hemlock basal area model. Of the 9,582 stands, 16% (1,489) of both the stands and FHTET hemlock basal area model were found to contain no eastern hemlock. As a result these points were dropped and the data was reassessed to see if differences were present when either the stand data or the FHTET model indicated that hemlock was present. A significant difference (Wilcoxon signed-rank test; $P <$ 0.0001) was again found between the basal area in the stand data and the FHTET hemlock basal area model. In looking at the distribution plot for the difference between the stand data and the FHTET hemlock basal area model it appears that the model is performing better with 83% data falling within ± 20 square feet (Figure 14) of the stand data.

A strong association (χ^2 = 2000.66, N= 9582, $P <$ 0.001) in the presence and absence of eastern hemlock was found between the stand data and the FHTET model. Examination of the cell frequencies showed that overall about 77% (7,343 out of 9,582) of the samples were in agreement for the presence or absence of eastern hemlock. Of these 7,343 observations, 16% of the survey stands and FHTET modeled data were in agreement for the absence of eastern hemlock, while 61% were in agreement for the presence of eastern hemlock. In 19% of the samples the FHTET model predicted the absence of eastern hemlock while field stand surveys found hemlock presence, and in 4% of the survey stands the opposite was found, with the model predicting hemlock presence where stand data indicated hemlock was absent.

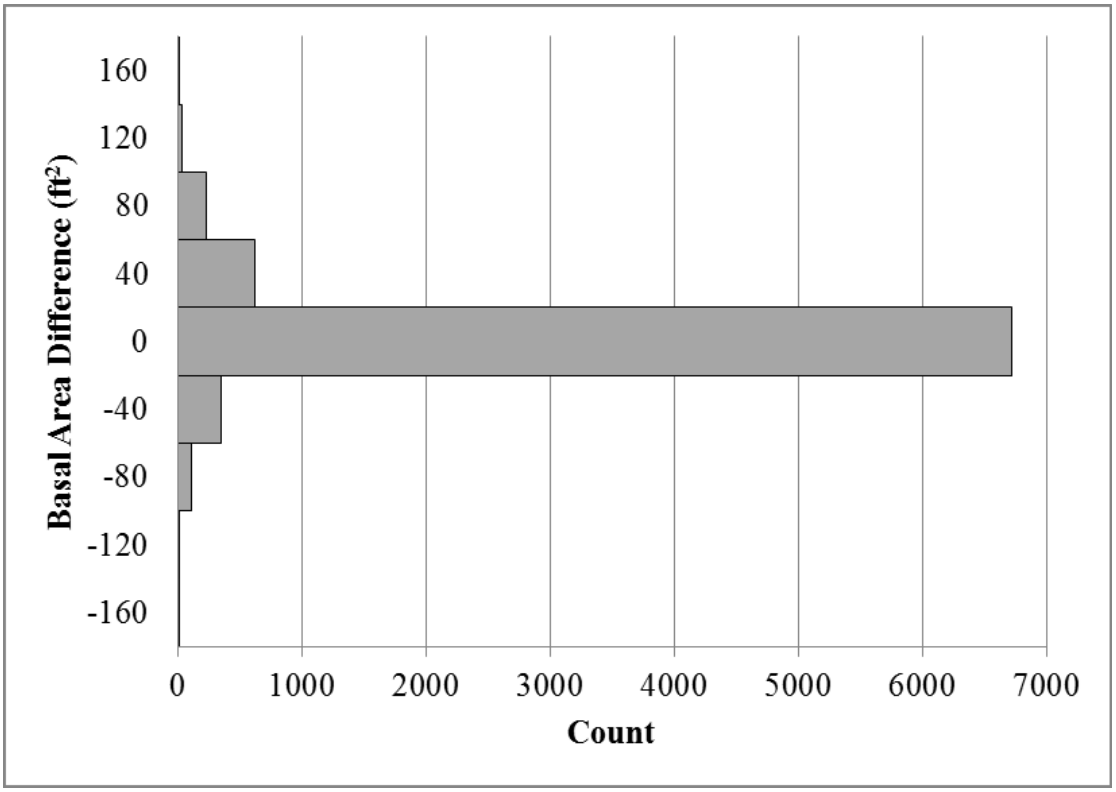

Figure 14. Difference in basal area between stand data and FHTET hemlock basal area model.

Assessment of the model: Discussion & Conclusion

Through the assessment of the point and stand polygon data we found a significant statistical difference between the FHTET hemlock basal area model and the field data. Our results suggest that the model tends to be under-estimating hemlock basal area in both the individual cells and in the polygons (Figure 13 & 14). Such differences between field basal area and model basal area are problematic. When we reduced the data to a binary response variable we found a strong association between the field data and the FHTET model data. While the FHTET model was useful for its spatial coverage of the resource area, the model has limitations, which restricts its usefulness for more fine-scale assessment and analysis.

FHTET is still in the process of revising and improving this model, and any modifications that could be made for this project would not produce any further information that would aid us at this point to conserve the priority hemlock resources of the High Allegheny. Therefore, no modifications were made in an attempt to make the model more accurate, and field data collected by partners will be relied upon for more fine-scale assessments of individual sites, for example the number of inches of hemlock basal area present in an area slated for protection through chemical application. The point data collected by this partnership will be provided to FHTET for their continuing revisions of the model.

Risk Mapping: Susceptibility to HWA infestation

Risk mapping was also completed for the High Allegheny Unglaciated Plateau, to evaluate areas of greatest risk and therefore most in need of monitoring. The risk mapping exercise previously completed by the Allegheny National Forest and Northern Research Station guided this GIS exercise (Moore, unpublished, 2011). Hemlock risk associated with HWA can be broken into two types: susceptibility and vulnerability. Susceptibility is the risk of introduction of a pest or pathogen to a certain area, while vulnerability is the risk of mortality due to the pest or pathogen following introduction. Susceptibility of hemlock to HWA introduction is dependent on many factors, because of the various ways in which HWA can spread or travel and be introduced to new areas (McClure 1990, Ouellette 2002). Some factors that contribute to HWA movement, such as wind (USDA Forest Service 2005), cannot easily be mapped at fine scales. After introduction, vulnerability of the hemlock to HWA-caused mortality is less well-understood. There are several factors that have been linked to hemlock vulnerability to mortality from HWA: soil moisture (Orwig et al. 2002), winter temperatures (Skinner et al. 2003, Paradis et al. 2007, Trotter and Shields 2009), foliar nutrient availability (Pontius et al. 2006), and tree health measured by crown vigor and other metrics (Fajvan and Wood 2010). The most definitive research points to late fall and early spring temperatures and the vigor of the hemlock itself, but these factors are more difficult to predict and map over wide spatial and temporal scales. Because of the difficulty associated with predicting hemlock vulnerability to HWA-caused mortality, susceptibility risk was the focus of the GIS analysis we conducted.

We obtained data to evaluate hemlock susceptibility to infestation from publicly-available sources for Pennsylvania and New York (including the US Forest Service, US Geological Survey, PA Department of Conservation and Natural Resources, and NY Department of Environmental Conservation). Roads, waterways, recreation areas, campgrounds, tree nurseries, lumber mills and yards, and the nearest known HWA infestations were all downloaded or digitized and mapped (Figure 15). Host presence is also an important factor, and we used the FHTET model to represent the hemlock host throughout the ecoregion. Roads, recreation areas, and campgrounds increase the risk of introduction through human movement (Koch et al. 2006, Prasad et al. 2010), while waterways increase risk because stream corridors are tied with bird movement (Koch et al. 2006). Tree nurseries are potential sources of HWA-infested nursery stock (Evans and Gregoire 2007), while lumber mills and yards have been identified as potential sources of HWA because of the transport of hemlock and other lumber (McClure 1990). Proximity to current HWA infestation is most likely the most important factor influencing susceptibility to HWA infestation (Faulkenberry et al. 2009). These factors vary in the level risk posed by each, and in some cases, as with roads and waterways, an increase in the size of the feature increases susceptibility of HWA introduction in the surrounding area. Some sources of risk, such as public land in general (because of recreation traffic) and private inholdings (that would possibly not be monitored as heavily), were mapped as well, although these data were simply overlaid.

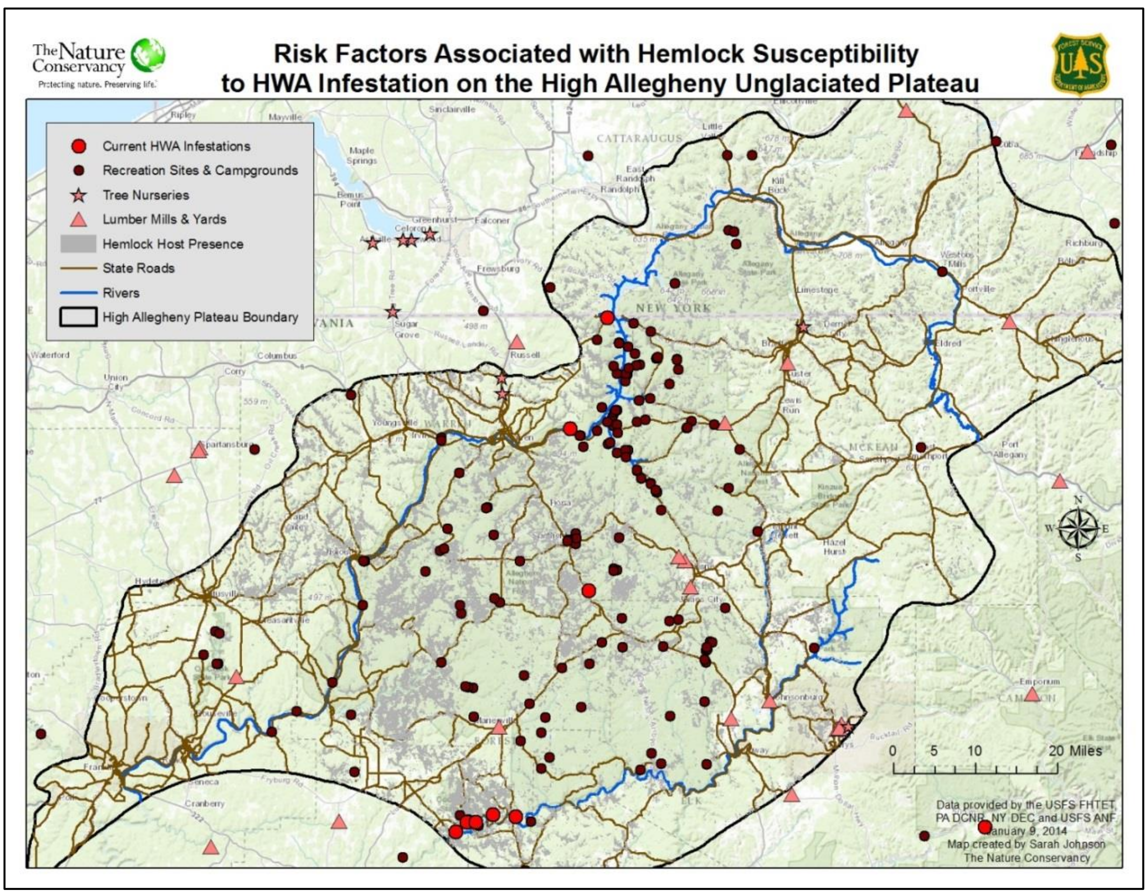

Figure 15. Map of risk factors considered for susceptibility to HWA infestation on the High Allegheny Unglaciated Plateau.

The mapped susceptibility factors all pose a certain level of risk of HWA introduction within a distance of the features, depending on the type of activity in, around, or along those features. For example, visitors to recreation areas and campgrounds pose a high risk of HWA introduction, and factors of wind or animal movement expand the at-risk zone around the recreation area. Therefore, the features of each risk factor dataset were buffered according to the possibility for HWA introduction and movement within a distance of each feature. State or major roads were buffered by 172 meters (Koch et al. 2006), while smaller roads were considered to pose a negligible level of risk. Large waterways and reservoirs along them were buffered by 50 meters (increased slightly from Koch et al. 2006 buffer distance of 35 meters to be conservative in risk estimates), while smaller perennial streams were considered to have low risk, and intermittent streams negligible risk. Campgrounds and recreation sites were given a double buffer, 1350 meters and 2000 meters to designate areas of higher or lower risk within the susceptible area surrounding these sites (McClure 1990). Currently known infestations were also given a double buffer of 1350 and 2000 meters. Tree nurseries and lumber mills and yards were not considered in the risk buffer analysis at this time because of the uncertainty associated with the radius of an at-risk area surrounding these features.

Areas of high susceptibility risk and medium susceptibility risk were considered for an analysis of high and medium risk hemlock in the ecoregion. We considered interior 1350 meter buffers around recreation sites, campgrounds, and currently known infestations to be areas of highest susceptibility risk. Exterior 2000 meter buffers around these features were considered to have medium risk. Large road and waterway buffers were considered to have medium risk. We merged all high risk buffers to represent the areas of highest HWA susceptibility, and all medium risk buffers were merged to represent the areas of medium susceptibility risk. The FHTET modeled hemlock basal area was overlaid and all hemlock occurring within each of these risk buffers was clipped out, resulting in two layers of FHTET hemlock: high risk hemlock, and medium risk hemlock (Figure 16).

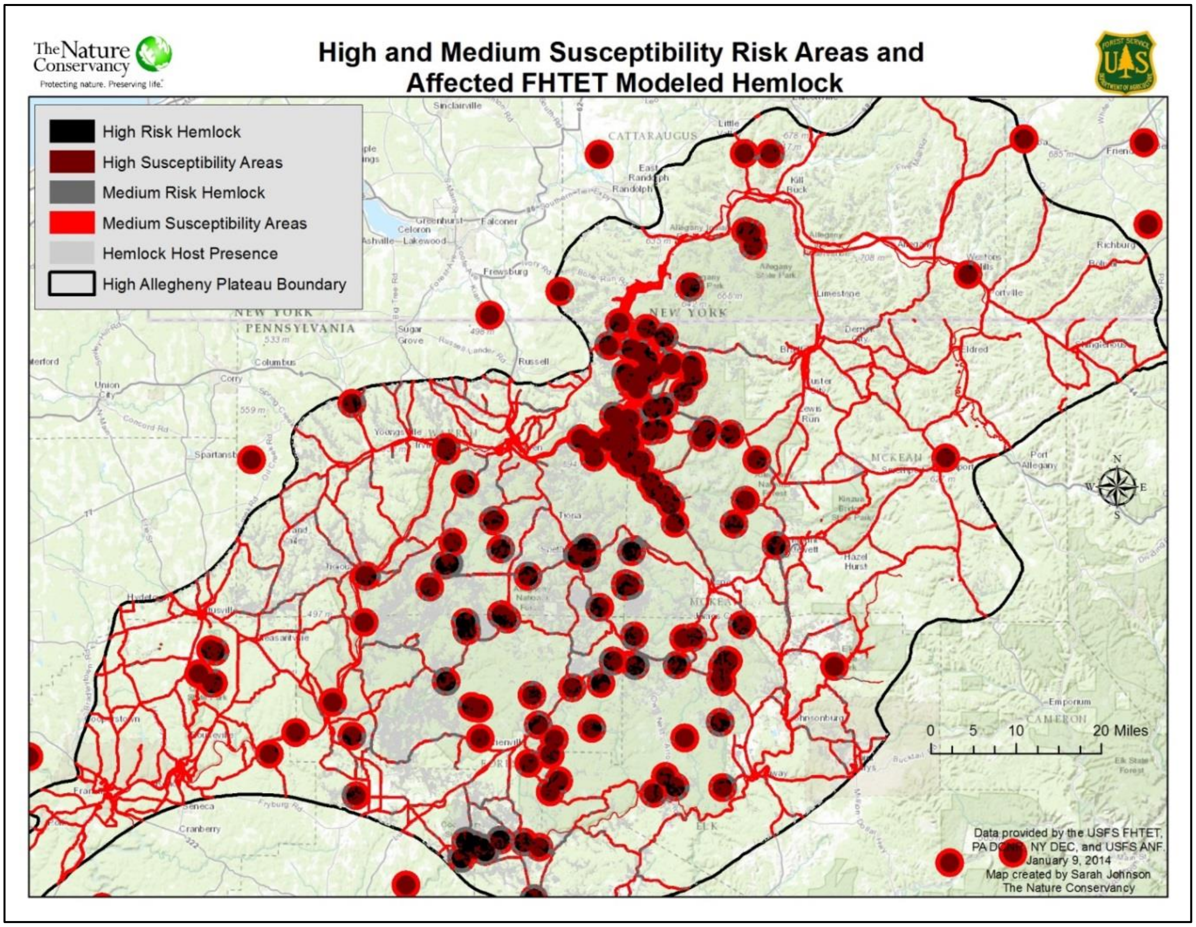

Figure 16. Medium and high risk buffers and hemlock occurring within each.

Figure 16 shows risk of HWA introduction from a broad perspective, based on the best available data about how HWA can travel and spread from one location to surrounding areas. Because much remains to be learned about these mechanisms, caution should be used in interpretation of this map. The most appropriate use is as a survey priorities map, indicating the most likely places in need of monitoring across the High Allegheny Plateau. More fine-scale risk mapping at the level of individual hemlock priority areas will allow us to further target monitoring priorities in the next phase of this work, and evaluate the proportion of high conservation value areas that are in medium and high risk zones.

Detection of HWA in Northwestern PA and Western NY

Surveys for HWA have been ongoing on the Allegheny National Forest since 2004, and Pennsylvania DCNR has been surveying in this area for many years as well. Prior to the start of this work in 2012, all surveys had negative results for areas within the High Allegheny Unglaciated Plateau. However, during the course of this work in 2013, HWA was discovered in several areas (Figure 15; currently located infestations are illustrated on the risk factors map). These infestations were discovered mainly through volunteers and unplanned detections. In spring of 2013, Pennsylvania DCNR staff at Cook Forest State Park (CFSP) discovered an infestation of HWA in one of the most notable hemlock old growth stands in the eastern United States and was voted one of the top priority areas on the High Allegheny Plateau (Table 4). Subsequent surveys in the CFSP area revealed HWA in several spots around the Clarion River corridor on DCNR land. After this infestation was discovered, staff at CFSP and USFS personnel collaborated to hold a volunteer training at CFSP for citizens interested in volunteering to "adopt" various drainages along the Clarion River corridor for HWA survey and monitoring. Many were in attendance and several agreed to adopt drainages for monitoring. Figure 17 illustrates the adopted drainages and surveyed areas. Survey and detection protocols many volunteers followed were developed by Rick Turcotte of USDA Forest Service, State and Private Forestry. Reports from these volunteers were initially negative, until a Millstone Township Road Maintenance Crew (who participated in the HWA survey training) found HWA on ANF land along Millstone Run, very near the Clarion River.

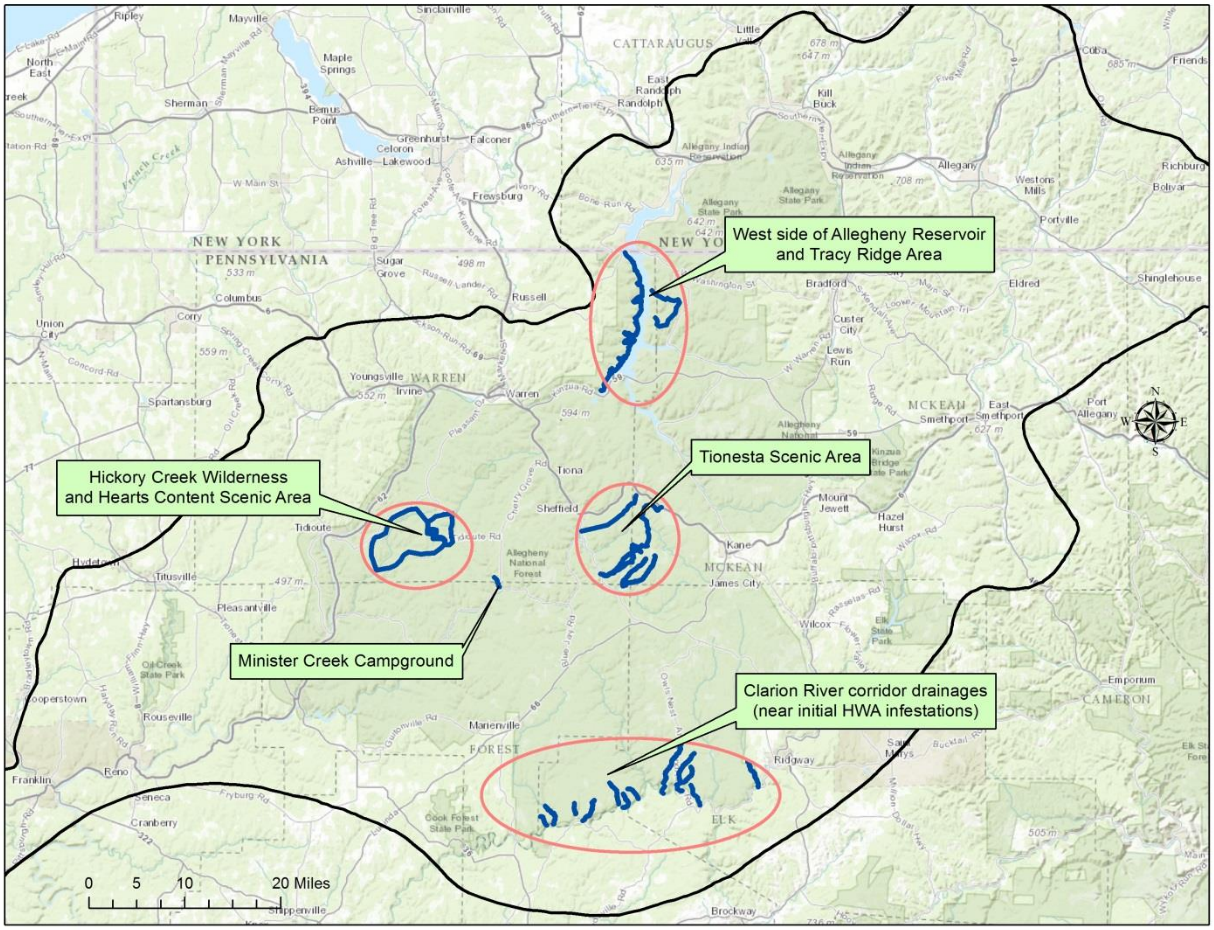

Figure 17. Map of areas adopted by HWA survey volunteers, both drainages and whole areas such as Hearts Content Scenic Area, on the Allegheny National Forest.

In summer of 2013, a member of the Steering Committee, Kirk Johnson with Friends of Allegheny Wilderness, discovered an early HWA infestation near Webbs Ferry along the western side of the Allegheny Reservoir near the New York border. A subsequent transect by Kirk identified one more infested tree near the reservoir. Shortly thereafter, a Pennsylvania Bureau of Forestry employee kayaking down the Allegheny River south of the Kinzua Dam (about 8 miles upstream of Warren, PA), discovered HWA on several trees along the northwest bank of the river. A subsequent survey by the same employee revealed another location with an HWA infestation along the same stretch of the river. The two sites are about 2 miles apart along the river south of the Kinzua Dam. In fall of 2013, a member of the collaboration, Dale Luthringer (Environmental Education Specialist for CFSP), discovered what he believed to be

HWA on a tree in the Tionesta Scenic and Research Natural Area (SRNA). This sample was then confirmed by the PA Department of Agriculture. The Tionesta SRNA is a notable old growth remnant deemed one of the top priority areas for the High Allegheny Collaboration (Table 4).

The majority of surveys have utilized the protocol presented to volunteers at the first HWA survey training, however detections have been made by casual forest observers and chance encounters. Further activities will include holding more volunteer trainings on the importance of the hemlock resource, HWA identification and biology, the High Allegheny Collaborative Strategy, and the USFS standardized detection protocol. We hope to get as many citizen volunteers aware of the threat and out looking for HWA as possible, and to form a cross-boundary monitoring crew, to survey for HWA on all participating ownerships within the High Allegheny Plateau. The early detection of HWA greatly increases the chances of success of management efforts, and allows resources managers the maximum amount of time to weigh various available options.

Camcore Training and Partnership for Hemlock Genetic Conservation

Through this collaborative project, contact was made with Robert Jetton, with Camcore at North Carolina State University in Raleigh, NC. Camcore is a non-profit, international tree breeding organization that primarily serves the private forestry sector through tree genetics work for plantation forestry programs in the tropics, subtropics and subtemperate regions (http://www.camcore.org/). However, in addition to genetics work for production forestry purposes, Camcore also has several gene conservation programs for species that are threatened by non-native forest pests (including eastern and Carolina hemlock), or changes in forest disturbance regimes (table mountain pine, *Pinus pungens* Lamb.).

The objective of Camcore's hemlock gene conservation project is to maintain, in perpetuity, viable seed reserves and plantations of hemlock that will be available for breeding and restoration efforts once effective HWA management strategies are in place. So far, Camcore has collected seeds from 407 mother trees in 59 populations of Eastern hemlock and 126 mother trees in 18 populations of Carolina hemlock (Jetton et al. 2013). Seeds have been placed into cold storage for long-term preservation at seed repositories in Raleigh, NC (operated by Camcore) and Fort Collins, CO (USDA-ARS-National Germplasm Repository). Conservation plantations have been established in Brazil (Camcore member Rigesa), Chile (Camcore member Bioforest-Arauco), and the US (Jetton et al. 2009). These plantations will serve as living genetic repositories and trees will be protected with chemical applications from HWA in the US plantation. Areas with plantations in South America are far less susceptible to HWA due to lack of host species. The range of eastern hemlock is quite large, and seed viability tends to be low even without the presence of HWA, therefore Camcore welcomes seed collections from volunteers, especially in areas of higher genetic variability (Jetton et al. 2013).

In October 2013, Dr. Jetton traveled from North Carolina to Kane, PA to provide a presentation and training to members of this collaboration for eastern hemlock cone collection for germplasm repositories and conservation plantations. Fourteen members of the collaboration were able to be in attendance and collection protocols and materials were described in both the presentation and field setting (Jetton et al. 2007). Many seed collection kits were distributed on the day of the training, and a further eight kits were distributed to other partners who couldn't be in attendance. Four collections were made in the fall of 2013, three by Hancock Forest Management, and one by the Pennsylvania Game Commission Northwest Region. This partnership with Camcore has already been fruitful for their genetic conservation efforts, and we will continue to work with Camcore to collect hemlock seed, and possibly site an eastern hemlock conservation plantation on partnering land within the High Allegheny Plateau subecoregion.

Conclusions & Next Steps

Key aspects of this project that contributed to its success were the engagement of stakeholder groups through personal communication (particularly phone calls and in-person meetings), integration of field knowledge from stakeholder groups into validating and prioritizing hemlock forests, the formation of the Steering Committee to guide the strategy, and collaboration with the USFS FHTET group for use and testing of their model of hemlock basal area. Maintaining engagement among collaborators is difficult and time-consuming, yet essential to the success of any partnership. Having strong and committed leadership helps to maintain engagement, address emerging issues, delegate various tasks and accomplishes other important goals, including keeping the project on track towards one overarching and unifying objective.

Provided this project continues to receive financial and professional support, the next steps with this partnership will include the formation of a Cooperative Pest Management Area (CPMA). The Cooperative Management Area will be based on the framework developed for Cooperative Weed Management Areas (CWMAs) in the western United States as partnerships between federal and state agencies as well as private landowners (Midwest Invasive Plant Network 2011). Many cooperative areas for the management of invasive species, including plants, animals, and insects, have been developed in the eastern United States; these will serve as models for establishing the agreements between The Nature Conservancy, US Forest Service, and all participating landowners, and conducting CPMA operations (USFS map of CWMAs in the Northeast and Midwest 2013). Each participating landowner or manager would sign a Memorandum of Understanding (MOU) agreement with The Nature Conservancy and the Forest Service, and TNC will be able to apply for funding on behalf of all participants, for monitoring and treatment activities to aid in protection of the identified priority hemlock conservation areas. The CPMA will also hold HWA volunteer trainings, develop a website to disseminate information and educate the public, conduct outreach and education activities, and support research efforts.

Several tasks will be completed to facilitate the activities of the CPMA. A more fine-scale prioritization within the priority hemlock conservation areas will allow participating landowners to focus HWA control and mitigation efforts. This fine-scale prioritization will consider several variables, including landscape fragmentation (i.e., gas development), rare species and communities occurrences, old-growth presence, high value recreation concentrations, and riparian corridors. Another task that will be completed is the updating and production of finer-scale risk maps so that sponsors of monitoring crews can further focus their efforts with knowledge of high-risk and high-priority conservation areas. All monitoring crews, whether volunteer or hired teams on public or private land, will be required/encouraged to use uniform monitoring protocols already in use by state and federal agencies. This will ensure that all data collected can be easily incorporated into existing monitoring records kept by Pennsylvania DCNR, New York DEC, and the US Forest Service, the three agencies who maintain such records.

This project provides a general framework to follow for any such undertaking to address the impacts of a non-native invasive forest pest. Essential pieces are collaboration with neighboring landowners, locating the impacted host(s) on the landscape, prioritizing the host(s) for protection and conservation, monitoring, and treating host(s) as appropriate. Another factor that should be considered is what landowners are willing to do to conserve priority hosts. Contact should be made with regional (federal) or state (PA DCNR or NY DEC) agencies that have expertise with HWA management. An integrated strategy that includes many different ways of conserving the host is best. HWA management strategies should consider chemical treatments and biological methods. Mitigation strategies would include silvicultural measures, consideration of surrogates, or herbicide treatments to control undesirable regeneration as the host species declines. Genetic conservation is also a viable way to ensure that the host species is conserved in seed orchards or seed banks for future reintroduction efforts, should this become necessary. These various strategies are discussed in detail as they pertain to hemlock in the Pennsylvania "Eastern Hemlock (*Tsuga canadensis*) Conservation Plan", written and compiled by the Pennsylvania Department of Conservation and Natural Resources Bureau of Forestry Divisions of Conservation Science and Ecological Resources (Mark Faulkenberry and Ellen Shultzabarger) and Forest Pest Management (Donald Eggen and Houping Liu).

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