An Ecological Perspective on HWA Resistance & Predation

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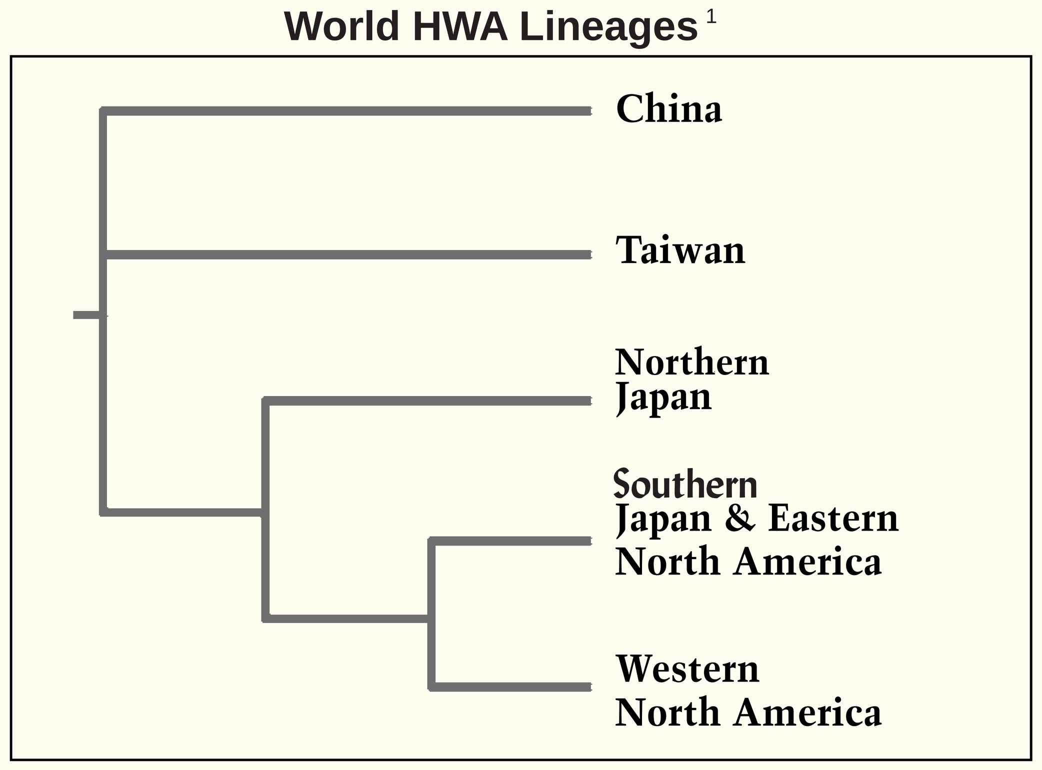
Introduction to Hemlock and HWA Ecosystems

Recent DNA analysis by Nathan Havill and associates[1] of samples of *Adelges tsugae* (Hemlock Woolly Adelgid/HWA) has transformed our understanding of HWA and its biogeographic relationships with hemlocks of the world. Rather than a single global organism, HWA involves a set of five genetically distinct organisms, each existing within geographically defined ecosystems. Such ecosystems involve sets of biologically distinct Adelgids, Hemlocks and HWA Predators which are interrelated within a particular geographical and climate area.

The figure below present's Havil's lineage map derived from mitochondrial DNA analysis for all known HWA populations. While China and Taiwan each have single native HWA lineages, Japan has two distinct lineages, and the lineage found in Southern Japan is identical to the HWA introduced to the Eastern US. Finally, the HWA in North America's Pacific NW is a long-term (native or endemic) resident lineage, rather than a recent "import" from Asia.

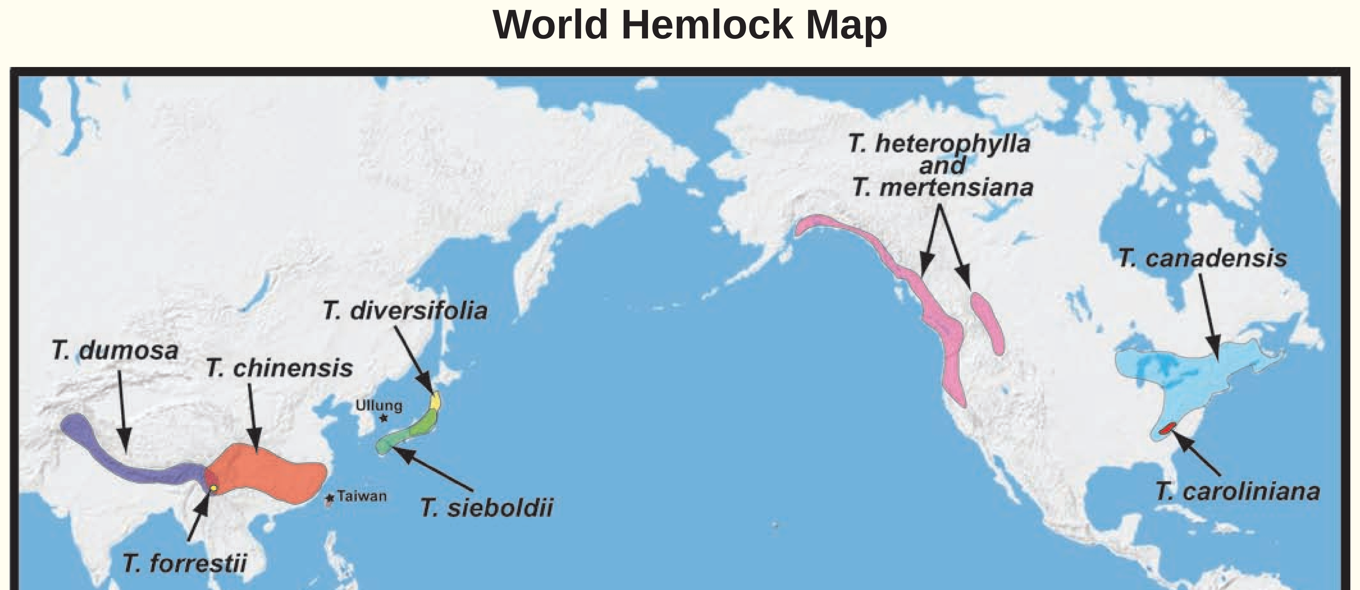
World HWA Lineages [1]



Similarly, the map below shows that world hemlock species are widely distributed across the northern hemisphere, with each species occupying a distinct biogeographic and ecological area. These findings suggest the use of an ecological perspective to focus on the interrelationships between biologically distinct sets of HWA, hemlocks and predators within distinct geographical and climate areas. Hemlock/HWA ecosystems will likely involve many relationships, but those involving biological resistance or susceptibility to HWA and HWA control by predators are of special interest.

And the recognition that such relationships are embedded in six different ecosystems suggests a different approach for assessing HWA biocontrol strategies for the Eastern US.

World Hemlock Map



Ecosystems and Hemlock Resistance to HWA

Two of the four Asian hemlocks are known to have high resistance to the HWA lineage that has been introduced to the eastern US. Research shows that *Tsuga chinensis* from China and *Tsuga diversifolia* from northern Japan have low susceptibility to this HWA from Southern Japan. But each of these hemlocks is susceptible to the native HWA organisms that they encounter in their home ecosystems.

In their native hemlock/HWA ecosystems, both *T chinensis* and *T diversifolia* have been observed to support significant numbers of their native HWA, as well as predators for those HWA. So resistance is not the dominant force governing hemlock survival in these ecosystems!

Settled Chinese HWA feeding on T chinensis

Western Hemlock, T heterophylla

In contrast, the Western HWA/Hemlock ecosystem does exhibit significant biological resistance relationships between the native hemlock *Tsuga heterophylla* and the native Pacific HWA lineage. Wild hemlocks in the PNW rarely host HWA infestations and therefore do not depend on HWA predators, which require HWA to feed and survive. And this high biological resistance to the Pacific HWA has been found to extend to both native hemlock species of the eastern US: *Tsuga canadensis & Tsuga caroliniana*.

What about our HWA "import" in the eastern US? The most relevant reference ecosystem for our HWA control efforts is the one at its origin in Southern Japan. Recent research[2] shows that the Southern Japanese hemlock, *Tsuga seiboldii* has about the same susceptibility to this HWA as our native hemlocks, *T canadensis* and *T caroliniana* and all three hemlocks show much more susceptibility than *T chinensis*.

This hemlock susceptibility to HWA in the Southern Japanese ecosystem suggests the importance of biological control agents in the coexistence of HWA and the Southern Japanese Hemlock (*T seiboldii*). And the parallels of low hemlock resistance to the same HWA organism in Southern Japan and Eastern US ecosystems, suggest that HWA predators that protect hemlocks in Japan may be capable of replicating this protective relationship in the Eastern US.

References:

1. Havill, Nathan & Michael Montgomery, "Role of Arboreta in Studying … http://arnoldia.arboretum.harvard.edu/pdf/articles/1897.pdf
2. Bentz, SE, Michael Montgomery & Richard Olsen 2008 "Resistance of Hemlock Species and Hybrids to Hemlock Woolly Adelgid" 2008 HWA Symposium
3. Cheah, Carole 2011 "Chapter 4: Sasajiscymnus tsugae, A Ladybeetle from Japan" in USDA Implementation and Status of Biological Control of HWA
4. Cheah, Carole 2008 "The Case for Sasajiscymnus tsugae" 2008 HWA Symposium

Ecosystems, HWA Predation and Hemlock Restoration

Predation and resistance are two examples of natural biological relationships that can operate within Hemlock/HWA ecosystems to facilitate coexistence of hemlocks with the Hemlock Woolly Adelgid. But like HWA and hemlocks, these relationships are not uniform across different ecosystems. And this requires a more careful, ecosystem-specific research agenda than is currently prevalent.

Likewise, inferences from one ecosystem to another require careful consideration of the system of relationships in which the components are embedded. For example, efforts to promote Eastern US releases of the Pacific predator beetle *Laricobius nigrinus* ignore the fact that these predators do not protect wild hemlocks from the Pacific HWA, but are only found feeding on HWA where hemlocks' natural HWA resistance has been overcome by external stresses (often in human occupied areas).

In contrast, the hemlocks of Southern Japan have low resistance to their native HWA and so depend on HWA predators for their survival and good health in coexistence with HWA. And Havil's discovery of the Southern Japan origin of the HWA attacking hemlocks in the Eastern US postdates the discovery of an HWA predator beetle from Southern Japan by over 15 years. This 1991 "predator quest" produced the first HWA predator that was USDA-approved for release in the eastern US – *Sasajiscymnus tsugae*[3].

Sasajicymnus tsugae feeding on HWA

St Larva →
← St Adult

Photo Credit: Carole Cheah, CAES

Laboratory and field studies have shown that *Sasajiscymnus tsugae* beetle populations can survive and spread in eastern US climates while feeding on its native HWA food source from southern Japan. Another important "test" for this cross-ecosystem predator transfer from Southern Japan is the ability of *Sasajiscymnus tsugae* (aka St or Sasi) to provide the same HWA protection for native hemlocks (*T canadensis* & *T caroliniana*) in the US that it does for *T seiboldii* and American hemlocks in Japan. Researchers at CAES have analyzed hemlock foliage density changes to measure the significant impacts of St predator beetle releases in CT[4].

St contributes to hemlock recovery both by reducing the damage to existing foliage and by ending the suppression of new growth production. The results of this HWA predation may first be visible as new foliage growth at the crowns of hemlocks. But continuing St predation produces stabilization of existing hemlock foliage and increasing new growth production, culminating in growth bursts on previously denuded hemlocks, as illustrated below.