Middle States Geographer, 2014, 47: 17-25

BATTLING THE BEETLE: MONITORING AND MANAGING EMERALD ASH BORER (*Agrilus planipennis*) IN WESTERN NEW YORK

James T. Kernan
Department of Geography
1 College Circle
State University of New York College at Genseso
Geneseo, NY 14454

ABSTRACT: *The emerald ash borer (EAB) is an invasive species that is spreading rapidly through the Eastern United States. EAB preys on ash trees (Fraxinus spp.), resulting in extremely high mortality rates. As ash trees are attractive, robust, and grow rapidly, they were commonly planted in parks, along streets, and in other public open spaces. Ash trees are also common in forests, particularly in Western New York. There are significant economic, ecological, and environmental problems associated with forest ash mortality. The response to the EAB invasion has faced challenges due to the economic difficulties, and a consequent shortage of resources. This paper discusses EAB management efforts in the context of literature that calls for spatially explicit approaches, early detection and rapid response, and community engagement. The responses in urban Rochester, New York and rural Livingston County, New York are compared to illustrate various approaches for studying and managing the invasion. A basic geographic information system (GIS) risk/cost assessment model is also described. Ash trees located on public land were mapped and inventoried for the model. Distance from known infestations, tree crown exposure, and proximity to high risk sites served as inputs. Buffering and overlay operations were performed to identify trees at greatest risk to infestation. The model identified 32 high risk trees, which would cost $4596 to treat with systemic pesticide.*

Keywords: *emerald ash borer, invasive species, urban, rural, GIS.*

INTRODUCTION

Emerald ash borer (*Agrilus planipennis* – referred to hereafter as EAB) is a fast-moving invasive bark boring beetle that feeds on native ash trees (*Fraxinus spp.*). EAB is believed to have dispersed to the United States in wooden shipping crates from Eastern Asia, the home range of the species (Raupp, Buckelew Cumming, & Raupp, 2006). First identified in Michigan in 2002 (Poland & McCullough, 2006), EAB has spread throughout the Great Lakes and Northeast Regions. EAB arrived in New York state in 2009 and spread eastward in 2010 and 2011 (Whitmore & Fierke, 2011). The beetles feed on the phloem of ash trees (Wang, Yang, Gould, Zhang, Liu, & Liu, 2010), girdling infested trees within 2-3 years and causing rapid mortality. When an ash tree is killed by the ash borer, there is an immediate safety risk from falling braches and eventual toppling. Therefore, widespread ash mortality presents a considerable financial burden in areas that have large numbers of ash trees. New York State is advocating statewide monitoring and early detection to slow the spread of EAB to avoid rapid, widespread mortality of ash trees, which would present significant public safety, economic, and ecological crises. Kovacs et al. (2010) estimate that the cost of EAB damage could reach $10.7 billion between 2009 and 2019, and much of this burden will fall on homeowners and local governments. The objectives of this manuscript are to: 1) discuss the nature of EAB in the context of recent research and forest management frameworks, 2) compare urban and rural management responses in Western New York based on interviews and direct engagement, and 3) present a GIS risk/cost assessment model based on primary data collected through an ash tree inventory.

Invasive species literature over the past few decades indicates conceptual changes in research frameworks and management strategies. Several of these trends are briefly reviewed to provide a structure for discussing EAB management. This review is intended to elucidate pertinent concepts rather than offer a comprehensive examination.

Invasive Species are a Geographic Problem

The ecological literature has acknowledged that invasive species are inherently a spatial problem, as effective management requires an understanding of the spatial distribution of the invader. Anderson et al. (2004) outline a framework for invasive species risk analysis and state that the final product of a risk assessment should be a risk map. They also list "Spatially explicit, multiscale decision support systems…" and "Better understanding of landscape ecology and landscape structure…." as the first two entries in a list of research needs (Andersen, Adams, Hope, & Powell, 2004). Chornesky et al. (2005) discussed research priorities for invasive species in the context of sustainable forestry. The authors echoed Anderson et al. (2004) in that they acknowledge the increasing importance of "spatially explicit models", and further emphasize the importance of spatial analysis and GIS-based risk mapping. Many studies have addressed these needs through spatial modeling and mapping of invasive species, including EAB (Prasad, et al., 2010), phragmites (Maheu-Giroux & de Blois, 2005), and invasive mussels (Haltuch, Berkman, & Garton, 2000). This spatial emphasis is critical as resources such as personnel, equipment, and herbicides/pesticides are often limited, and must be deployed as efficiently as possible.

Shift from Eradication to Containment

The literature also suggests a conceptual change in management objectives at a national scale. The emphasis has shifted from seeking to eradicate invasive species to that of containment and delay. This is exemplified in the "slow the spread" campaign associated with gypsy moths. This strategy was piloted by the USDA Forest Service in the 1990's, and sustained efforts appear to have helped contain the spread (Sharov, Leonard, Liebhold, Roberts, & Dickerson, 2002). Management methods based on "slowing the spread" have been tested for EAB through simulation modeling, and reduced spread rates were predicted (Mercader, Siegert, Liebhold, & McCullough, 2011). This delay strategy is evidenced in the early detection and rapid response (EDRR) approach that has been broadly advocated by agencies such as the USDA Forest Service (Rabaglia, Duerr, Acciavati, & Ragenovich, 2008), and incorporated (explicitly or implicitly) in EAB response plans by many states in the infestation area, including New York (Williamson, Carlson, Andritz, Kramarchyk, & Siegert, 2011).

Community Engagement & Citizen Science

Krasny and Lee (2002) discuss invasive species in the context of environmental education, addressing the role that social learning plays in invasive species control. Social learning and community outreach may improve efforts to respond to rapidly advancing, widespread invaders such as EAB. Furthermore, Dickinson et al. (2012) argue that citizen science initiatives, which establish dispersed teams of observers, can benefit ecological studies "at unprecedented spatial and temporal scales." Citizen scientists can be particularly effective at establishing baseline conditions and monitoring species populations (Dickinson, et al., 2012), both of which are critical to effectively studying and managing biological invasions.

EAB MANAGEMENT IN WESTERN NEW YORK

To a large degree, EAB management efforts by various agencies and institutions in Western New York State reflect trends in the literature, as they are spatial in approach, emphasize EDRR, and promote community outreach and education. A brief overview on the role of state government and the Cornell University Cooperative Extension (CUCE) is critical to understanding EAB efforts in Western New York. The New York Department of Environmental Conservation (DEC) has adopted a Slow Ash Mortality (SLAM) management approach for the state (Williamson, Carlson, Andritz, Kramarchyk, & Siegert, 2011). This approach acknowledges the gravity of the EAB invasion, as it emphasizes delaying the spread over a longer period of time so that communities and landowners can plan for the economic burdens, rather than seeking eradication of EAB. This conceptual and practical approach is reflective of the "slow the spread" approach. The state evaluates risk and recommends management efforts based on spatial parameters, primarily distance from known infestations. SLAM is also based on EDRR, the rapid response referring to the destruction of infested ash trees. As such, the DEC actively monitors forests for new infestations, and maintains a reporting hotline and current infestation maps for the public. The DEC and CUCE both produce educational materials to inform the public, provide expertise to local governments and landowners, and communicate with the public through the media. CUCE has also provided workshops for landowners and "first-responder" training for environmental professionals so that they can identify local infestations. Public education and outreach are critical when dealing with such a large problem as a forest invasive (Krasny and Lee, 2002; Dickinson et al., 2012), particularly given the limited resources that are available in the current economic downturn. The efforts of the DEC and the CUCE have directly influenced local EAB response efforts in New York State.

A comparison of response efforts in the City of Rochester and rural Livingston County in Western New York demonstrates how the concepts expressed in the literature (spatial approach, EDRR, and community engagement) translate to local-scale efforts. Information presented in these cases was gathered by the author through interviews with key personnel, participation in workshops and public awareness activities, and direct involvement with data collection, public outreach, and management efforts.

Urban Response Case

The City of Rochester is located in Monroe County (population 744,344), and shares a border with Livingston County (population 65,393) to the south (United States Census Bureau, 2010) (Figure 1). Rochester has a population of 210,000, is the third most populous city in the state (United States Census Bureau, 2010), and is the home to many widely known universities and businesses. Livingston County contains the State University of New York College at Geneseo and other local and regional institutions and businesses. These geographic disparities result in very different resource bases, and very different approaches to EAB.

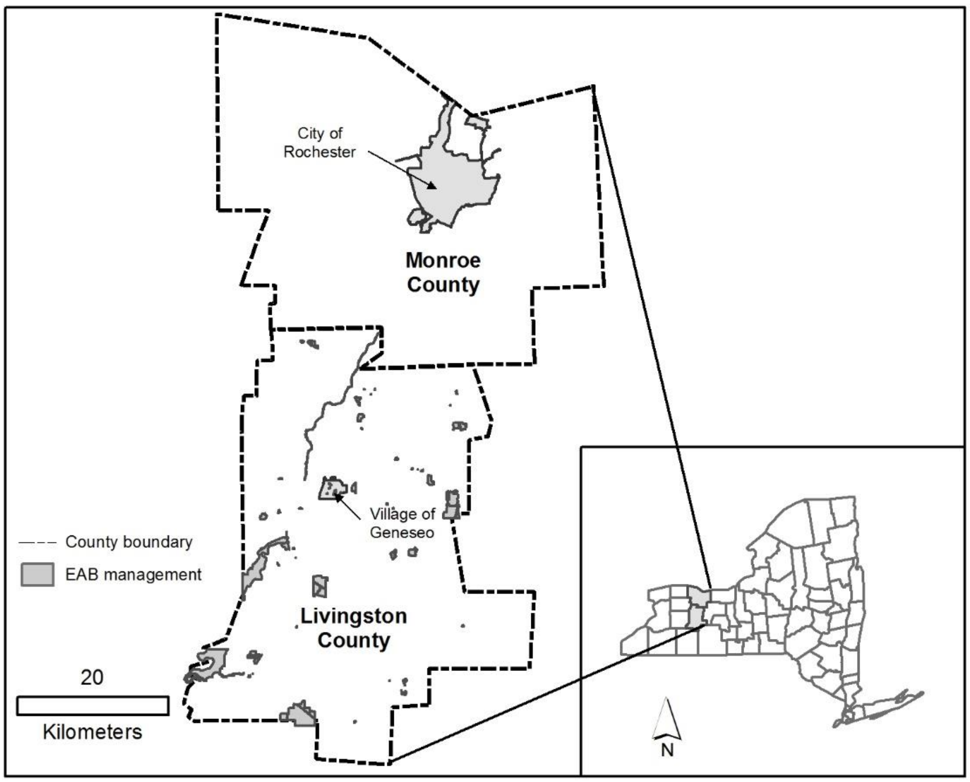

Figure 1. The location of Monroe County and Livingston County in Western New York (inset map) and EAB management and monitoring areas (gray shading) addressed in the case studies. The City of Rochester is illustrated in Monroe County, and the Village of Geneseo, public open space, and Genesee Valley Conservancy (GVC) lands are illustrated in Livingston County.

In the urban response, efforts were managed by the City of Rochester Division of Forestry. The City Forester B. Liberti and staff A. Place and M. Staples were interviewed on 10 April 2012. The interview indicated that the division had thirteen full-time staff who manage trees along streets and in parks and cemeteries. The city had an existing relational database of trees created in 1991, prior to the arrival of EAB. After EAB was identified in the vicinity, division personnel converted the addresses in the relational database to a geographic information system using geocoding, an operation that matches address data to physical locations on a digital map. The division then used existing GPS and GIS assets to manage the logistics of their EAB response plan. Approximately 4000 ash trees (≥ 4 inches diameter at breast height) were treated with injected systemic pesticide, and an additional 700 were removed and replaced with other species. The trees that were removed were either already stressed or damaged, or were not suitable for pesticide application. In terms of labor, the division estimates that 320 hours were spent on administration, 1120 hours were spent on ash removal and replanting, and over 2700 hours were spent on pesticide treatment. Forestry efforts were supported by special appropriation requests to the City Council. An initial appropriation of $150,000 was granted to support pre-EAB work, and an additional $460,000 appropriation supported the removal, replanting, and treatment efforts. In the urban model, the City of Rochester leveraged its access to resources to rapidly address the problem. A SLAM team was organized to maintain efforts, and a Monroe County EAB Task Force was mobilized.

Rural Response Case

Livingston County efforts began in 2010, when EAB arrived in the northeastern part of the county. The Livingston County Planning Department (LCPD) also initiated a rapid response to the problem, but the approach was significantly different due to limited resources. Based on a history of collaborating on GIS projects and intern placement, the LCPD contacted the SUNY Geneseo Geography Department to update a GIS database of all publicly-owned open-space in the county. When this dataset was completed, they dedicated time during the summer of 2011 and 2012 to conduct an inventory of ash trees on these public lands and in public right-of-ways, assisted by eight interns from the Biology and Geography Departments at SUNY Geneseo. The LCPD borrowed a GPS from the Livingston County Transportation Department, and the interns mapped ash trees in the field, and measured diameter at breast height (dbh). Interns and LCPD staff converted the GPS data to a GIS dataset containing more than 700 ash trees. This work was completed using 12 days of professional staff time, unpaid internship time, and no special funds were allocated. LCPD has also worked with the Cornell University Cooperative Extension during this period, hosting a homeowner workshop, and has communicated with residents and municipal governments through the media and mailings. Student researchers continued the inventory work during the summer of 2013 under my supervision. SUNY Geneseo also mobilized teams of students and community volunteers in 2012 and 2013 to participate in a regional ash tagging event to raise public awareness about EAB. Outreach has extended to the local high school, and students in a seventh grade accelerated science class participated in a program to measure and map ash trees in 2011-2014. This program integrates college student mentoring and geospatial education. A Livingston County EAB Task Force exists in name, but has not been active beyond these efforts.

In both the urban and rural models, personnel leveraged existing resources to approach the EAB problem from a spatial perspective, implementing geotechnology and mapping trees. The mapping was the first step toward early detection and rapid response. However, the City of Rochester had a resource advantage, and enacted a rapid response to treat trees, in many cases prior to any signs of infestation. Livingston County remains in the initial phases of early detection and lacks the resources necessary for rapid response (funds for treatment or removal and replanting). Both models also recognized the value in community engagement, and have taken steps to educate citizens about EAB. Future efforts in Rochester will require additional appropriations, and sustained commitment from the SLAM team and Monroe County Task Force. Work in Livingston County continues to face resource challenges.

EAB GIS RISK/COST MODEL

For several years, research that emphasizes undergraduate engagement has maintained EAB efforts in Livingston County. Internal grants awarded by SUNY Geneseo were used to acquire a GPS receiver, and to field eight undergraduate research students (four each in summer 2011 and summer 2012). Another research student was funded through a college STEM program to conduct related work on a local research reserve. Twelve additional undergraduate volunteers have put in time 2012-2013. As a result of this work, the ash inventory has been extended to two properties owned by the Genesee Valley Conservancy (a local land conservancy) and the Geneseo Central School District grounds, and comprehensive tree inventories have been completed for the SUNY Geneseo campus (partially funded by the Grounds Department) and the Village of Geneseo core (Figure 2). A limited monitoring network has been established to facilitate ongoing early detection, and the GIS now contains over 1500 trees.

DATA AND METHODS

Data collected during the ash inventory was used to develop a GIS model to evaluate the risk of ash trees on public land in Livingston County to EAB infestation, and estimate the cost of treatment options. There have been robust GIS analyses of invasive species, including Prasad et al. (2010) who modelled EAB spread with a spatial cellular automata model, and Shatz et al. (2013) who modelled the potential distribution of Asian longhorned beetle. However, the model presented in this paper was based on simple buffering and overlay techniques, and is intended to demonstrate how GIS can be rapidly deployed to study invasive species with limited resources. The model used three spatial criteria (Table 1). The first criterion was the distance from known infestations, based on the NY DEC threat level system which evaluates risk spatially and suggests appropriate management and outreach actions. The NY DEC threat levels range from "red" (< 5 miles from an infestation, "orange" (5-10 miles from an infestation), and "yellow" (>10 miles from an infestation) (Williamson, Carlson, Andritz, Kramarchyk, & Siegert, 2011). Five and ten mile buffers were calculated for known infestations. Ash trees within the five mile buffers were assigned a risk value of 3, trees within the ten mile buffers were assigned a risk value of 2, and those outside of the buffers were assigned a risk value of 1.

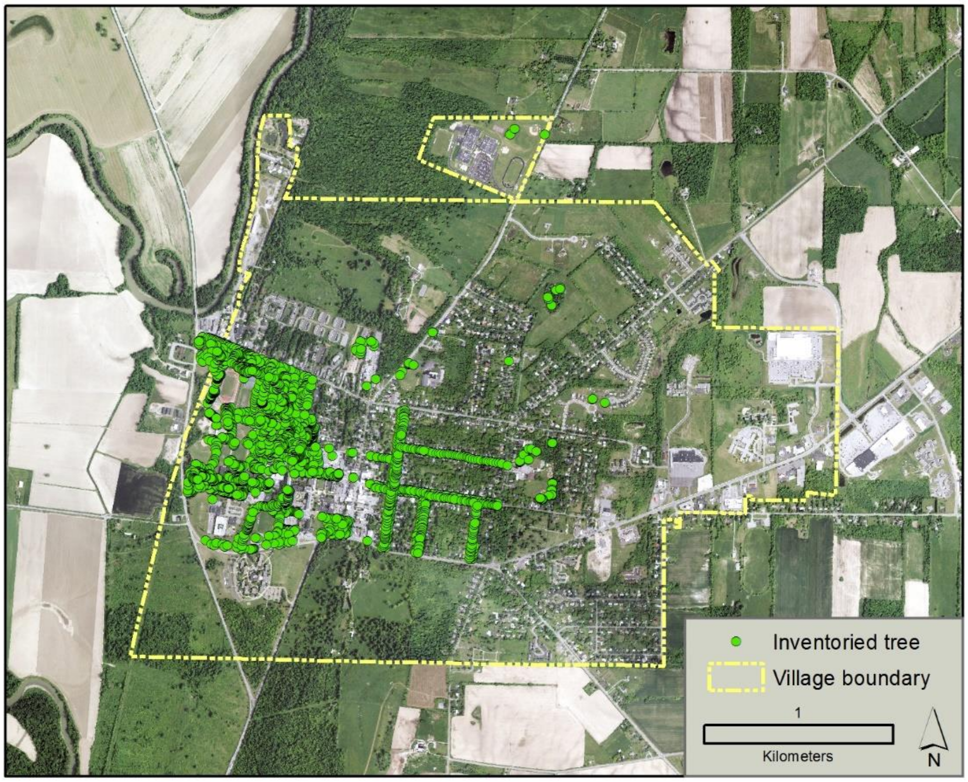

Figure 2. Detail of trees (all species) inventoried in the Village of Geneseo. Public parks, Genesee Valley Conservancy (GVC) lands, the college campus, the central school campus, and the county courthouse grounds were included in the inventory. GVC and public lands throughout Livingston County were also surveyed for ash trees.

The second criterion was distance from potential "high risk" geographic features. These high risk geographic features have an elevated risk of receiving and/or distributing infested ash wood. The NY DEC identifies "campgrounds, rest areas, mills, firewood producers, and industrial areas" as high risk (Williamson, Carlson, Andritz, Kramarchyk, & Siegert, 2011). In this study, students referred to county recreation maps, the county Chamber of Commerce, and conducted internet searches to identify potential risk areas. A list of campgrounds, an interstate rest area, and several businesses associated with firewood, lumber products, or the manufacturing of wooden packing materials were identified. Given the sensitive nature of EAB in wood industries, it was not practicable to determine if these businesses did indeed use ash wood. As such, risk was assumed, but the names and locations of the businesses are not reported, described, nor mapped in this paper. Furthermore, there has been speculation that EAB can disperse from open loads of firewood or lumber traveling along primary highways. As such, the I-390 corridor was also considered a "risk area", and was mapped as a linear feature in the GIS. Risk level for these locations was based on *a priori* assumptions. It was decided that campgrounds and firewood distributors were of greatest concern (high risk), as the NY DEC allows the transportation of firewood up to 50 miles from its origin. Therefore, campground fire wood and fuel wood for home heating can be readily distributed throughout the county. The wood industry businesses were of moderate concern (moderate risk), as ash is used for lumber and for finished wood products such as pallets, crates, furniture or cabinets. However, softwoods are often used for packaging, and other hardwoods such as oak, hickory, and beech tend to be preferred for hardwood furniture and cabinets. The I-390 corridor and the associated rest stop were of least concern (low risk). Although firewood and lumber are still transported, camp wood is often carried inside of vehicles, and it was assumed that wood industry businesses may be more conscientious about inspecting and transporting products. Thus a new infestation is more likely at a wood industry production site, delivery site, or campground (wood may be stored outdoors for a period of time) than through a random dispersal from a vehicle on the interstate. Two mile buffers were applied to each of the risk locations, representing potential dispersal areas if EAB were introduced. Each buffer was assigned a risk value based on the *a priori* assumptions, high risk = 3, moderate risk = 2, and low risk = 1 (Table 1).

Table 1. GIS model criteria.

Criteria	**Value**	**Risk Weight**
Distance from Infestated Site (miles)		
NY DEC Tier 1	<1 mile	3
NY DEC Tier 2	1- 5 miles	2
NY DEC Tier 3	5.1-10 miles	1
Crown exposure (% of crown circumference open to air)		
Full exposure	100%	3
Partial exposure	25-99%	2
Low exposure	<25%	1
Distance from high risk location (miles)		
Campground	2	3
Fire wood provider	2	3
Wood industry business	2	2
Highway rest stop	2	1
Highway corridor	2	1

The third and final criterion is based on the growth environment of individual ash trees. EAB prefer trees in sites with full sun exposure and warmer conditions (McCullogh & Siegert, 2007). Open-grown trees such as street and park trees are the most vulnerable, followed by hedgerow and forest edge trees, then forest interior trees. Growth environment was determined by field observations, and by visually analyzing the GIS points on a backdrop of digital orthophoto quarter quads (DOQQs). Risk attributes were assigned to all trees, including open-grown trees on streets and in parks (risk=3), trees with partial crown exposure in hedgerows and at forest edges (risk=2) and trees in forest interiors (risk=1) (Table 1).

After the criteria were operationalized in the GIS, map overlay techniques were used to assign the risk values from the NY DEC threat level buffers and the high risk geographic location buffers to the point features (ash trees). The growth environment risk attributes were directly entered for each tree. The risk values were then summed and the model returned a "total risk" value (range 4-17). As this total risk value was based on ordinal inputs, it is not mathematically meaningful. However, the total risk attribute is proportional to the degree of exposure to the three risk criteria. Therefore, trees with the highest values would be considered at the greatest risk for infestation. A natural break classification was applied to the total risk attribute to generalize the results (range of 1-7) for a final risk map (Figure 3).

Finally, the risk model output was used to estimate the costs associated with managing the highest risk trees (total risk ≥ 5). It was assumed that all high risk trees with a diameter at breast height (dbh) > 4 in and < 30 in dbh were suitable for treatment with injected systemic insecticides. Studies indicate that such treatments are less effective on small diameter and larger diameter, more mature trees (Herms, McCullough, Smitley, Sadof, Williamson, & Nixon, 2009). Treatment costs were estimated at $12 per inch of diameter based on insecticide manufacturer's pricing provided by A. Gorden, a representative of Arborjet, at an 8 September 2011 workshop. Total diameter of treatable high risk trees was calculated in the GIS. High risk trees that were not suitable for treatment were to be considered for removal and replanting.

RESULTS

All trees with a total risk value of five or higher (n=89) trees were identified (Figure 3). However, many of these trees were between 5-10 miles from the current known infestation. Current management recommendations are to "wait and watch" at such distances, as EAB naturally disperses slowly (0.5 miles/year). Therefore, the selection was limited to trees that fall within one mile of the known infestation (n=35). Thirty-two of these trees fell in the diameter range that was suitable for treatment, and the total diameter was 383 inches. Total cost for one treatment would cost $4596, and results indicate that some insecticides may remain effective for two, or even three years (Herms, McCullough, Smitley, Sadof, Williamson, & Nixon, 2009). Cost to treat the 32 trees and remove and replant the other three would be $7596. The model can be be an effective tool for initial planning and can be used to support ongoing efforts as the invasion unfolds.

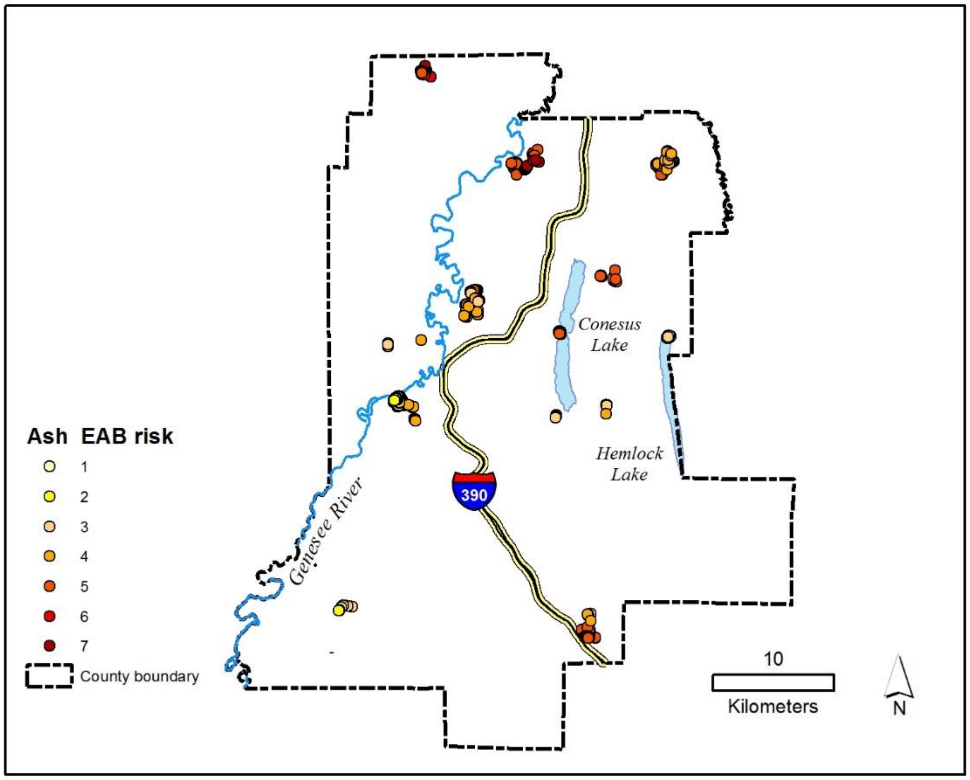

Figure 3. EAB infestation risk for ash trees located on public and Genesee Valley Conservancy land in Livingston County, NY. The areas of greatest risk are in the northern part of the county, closest to the known infestations.

CONCLUSION AND RECOMMENDATIONS

The emerald ash borer invasion provides an opportunity, albeit a tragic one, to reflect on the evolution of invasive species research and management, and to consider how the concepts discussed in the literature are operationalized. The need for spatial approaches expressed in the literature is evident in recent research and management efforts at the national, state, and local level, as indicated by the case studies presented in this paper. The transition from species eradication to species containment is clearly reflected in "slow the spread" and EDRR strategies that have been analyzed by scientists, and adopted in management plans. Community engagement and outreach plays a significant role. The comparison of local urban and rural response plans shows how many of these concepts can be achieved, even with limited resources. A useful, spatially explicit risk model was developed in Livingston County with minimal financial, technological, and personnel assets. While the response to EAB in Western New York is in alignment with current management approaches, its efficacy on such an insidious invader remains to be seen. Efforts are underway in Livingston County to establish a network of long-term monitoring plots and marker trees to facilitate EDRR, and to document the infestation as it spreads.

Acknowledgments

This work was funded by the State University of New York College at Geneseo Office of Sponsored Research and the Geneseo Foundation. Heather Ferrero and Mary Underhill of the Livingston County Planning Department initiated the efforts in Livingston County, and conducted most of the ash inventory work. Student Kevin Bronson collected data in the field and conducted interviews with personnel from the City of Rochester Division of Forestry and Livingston County Planning Department. Randy French, seventh grade accelerated science teacher at Geneseo Central School District, has dedicated time and students to the project for the past three years. The Genesee Valley Conservancy has granted student access to local properties for inventory purposes.

REFERENCES

Andersen, M. C., Adams, H., Hope, B., & Powell, M. 2004. Risk Analysis for Invasive Species: General Framework and Research Needs. *Risk Analysis.* 24(4): 893-900.

Chornesky, E. et al. 2005. Science Priorities for Reducing the Threat of Invasive Species to Sustainable Forestry. *BioScience*. 55(4): 335-348.

City of Rochester. (n.d.). Forestry Division. http://www.cityofrochester.gov/article.aspx?id=8589943541. (last accessed November 15, 2014.

Dickinson, J. et al. The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment.* 10(6): 291-297.

Haltuch, M., Berkman, P., & Garton, D. 2000. Geographic information system (GIS) analysis of ecosystem invasion: Exotic mussels in Lake Erie. *Limnology & Oceanograpy.* 45(8): 1778-1787.

Herms, D. et al. 2009. Insecticide options for protecting ash trees from emerald ash borer. North Central Integrated Pest Management Center. http://www.emeraldashborer.info/files/multistate_eab_insecticide_fact_sheet.pdf. (last accessed May 27, 2014).

Kovacs, K. et al. 2010. Cost of potential emerald ash borer damage in U.S. communities, 2009-2019. *Ecological Economics.* 69: 569-578.

Krasny, M. 2002. Social learning as an approach to environmental education: Lessons from a program focusing on non-indigenous, invasive species. *Environmental Education Research.* 8(2): 101-119.

Maheu-Giroux, M., & de Blois, S. 2005. Mapping the invasive *Phragmites australis* in linear wetland corridors. *Aquatic Botany*. 83(4): 310-320.

McCullogh, D., & Siegert, N. 2007. Using girdled trap trees effectively for emerald ash borer detection, delimitation, and survey. United States Forest Service. http:// http://na.fs.fed.us/fhp/eab/survey/eab_handout.pdf. (last accessed November 15, 2014).

Mercader, R. et al. 2011. Simulating the effectiveness of three potential management options to slow the spread of emerald ash borer (Agrilus planipennis) populations in localized outlier sites. *Canadian Journal of Forest Research.* 41(2): 254-264.

Poland, T., & McCullough, D. 2006. Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry*. 104(3): 118-124.

Prasad, A. et al. 2010. Modeling the invasive emerald ash borer risk of spread using a spatially explicit cellular model. *Landscape Ecology*. 25: 353-369.

Rabaglia, R. et al. 2008. *Early detection and rapid response for non-native bark and Ambrosia beetles.* USDA Forest Service.

Raupp, M. et al. 2006. Street tree diversity in Eastern North America and its potential for tree loss to exotic borers. *Arboriculture & Urban Forestry*. 32(6): 297-304.

Sharov, A. et al. 2002. Slow the spread: A national program to contain the gypsy moth. *Journal of Forestry*. 100: 30-35.

Shatz et al. 2013. Characterizing the potential distribution of the invasive Asian longhorned beetle (*Anoplophora glabripennis*) in Worcester County, Massachusetts. *Applied Geography*. 45:259–268.

Wang, X. et al. 2010. The biology and ecology of the emerald ash borer, *Agrilus planipennis*, in China. *Journal of Insect Science.* 10(128): 1-23.

Whitmore, M., & Fierke, M. 2011. Emerald ash borer in New York: 2010 update. *The New York Forest Owner*. 14-16.

Whitmore, M., & Smallidge, P. 2011. Woodlot management and the emerald ash borer. *The New York Forest Owner.* 14-16.

Williamson, B. et al. 2011. *Emerald Ash Borer Management Response Plan.* New York State Department of Environmental Conservation. http://www.dec.ny.gov/docs/lands_forests_pdf/eabresponseplan.pdf. (last accessed December 9, 2014).