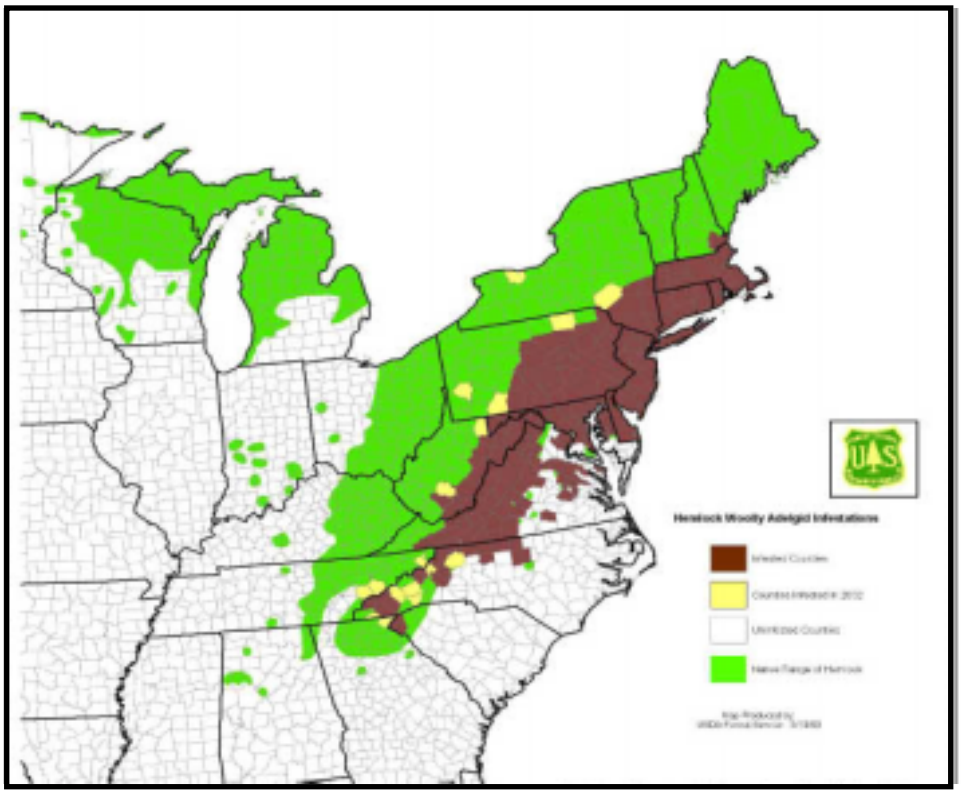
2002-2003 Winter Mortality of Hemlock Woolly Adelgid in the Northeastern U.S.

Kathleen S. Shields[1] and Carole A. S-J. Cheah[2]
[1]USDA Forest Service, Northeastern Center for Forest Health Research, Hamden, CT;
E-mail: kshields@fs.fed.us, Phone: (203) 230-4320
[2]The Connecticut Agricultural Experiment Station, Valley Laboratory, Windsor, CT;
E-mail: ccheah@fs.fed.us, Phone: (203) 230-4305

Introduction

The hemlock woolly adelgid (HWA), *Adelges tsugae* Annand, is a non-native pest responsible for extensive mortality and decline of hemlock trees in the eastern United States. Its range currently includes counties in 15 states from the Smoky Mountains to southern New Hampshire (Fig. 1). Cold winter temperatures may be a factor in reducing field populations of this insect and limiting its spread. We assessed the mortality of selected HWA populations in the northeastern U.S. after the winter of 2002-2003, the coldest winter in nine years (National Weather Service).

Figure 1. Hemlock Woolly Adelgid Infestations 2002



Methods

Between 9 March and 24 April 2003, one or two branch tips (30-40 cm long) were cut from 10 HWA-infested eastern hemlocks, *Tsuga canadensis* (L.) Carrière, at each of 36 sites in NH, MA, CT, NY, PA, and NC. All trees had new growth, no history of fertilization or insecticide treatment, and light to moderate HWA infestations. Samples were examined within 2-5 days of collection. The length of new growth and the number of living and dead HWA sistens that were 2nd, 3rd, or 4th stage nymphs or adults were counted. First instar nymphs also were counted but not included in the assessment of winter mortality. Mortality assessments were made by carefully probing each woolly mass and adelgid found on the new growth of branch tips. Where possible, at least 100 HWA sistens, nymphal stage 2 or older, were examined from each of the 10 trees at each site, totaling at least 1,000 HWA per site. Latitude, longitude, and elevation were recorded at each site. Highest and lowest daily temperatures for the period November 2002 through March 2003 were obtained from the National Climate Data Center for the weather station closest to each site. Data were analyzed using the Spearman rank correlation test. Values of $P<0.05$ were considered significant.

Table 1. Site information and mean percent mortality of HWA sistens, 2nd instar or older.

Collection Site	Hardiness Zone	Lat.	Long.	Elev. (m)	Mean low temp. (°C)	Min. temp. (°C)	Total HWA > N1	Percent mortality ± std
#1 NH, Portsmouth-1	5B	43*02'	70*46'	8.0	-7.0	-24.5	1107	99.4 ± 1.04
#2 NH, Portsmouth-2	5B	43*02'	70*45'	5.0	-7.0	-24.5	890	90.4 ± 10.00
#3 MA, Mt. Tom (lower)	5B	42*16'	72*36'	66.8	-8.3	-27.2	1251	83.2 ± 8.01
#4 MA, Mt. Tom (upper)	5B	42*14'	72*38'	185.9	-8.3	-27.2	1269	76.1 ± 13.00
#5 CT, Hartland-1	5B	42*01'	72*55'	191.0	-7.6	-25.0	1023	84.3 ± 8.73
#6 CT, Union,	5B	42*01'	72*07'	273.0	-8.2	-23.4	1682	74.8 ± 11.39
#7 CT, Hartland-2	5B	42*00'	72*53'	329.3	-7.6	-25.0	1102	89.9 ± 6.49
#8 CT, Norfolk	5B	41*58'	73*13'	396.0	-7.6	-25.0	1204	92.1 ± 4.74
#9 CT, Stafford	5B	41*57'	72*24'	234.8	-8.2	-23.4	1073	96.1 ± 2.79
#10 CT, Granby	5B	41*57'	72*52'	260.0	-7.6	-25.0	1196	96.0 ± 3.00
#11 CT, Barkhamsted	5B	41*55'	72*59'	244.0	-7.6	-25.0	1506	87.7 ± 5.54
#12, CT, New Hartford	5B	41*52'	73*02'	253.1	-7.6	-25.0	1012	84.9 ± 11.60
#13 CT, Eastford	5B	41*51'	72*05'	137.0	-8.2	-23.4	1463	81.4 ± 11.52
#14 CT, Pomfret	5B	41*51'	71*58'	122.0	-8.2	-23.4	1895	76.7 ± 11.52
#15 CT, Andover	6A	41*45'	72*21'	161.6	-8.2	-23.4	971	81.1 ± 7.08
#16 CT, Watertown	5B	41*39'	73*05'	124.0	-7.6	-25.0	1358	91.1 ± 4.51
#17 CT, Voluntown	6A	41*35'	71*48'	94.0	-2.6	-20.0	1488	95.6 ± 3.67
#18 CT, E. Hampton	6A	41*33'	72*26'	25.3	-2.6	-20.0	1388	86.7 ± 10.54
#19 CT, E. Haddam	6A	41*28'	72*20'	56.8	-2.6	-20.0	1680	91.7± 7.83
#20 CT, Ledyard	6A	41*27'	71*56'	58.8	-2.6	-20.0	1097	93.3 ± 6.42
#21 CT, Southbury	6A	41*25'	73*12'	61.0	-4.7	-18.9	1496	85.1 ± 5.05
#22 CT, Hamden-1	6B	41*25'	72*53'	53.2	-5.3	-20.6	1079	72.0 ± 13.99
#23 CT, Hamden-2	6B	41*21'	72*55'	12.3	-5.3	-20.6	1161	65.7 ± 14.51
#24 CT, Madison	6B	41*21'	72*36'	68.3	-5.3	-20.6	1082	97.2 ± 2.94
#25 CT, Killingworth	6B	41*21'	72*35'	36.3	-5.3	-20.6	1560	88.9 ± 10.46
#26 CT, Stamford	6B	41*08'	73*37'	132.0	-4.7	-18.9	1232	59.1 ± 5.38
#27 NY, Rhinebeck-1	5B	41*57'	73*51'	122.0	-11.8	-25.6	931	92.3 ± 7.28
#28 NY, Rhinebeck-2	5B	41*53'	73*54	84.0	-11.8	-25.6	606	89.7 ± 7.69
#29 NY, Esopus	5B	41*51'	74*00'	81.0	-11.8	-25.6	417	91.5 ± 11.28
#30 PA, Milford,	5B	41*19'	74*49'	204.3	-7.1	-20.0	1319	65.2 ± 13.52
#31 PA, Childs Park	5B	41*13'	74*53'	217.1	-7.1	-20.0	1262	63.4 ± 8.05
#32 PA, Breininger Gap	6A	40*48'	77*14'	328.1	-3.9	-16.7	1234	67.5 ± 7.17
#33 PA Hemlock Natural Area	6B	40*14'	77*38'	579.3	-3.9	-16.7	1286	90.4 ± 3.55
#34 PA, Three Square Hollow	6B	40*12'	77*33'	444.0	-3.9	-16.7	1027	83.7 ± 8.62
#35 PA, Bear Valley	6B	40*00'	77*48'	489.6	-3.4	-17.2	1123	72.5 ± 14.96
#36 NC, Highlands	6B	35*01'	83*13'	1170.7	-1.3	-18.3	886	11.2 ± 4.86

Results

In the northeastern U.S., HWA sistens aestivate during the summer months as 1st stage nymphs. Aestivating nymphs are flattened and dark in color (Fig. 2) and many do not survive the summer. In October, surviving nymphs begin feeding and resume development through four instars, generally maturing by February. First stage nymphs that have resumed feeding are convex and appear trihedral with waxy wool secretions along the dorsal and lateral margins (Fig. 3). Nymphal exuviae are usually found in close proximity to HWA that have molted (Fig. 4), although these may be dislodged during the winter.

Because samples were collected and evaluated in March and April, living HWA were adults or late stage nymphs. Living HWA generally had masses of waxy wool associated with them (Fig. 5) and sometimes exuded a drop of “honeydew” (Fig. 6), although many woolly masses contained advanced stages of dead adelgids. When teased from the wool, living HWA were plump, their integument exhibited turgor, and active wax-producing glands were apparent on the dorsum (Fig. 7). Living insects were slightly pink/purple in color, especially on the ventrum (Fig. 8). When pierced, their hemolymph was claret in color. Dead HWA were dull gray or black; early instars were dehydrated and brittle (Fig. 4), while late instars and adults lacked turgor and movement (Fig. 9). When pierced, they sometimes exuded either clear (water) or black/brown fluid (products of histolysis).

Figures 2-9, Living and dead HWA. (2) Aestivating 1st instars; (3) 1st instars that have fed; (4) Exuvia near dead nymph; (5) Woolly masses and dead nymphs; elongate scale also present; (6) Honeydew produced by living adult; (7) Living nymph; (8) Living adult; (9) Dead adult.

Table 1 shows site information and percent mortality of HWA sampled at each site. Mortality ranged from 11.2% at the NC site to 99.4% at a NH site (Fig. 10). Initial analysis indicates that mortality was positively correlated with degrees of latitude (r=0.422, P=0.010) (Fig. 11), even when the outlying NC site is excluded (r=.371, P=0.028). There were no significant correlations between percent mortality and plant hardiness zone, elevation, or mean low temperature, but there was a slight negative correlation between percent mortality and the minimum temperature recorded at each site (r=0.333, P-0.047) (Fig. 12).

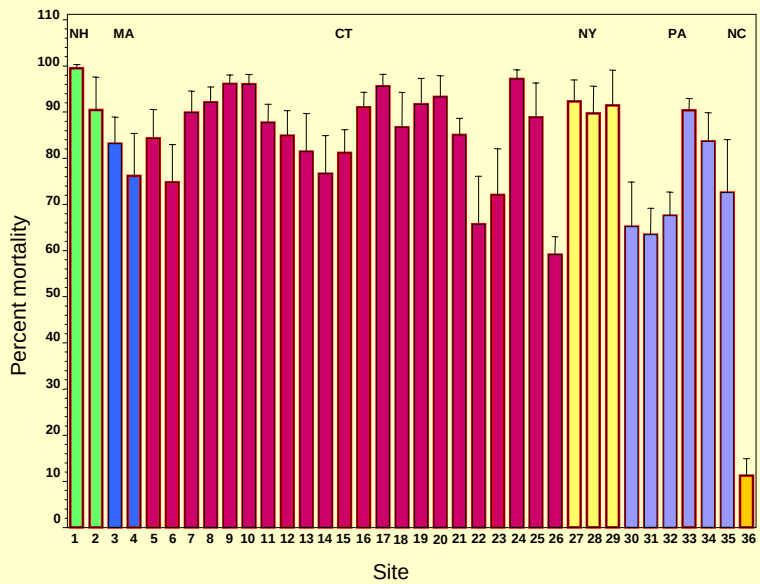


Figure 10. Percent mortality of HWA from each site.

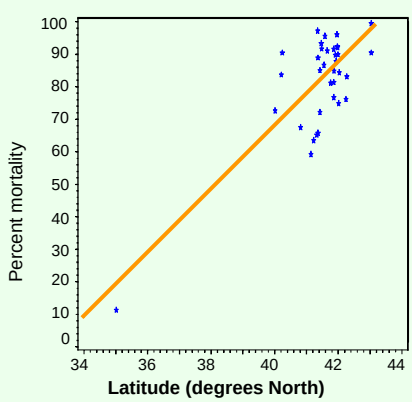


Figure 11. HWA mortality at latitudes sampled.

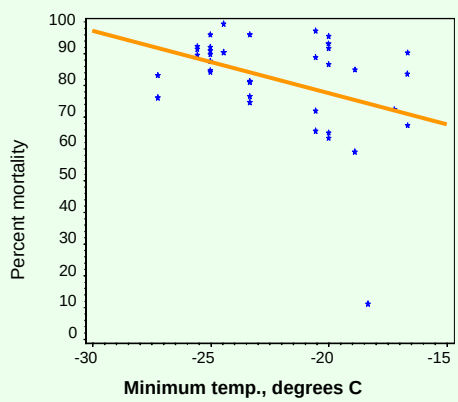


Figure 12. HWA mortality at minimum recorded temperature.

Acknowledgments

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