INITIAL RESULTS IN MEASURING HEMLOCK WOOLLY ADELGID POPULATIONS IN TREES AND FORESTS

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Abstract

An invasive exotic insect, the hemlock woolly adelgid (HWA) (*Adelges tsugae*) has caused widespread mortality of eastern hemlock trees (*Tsuga canadensis*) and threatens to extirpate the species from North American forests (McClure et al. 2001, Orwig et al. 2002). HWA-induced mortality is a concern because hemlocks provide important forest structure, habitat, economic benefits, and aesthetic values (Beatty 1984, Kelty 1989, DeGraaf et al. 1992 p. 92, Snyder et al. 2002). Neither HWA population densities nor their distribution in forests is well understood, hampering the ability of forest managers to respond to the pest. No published studies have described the distribution of HWA in tree crowns or within forest stands (Gray et al. 1998, McClure and Cheah 1999, Adams et al. 2002, Casagrande et al. 2002, Mayer et al. 2002). In addition, standard monitoring methods have inestimable bias and provide limited results. Lacking better information, land managers often have to assume that HWA is evenly distributed and saturates the environment.

The goal of this research is to create better monitoring methods and estimates of HWA densities that can help forest managers mitigate the pest's negative impacts. The first step is the development of a sampling system appropriate to the biology of HWA. The second phase is a survey of HWA densities in a New England forest. Early results from sampling suggest that there is little pattern to HWA's distribution within individual trees, upper and lower portions of the crown are infested at similar densities. However, there are differences between HWA populations on trees in neighboring forest stands. While, final results of the study are not yet available, other research may benefit from the methodology and initial trends documented here.

Methods

My hypothesis is that HWA populations per needle differ between stands within a forest, but not at the scale of individual trees. I suggest that HWA populations do not vary systematically within tree crowns or between trees within the same stand. However, HWA populations do differ across a forest at the scale of several hundred meters. To test my hypotheses, this research compares estimates of HWA populations in different parts of hemlock crowns, between trees, and between stands by sampling HWA in naturally infested forests. Sampling HWA is complicated by its small size, lack of pheromones, and tree crown habitat. I have modified the randomized branch sampling (RBS) methodology to estimate HWA per needle in hemlock crowns (Jessen 1955, Gregoire et al. 1995). RBS treats a tree as a series of paths from the ground to each terminal shoot. Under RBS the researcher randomly selects a path to a terminal shoot and the characteristics of interest, number of HWA and needles in this case, encountered along this path become part of the sample. The RBS path can be terminated at any branching node to allow sampling of entire branches. The path is created by a series of random selections at each node. In other words, at each fork in the branch the researcher randomly chooses which branch to follow. The researcher can adjust the probability of selecting a branch to increase the likelihood of sampling more of the quantity of interest, so long as the probabilities at any particular fork sum to one. No design bias is introduced if the selection remains probabilistic. The inverse of the product of the unconditional selection probabilities for a sample is used to inflate the sample to an estimate for the whole tree. RBS provides an operationally efficient mechanism for unbiased estimation of both the mean and variance of the quantity sampled (Gregoire et al. 1995).

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I have altered my sampling scheme to include the simple random selection of the first node to more efficiently deal with the branching pattern of hemlock, while retaining an unbiased design. After felling the sample tree, I divide the crown into thirds and take at least three samples from each third. My preliminary sample of 16 trees from four stands suggests that there is little difference between crown thirds, nor does there appear to be a difference in the number of HWA per needle between trees in the same stand. All four stands are hemlock / hardwood mixtures about 80 to 100 years of age on the Yale Myers forest in Union, CT, within 2 km of each other. Initially counts included only HWA eggsacks. Now counts also include the most recent generation of HWA (sistens) on new growth as a more time sensitive measure of HWA density. Table 1 below shows the number of HWA eggsacks and HWA sistens per 100 needles at specified height ranges above the ground.

Table 1.—HWA eggsacks and sistens per 100 needles at specified heights above the ground.

Height above	HWA eggsacks per 100 needles			HWA sistens per 100 needles		
the ground	Median	Mean	Maximum	Median	Mean	Maximum
5m – 9.9m	0.0	2.5	14.1	53.2	53.4	146.0
10m – 14.9m	0.0	4.5	31.2	44.9	43.8	150.0
15m – 19.9m	0.3	4.6	31.7	1.6	10.9	79.2
> 20m	0.6	9.4	43.9	20.5	28.1	78.1

Further sampling will allow for a Tukey-Kramer test for differences between the HWA densities in crown strata. Similarly more sampling is required to test for differences in HWA densities between stands. Preliminary sampling suggests that stands 2 and 4 are different from stand 3 and perhaps stand 1, as shown in Table 2 below.

Table 2.—HWA eggsacks per 100 needles in four different stands.

Stand	Median	Mean	Maximum
1	0.4	3.0	23.2
2	0.0	0.4	10.4
3	12.0	13.3	43.9
4	0.0	0.5	7.7

Comparison of the HWA populations in different stands in the forest requires a method for unbiased selection of the trees sampled. Since the randomize branch sampling employed in this study is a destructive sampling scheme, I have selected trees based in part on the possibility of safely felling them. In order to remove the constraint of sampling only easy-to-fell trees, sampling for stand differences will take advantage of commercial timber harvests at the Yale Myers Forest. Randomly selected trees will be pre-marked, safely machine felled, and then sampled for HWA. A random sample of trees from different stands will allow unbiased estimates of HWA per needle in each stand.

Conclusions

Early results show that randomized branch sampling is an effective way to sample for HWA and that HWA densities may vary more from stand to stand than within a tree or between neighboring trees. If continued research confirms these results it will suggest that differences in stand conditions have an effect on HWA populations, which may have implications for hemlock survival.

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