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HWA WINTER MORTALITY IN CONNECTICUT & IMPLICATIONS FOR MANAGEMENT AND CONTROL

The hemlock woolly adelgid, (HWA), *Adelges tsugae* Annand is a non-native, serious and extremely damaging pest from Japan which has plagued and decimated native North America eastern or Canadian hemlock, *Tsuga canadensis* Carriere, and Carolina hemlock, *Tsuga caroliniana* Engelmann. There has been rapid expansion in the eastern HWA range, particularly in the past 30 years since its first detection in central Virginia in the early 1950s. Hemlock woolly adelgid was first brought to the attention of the Connecticut Agricultural Experiment Station, New Haven in 1985. Hemlock mortality rapidly followed the spread of HWA infestations in southern Connecticut when trees were stressed by drought and other pests during the next 15 years. The biology, impact and life cycle of HWA were closely studied in the late 1980s and early 1990s (McClure 1987, 1989, 1990, 1991). There are two annual generations of HWA on our hemlocks and the unique biology of the HWA sistens generation, which feeds during the fall and winter, together with its sessile habit which exposes the adelgid to weather extremes, makes this winter generation vulnerable to unpredictable winter conditions. This is significant to homeowners, arborists and forest managers alike, as the degree of HWA winter mortality influences the magnitude of the successive summer progrediens generation, and therefore the need and extent for subsequent management and control.

Statewide assessments of HWA winter mortality patterns in Connecticut have been conducted at the Valley Laboratory, Windsor since 2000 (Cheah 2006). Recently, 16 years of data have been analyzed, demonstrating vulnerabilities of HWA to extreme or unusual winters in Connecticut (Cheah 2016). For winter mortality assessments, 10 HWA-infested trees were sampled per site in early spring and >1000 HWA were counted to obtain the mean percentage HWA mortality. Daily minimum temperature records from the nearest official weather stations have supplied the temperature data for analyses. This Connecticut dataset has revealed patterns which enable accurate predictions of percent HWA surviving the winter (Cheah 2016). Magnitude of annual hemlock woolly adelgid winter mortality in Connecticut forests varies in the three official climatic divisions (Fig. 1) and is strongly influenced by the degree, duration and frequency of minimum daily subzero temperatures occurring from December through February, the meteorological definition of the winter season.

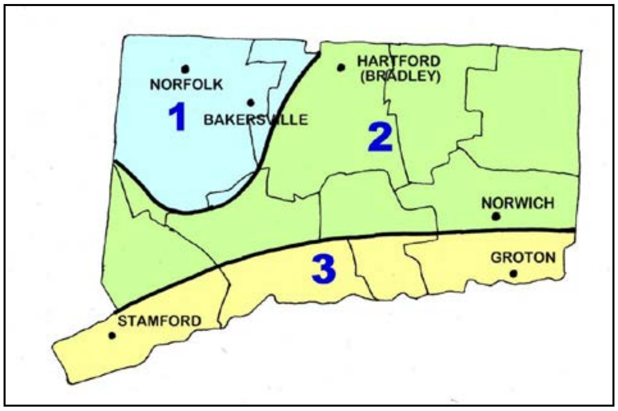
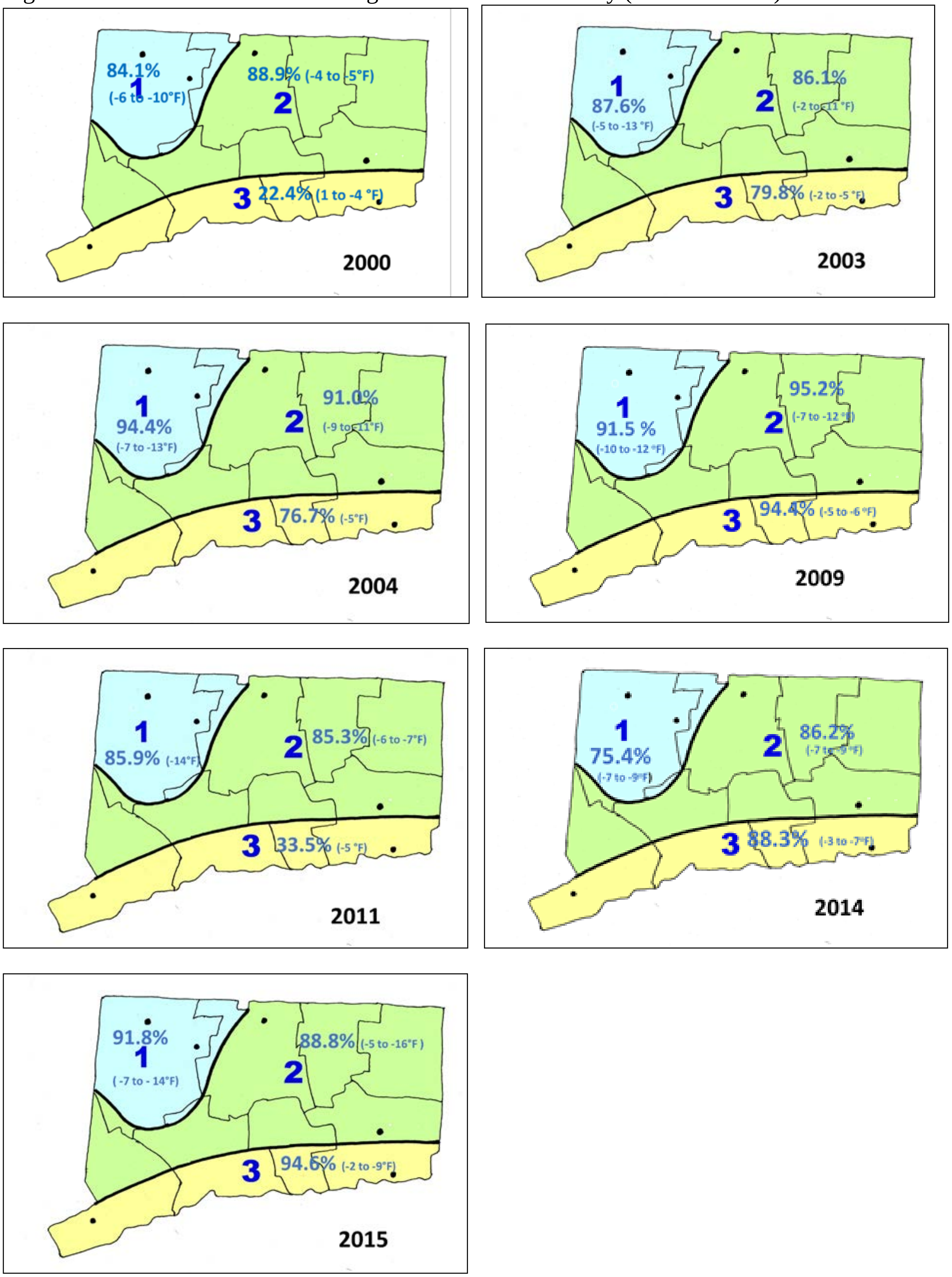


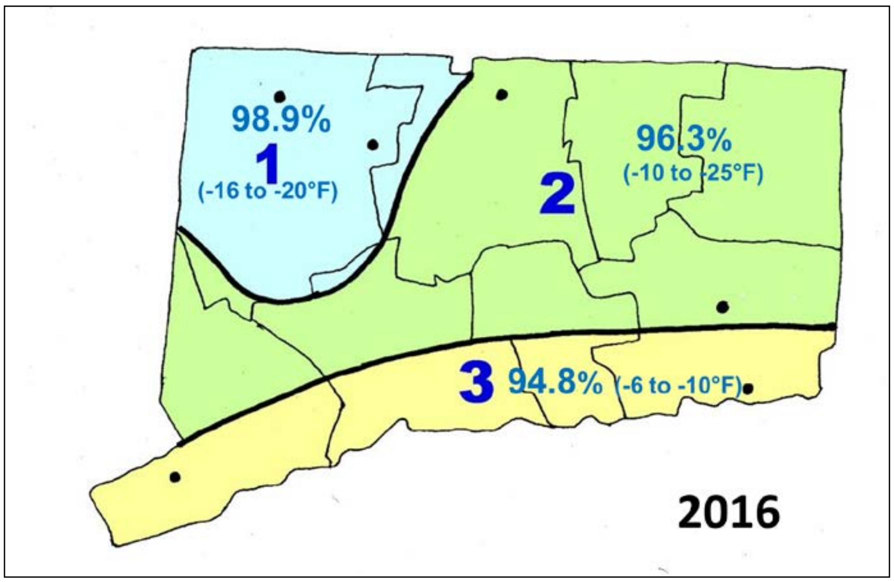
Figure 1. The three climatic divisions of Connecticut, adapted from Climatological Data of New England, National Oceanic and Atmospheric Administration (NOAA). Locations of some major weather stations are shown.

In general, the increasing trend for much warmer winters in the past 20 years has enabled the rapid northerly and westward spread of HWA into the Northeast and even southern Canada. But occasionally, a severe winter will result in significant reductions in HWA populations, and successive cold winters can contract HWA range and density. The climate of Connecticut is strongly influenced by its topography and distance from the modifying influence of Long Island Sound (Brumbach 1965). Although Connecticut is a small state, there are three recognized climatic divisions. The coldest and most snowy winters are generally experienced in the higher hills of Northwest Connecticut (Division 1). The central region (Division 2), with lower hills and the Connecticut River Valley can have more variable conditions in the same winter season and the coastal plain (Division 3) has the mildest winters due to its proximity to water. Climatic divisions in Connecticut are an important influence on the daily minimum winter temperatures experienced and hence, the subsequent winter kill of HWA. Recently, the increased frequency and penetration of polar vortex outbreaks in winter, extending far down into Connecticut in 2014, 2015 and 2016, have profoundly affected the survival of HWA, particularly in forested and natural landscapes which are not moderated by urban heatsinks. The following figure 2 shows the most extreme past winters which have resulted in significant winter mortality of HWA populations in sampled forests throughout Connecticut from 2000-2016.

Figure 2. Connecticut winters with high HWA winter mortality (most divisions) from 2000-2016.



In 2000, when this study was initiated, the cold snap did not extend into Division 3, resulting in high mortality of HWA in central and northern regions but with little or no effect on HWA survival along the coast. Recently, the winters of 2014 and especially 2015, were severe and resulted in heavy winter mortality of HWA in most of the state. But in 2016, HWA suffered its greatest winter mortality statewide since these assessments were initiated. Although the winter of 2016 was the warmest winter on record in 121 years in many northeastern states in terms of average winter temperatures (Northeast Regional Climate Center at Cornell University), a very brief but lethal two day mid-February cold snap occurred. Daily minimum temperatures plummeted to the lowest levels in many decades, even along the shore, resulting in the highest HWA winter mortalities recorded since 2000, substantially reducing subsequent progrediens HWA populations in late spring and early summer. The overall HWA winter mortality for Connecticut in 2016 was 97 ± 2.6% throughout the three climate divisions.



IMPLICATIONS FOR MANAGEMENT

The ability to project subsequent HWA infestation trends based on winter mortality assessments can help homeowners, arborists and landscape managers make prudent and economical decisions on the need and frequency of annual treatments such as the application of horticultural oil sprays to control overwintering populations of HWA. In general, minimal horticultural oil treatments are required after high winter mortality of HWA is recorded as infested branches can be easily pruned out or spot-treated when the summer progrediens generation are visible. Long-term systemic chemical control, which can be expensive and detrimental to the environment is also not recommended. Following severe winter reductions of HWA populations as in 2016, most hemlocks will have little to no HWA alive higher up in the tree crown and live HWA will tend to be on the lower limbs which may have been protected by snow cover in parts of the state where it occurred.

These Connecticut winter studies have also shown that snow cover can be very protective in enhancing HWA survival. In 2011, a winter of record-breaking snowfall, adelgid–infested limbs closer to the ground which were buried under snow, had much higher HWA survival than on exposed branches above snow. In 2016, the reverse happened and northwest Connecticut had the least snowfall in many winters while there were heavy snowstorms along the shore and in parts of northeast Connecticut. Thus, homeowners should take care not to cover infested hemlocks during snow ploughing and snow removal, which would increase adelgid survival. Infestations on hemlocks in warmer urban and suburban areas may also have higher winter survival, especially closer to buildings and could require more treatments than those in more open and natural landscapes.

Hemlocks may also appear to be infested in the spring as the sistens wool will remain for a while on the tree branches even though the adelgids have long since died (Figure 3).

Figure 3. Dead adelgids remain on hemlock foliage though killed during the winter.

Adelgids of any developing and feeding stage may be killed by winter extremes. Under the wool, dead adelgids are dessicated and shriveled, as compared with live HWA, but this is only apparent when viewed under a microscope (Figure 4). Adelgids which survive winter kill tend to develop larger egg masses and wool in the absence of competition, compared to surrounding winter-killed HWA (Figure 5).

Figure 4. Dead HWA (left) and live HWA (right).

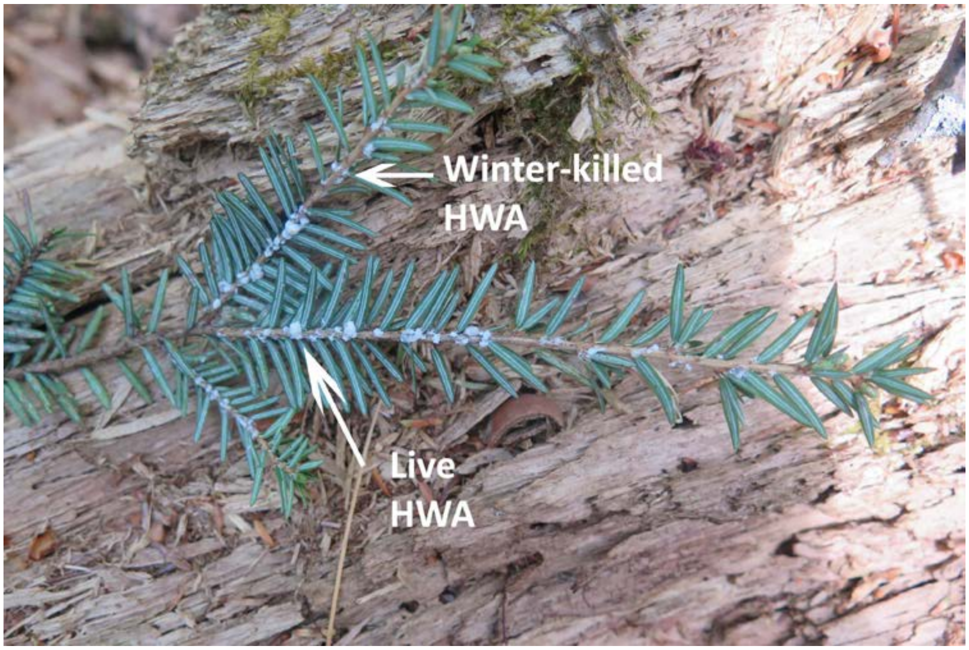


Figure 5. Difference in sizes between winter-killed and surviving HWA.

In 2016, many of the adelgids killed were late nymphal instars or small adults as the winter had been mild preceding the cold snap. The dataset from Connecticut winters shows that HWA can either be killed during sudden cold snaps or during prolonged extreme cold, as in 2015. The extent of the adelgid mortality will depend on the duration or degree of subzero cold when the daily minimum temperatures drop below 0°F. In contrast, the warmest winters with no subzero cold events occurred during 2002, 2010 and 2012 and correspondingly, winter mortalities of HWA were minimal. After mild winters, HWA management and control is highly necessary.

An option currently being explored is to implement augmentative biological control using the specialist ladybeetle *Sasajiscymnus tsugae* Sasaji and McClure (Figure 6) in small scale releases to target surviving HWA after heavy winter kill. This species was previously reared and released throughout Connecticut from 1995-2007 (Cheah 2010) but has not been recently augmented. It is the only species which can be reared commercially and is available to homeowners and other private property owners through a company in Pennsylvania, Tree Savers. This beetle has two generations and is well suited and adapted to Connecticut's hot humid summers (Cheah and McClure 1998, Cheah and McClure 2000, Cheah et al. 2005, McClure and Cheah 1999) and thrives on the progrediens HWA, continuing to feed throughout the summer on the subsequent dormant first instars of HWA. Re-introductions of *S. tsugae* could be an effective biological control strategy to further reduce and manage HWA after severe winters.

Figure 6. *Sasasjiscymnus tsugae:* adults feeding on all HWA stages, including dormant first instars during the summer

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