Monitoring Hemlock Woolly Adelgid and Assessing its Impacts in the Delaware River Basin

David W. Williams,[1] Michael E. Montgomery,[2] and Kathleen S. Shields [2]

[1] USDA Forest Service, Northeastern Research Station
11 Campus Blvd, Suite 200, Newtown Square, PA 19073

[2] USDA Forest Service, Northeast Center for Forest Health Research
51 Mill Pond Road, Hamden, CT 06514

Abstract

The Collaborative Environmental Monitoring and Research Initiative (CEMRI) was established recently to test strategies for multi-agency collaboration in environmental monitoring (Murdoch and Jenkins 2002). Participating agencies include the U.S. Geological Survey (USGS), USDA Forest Service, National Park Service, National Aeronautics and Space Administration, and U.S. Environmental Protection Agency. CEMRI's objective is to test potential collaborative strategies among the agencies that can be applied throughout the United States. The scientific rationale for this initiative is the realization that, to be effective, ecosystem management, environmental assessment, and environmental health monitoring must take into account the mosaic of complex relationships among air, land, water, living resources, and human activities. The often narrowly targeted monitoring programs of individual agencies are poorly suited to capture and understand such complex relationships. By coordinating existing monitoring efforts under CEMRI, the programs of individual agencies can continue to satisfy their specific agency missions while also contributing to a national multiscale, multiresource tracking system and do so in a relatively economical fashion. The Delaware River Basin was chosen as the pilot region for testing the concepts embodied in CEMRI.

Keywords:

Hemlock woolly adelgid, CEMRI, environmental monitoring.

Introduction

The conceptual framework for CEMRI encompasses three broad categories of spatial and temporal monitoring (Murdoch and Jenkins 2002). The first category, called Tier 1, involves frequent monitoring and detailed research on processes, trends, and causal relationships at relatively few intensively monitored sites within relatively small areas. The second category, Tier 2, involves infrequent and multipoint monitoring on the ground, as exemplified by annual surveys carried out by the Forest Service's Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) units. The third category, Tier 3, involves temporally and spatially continuous monitoring and analysis, as exemplified by satellite remote sensing. Activities among the three tiers complement each other, enhancing the overall monitoring effort.

Among the five component projects of the CEMRI pilot test in the Delaware River Basin is the "Identification and Monitoring of Forests Vulnerable to Non-native Invasive Pest Species." The project has three primary objectives:

1. To develop and evaluate monitoring protocols for selected pests that can be implemented cost-effectively as part of extensive monitoring programs;
2. To test a collaborative monitoring strategy to track pest movement; and
3. To develop maps depicting forested areas most vulnerable to specific pests.

Here we address plans for meeting these objectives with respect to hemlock woolly adelgid (*Adelges tsugae* Annand), one of three target invasive insect species in the Delaware River Basin. This region is particularly interesting because it is in the process of being invaded by hemlock woolly adelgid (HWA). The adelgid was first found in the lower Delaware River Basin in the 1970s, but has not yet been observed at its upper extreme in the upper Neversink River watershed. In the context of HWA, a secondary goal of the third objective is to use vulnerability maps to project changes in stream water quality following the loss of hemlock cover.

The monitoring program for HWA is currently cooperative among state agencies and the USDA Forest Service, and also includes the National Park Service. The State of Pennsylvania, the Forest Service, and the National Park Service maintain many small permanent plots to monitor the health of hemlock trees over time. These plots represent Tier 1 of the CEMRI framework. Sampling at the permanent plots occurs in two stages. First, the overall health of an infested tree is evaluated using the Forest Service FHM crown rating system. Second, counts are made on marked branches to estimate numbers of terminals that are infested by the adelgid and those that produce new growth. Over time the monitoring program gives a picture of the effects of HWA on its host. Information from this cooperative program and our own studies will help to achieve Objective 1, the development and evaluation of monitoring protocols.

Throughout the Delaware River Basin, the larger scope of our Objective 2 is to monitor the range changes of HWA as it expands relentlessly to the north and west. In addition to our own surveys, we will make use of annual surveys by the Forest Service FIA and state agencies. FIA will incorporate counts of the presence of HWA on hemlocks in their plot inventory protocols. Given the extensive nature of the plot system, we should get a good picture of invasion of new areas annually. Similarly, we will incorporate information from state agencies, including the Pennsylvania Department of Conservation and Natural Resources and the New York Department of Environmental Conservation. Spatially extensive surveys such as these represent Tier 2 of the CEMRI framework.

The use of remotely sensed data from Landsat Thematic Mapper (TM) images to estimate defoliation caused by the adelgid is currently under development (Royle and Lathrop 1997; Bonneau et al. 1999). Such images will be employed to develop a history of damage resulting from HWA infestation for the Delaware River Basin. Monitoring at this large spatial scale represents Tier 3 of the CEMRI framework. Leaf-off, cloud-free and snow-free images from 1984 (before adelgid infestation), 1998, and 2001 will be used to identify hemlock stands in 30 m pixels across the region.

By comparing hemlock stands in the later images with the 1984 image, we will be able to detect changes in the quantity and quality of hemlock cover resulting from attack by HWA. The final maps showing recent levels of hemlock damage will be used as vulnerability maps to satisfy our Objective 3. Data from the intensive and extensive plot surveys detailed in the previous section will be used as ground truthing in interpreting the maps from remotely sensed images.

In addition to producing a map of hemlock forests vulnerable to HWA, we want to understand better the various site factors that are associated with the presence of hemlock stands that may predispose a stand to damage and decline. Accordingly, we will analyze the relationships between stand presence and condition and various physiographic, climatic, edaphic, and biotic factors. If strong correlations are found, we hope to develop a model to predict stand presence and condition. However, a recent study has suggested that site factors may have little role in the vulnerability of forests to HWA (Orwig and Foster 2000). This is probably especially true under the current transient conditions of the adelgid invasion and may render the development of such a model difficult.

Replacing overstory species in a riparian habitat through selective mortality induced by an invasive herbivore can alter water quality in the stream below. In the Delaware River Basin, hemlock stands are known to help maintain relatively cool stream temperatures, and water temperature determines the composition of stream communities of macroinvertebrates and fish (Evans et al. 1996). As hemlock stands are killed by HWA and replaced by stands of deciduous hardwoods, stream communities will be altered permanently.

The map of hemlock forest vulnerability described above may be used to develop a map of water quality changes resulting from HWA activity. As a first step, we will superimpose the map of hemlock stands on the National Hydrologic Dataset GIS stream coverage for the Delaware River Basin provided by the USGS. Then, using available information from the surveys and intensive study plots on the relationship between hemlock health and downstream water quality, we will generate a map of streams that are vulnerable to water quality changes resulting from adelgid outbreaks. Development of such a product will help to meet one of the prime goals of CEMRI—to bridge the gap in monitoring efforts among federal agencies responsible for environmental monitoring.

Acknowledgment

We thank Kevin McCullough, Andrew Lister, Denise Royle, and David Pachan, and appreciate the support of the USDA Forest Service, Forest Health Monitoring Program.

References

Bonneau, L.R., K.S. Shields, and D.L. Civco. 1999. Using satellite images to classify and analyze the health of hemlock forests infested by the hemlock woolly adelgid. *Biological Invasions* 1: 255-267.

Evans, R.A., E. Johnson, J. Shreiner, A. Ambler, J. Battles, N. Cleavitt, T. Fahey, J. Sciascia, and E. Pehek. 1996. Potential impacts of hemlock woolly adelgid (*Adelges tsugae*) on eastern hemlock (*Tsuga canadensis*) ecosystems, pp. 42-57. In Salom, S.M., T.C. Tignor, and R.C. Reardon, (eds.). *Proceedings of the First Hemlock Woolly Adelgid Review*, Charlottesville, Virginia, 12 October 1995. U.S. Department of Agriculture, Forest Service, Morgantown, WV.

Murdoch, P.S. and J.C. Jenkins, (eds.) 2002. The Delaware River Basin Collaborative Environmental Monitoring and Research Initiative: Pre-integration Assessment. Unpublished manuscript, USDA Forest Service.

Orwig, D.A. and D.R. Foster. 2000. Stand, landscape, and ecosystem analyses of hemlock woolly adelgid outbreaks in southern New England: An overview, pp. 123-125. In McManus, K.A., K.S. Shields, and D.R. Souto, (eds.). *Proceedings: Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America*, U.S. Department of Agriculture, Forest Service, Newtown Square, PA.

Royle, D.D. and R.G. Lathrop. 1997. Monitoring hemlock forest health in New Jersey using Landsat TM data and change detection techniques. *Forest Science* 43: 327-335.