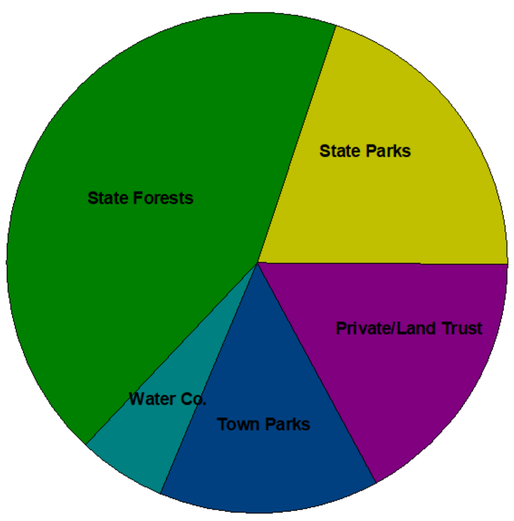
Biological Control of Hemlock Woolly Adelgid….

Dr. Carole Cheah
Valley Laboratory, Windsor

Updates on the status of 2 Connecticut biological control programs are presented.

- Hemlock woolly adelgid, *Adelges tsugae* (HWA), is a serious exotic forest and nursery pest of native hemlocks in eastern North America.
- Recent severe winters from 2014-2018 have greatly reduced populations of HWA in the Connecticut landscape. However, the winter of 2020 was the 6th warmest on record in Connecticut with negligible HWA winter mortality.
- Biological control of HWA has been Connecticut's major strategy of managing HWA and saving the hemlock forests.
- Long term data from release sites indicate the efficacy of this strategy.
- Since 1995, >178,000 of the tiny HWA predatory ladybeetle, *Sasajiscymnus* (=*Pseudoscymnus*) t*sugae*, native to southern Japan, have been reared and released in Connecticut's hemlock forests at 35 statewide sites. Currently, > 185,000 *S. tsugae* have been released throughout Connecticut since 1995.
- Recent new releases in 2017 and 2020 to combat the resurgence of HWA after milder winters were made possible through generous donations from Tree-Savers, the commercial producer in Pennsylvania, who have made this predator available to the public through purchase: https://tree-savers.com/

Sasajiscymnus tsugae CT release sites
1995-2018



Link to recent interview:
https://www.registercitizen.com/opinion/article/Robert-Miller-Lady-beetles-spell-doom-for-woolly-15368797.php

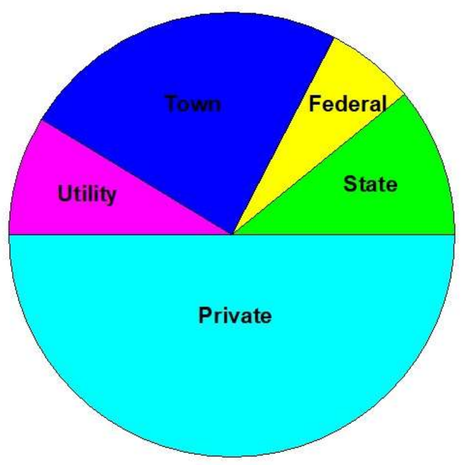
Link to recent video by Local Motives:
Hemlock Woolly Adelgid Web Series Story at: https://youtu.be/wnkhJ8BSP64

…..and Mile-a-Minute Weed

Releasing weevils on Calf Island with Kris Vagos, USFW Stewart B. McKinney NWR

Another threat to native vegetation diversity is the invasive non-native mile-a-minute weed, *Persicaria perfoliata* (MAM). This troublesome vine was first confirmed in Connecticut in 2000 but as of 2019, has spread to 59 towns in the state,. Through the national biological control program for MAM funded by USDA APHIS PPQ from 2009-2019, approx. 60,000 *Rhinoncomimus latipes*, a small weevil from China that specializes on MAM, have been released in 27 CT towns to counter the spread of MAM. This program was a collaboration with the University of Connecticut from 2009-2018. Weevils have survived Connecticut winters, adapted to challenging environmental conditions and are spreading widely in many areas to feed on MAM.

Type of *Rhinoncomimus latipes* sites in CT



HEMLOCK WOOLLY ADELGID, *Adelges tsugae*

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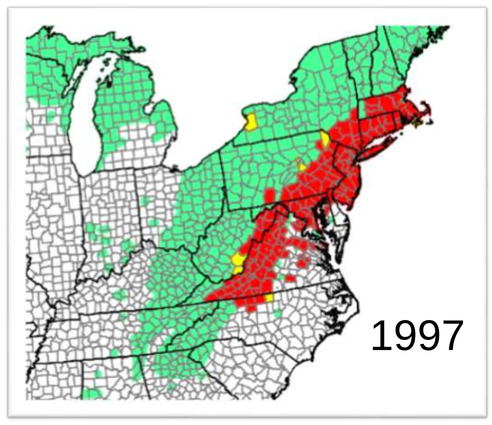
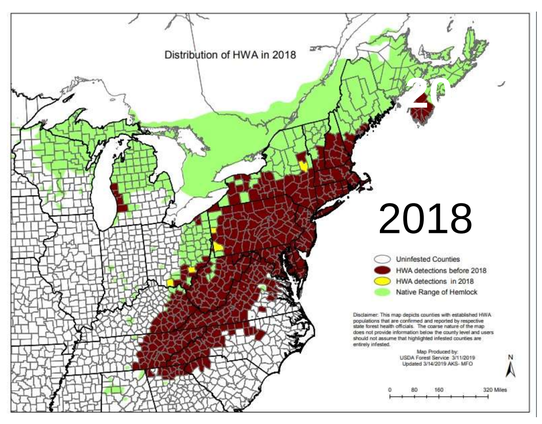
1997-2018 HWA Infestations in Eastern USA
USDA Forest Service





•HWA (Eastern USA) Origin: Southern Japan; accidental introduction to Virginia in early 1950s; also native to China & Nepal and the PNW; HWA was first reported in CT in 1985 and has been researched at the Valley Laboratory, CAES, since then. HWA only infests hemlocks (*Tsuga* spp).

•Susceptible native species: Eastern & Carolina hemlocks; 20 eastern states, from KY to ME, west to OH and MI, currently affected; also southern Ontario (2014), Nova Scotia, and the Adirondacks (2017).

•All HWA are females with 2 generations/year, capable of explosive population increase. Feeding drains the tree's storage reserves, causing tip dieback through needle drop and retardation of growth.

•Shade tolerant but drought sensitive hemlocks are fundamental to watershed protection, wildlife cover and are a popular landscape tree/hedge species. Stressed trees can die in several years: drought severely compromises hemlock health, especially on marginal sites. Riparian areas, trout streams, important wildlife, avian and amphibian cover & habitat, recreational areas and watershed stands, are threatened by eastern hemlock decline & loss

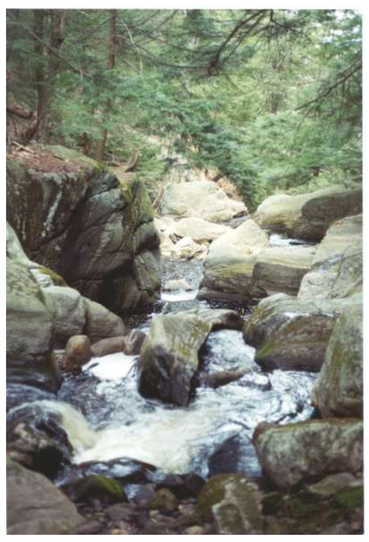
•Lack of effective natural enemies in the US prompted biological control explorations in Asia & Pacific NW by USDA Forest Service; several other predator species have been released in other states but *Sasajiscymnus tsugae* is the major and only predator released throughout Connecticut.

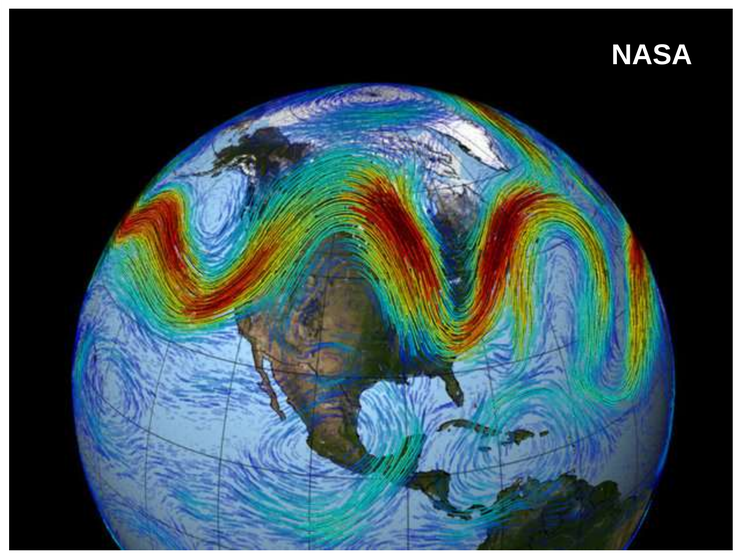
• Overall trends in warming winters have facilitated the expansion of HWA. However, with accelerated Arctic warming, instability in the jet stream has resulted in winter incursions of arctic air into the lower mid-latitudes (polar vortex events). Successive high winter kill of HWA in CT during these polar vortex events in 2014, 2015, 2016 and 2018 have greatly reduced HWA levels, enabling widespread hemlock recovery.

• But in a rapidly changing, unpredictable climate, CT also suffered an extreme drought in late 2015-2017, which precipitated native hemlock borer, *Melanophila fulvoguttata* (HB) outbreaks. Recent hemlock mortality and decline is not due to HWA but to extreme drought, HB and the rapid expansion of elongate hemlock scale, *Fiorinia externa* (EHS), which has higher survival than HWA during severe winters.

• Heavy and continuous rains in 2018, the 4th wettest year, and a wet spring 2019, facilitated rapid hemlock recovery in most of CT, even in marginal sites, demonstrating the remarkable resilience of this species.

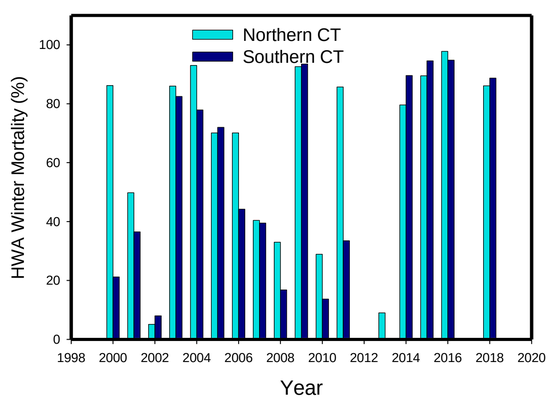
Habitats, wildlife and recreation at risk



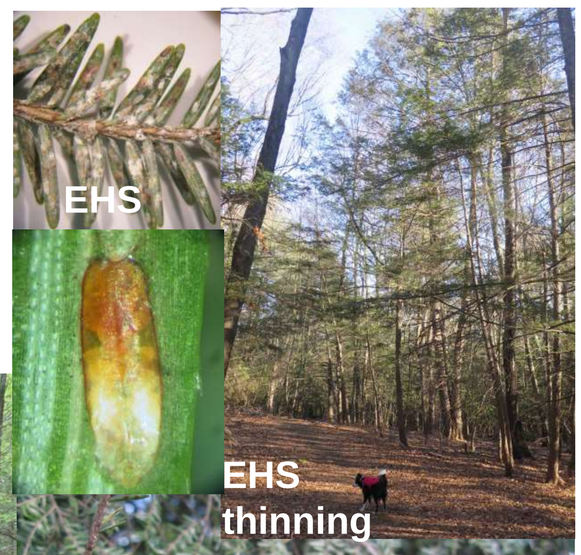


Alarming rates of Arctic ice melting as the planet warms to unprecedented levels, have led to open oceans absorbing more heat in a rapid feedback loop, leading to greater instability of the jet stream year round. Polar vortex events have become more frequent in winter accompanied by unpredictable patterns of extreme summer droughts, abnormally heavy rains and flooding.

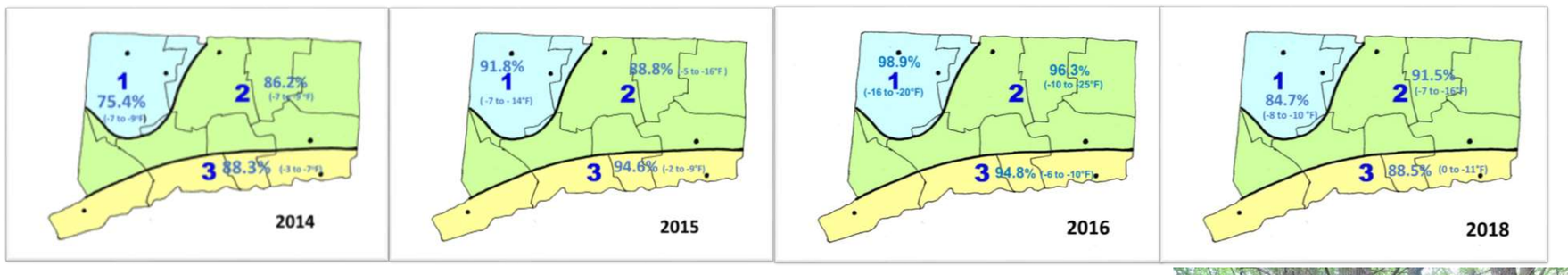
HWA Winter Mortality Trends in CT 2000-2018



Elongate hemlock scale (EHS) infestations have intensified and spread in recent years, leading to heavy needle drop and thinning hemlock crowns

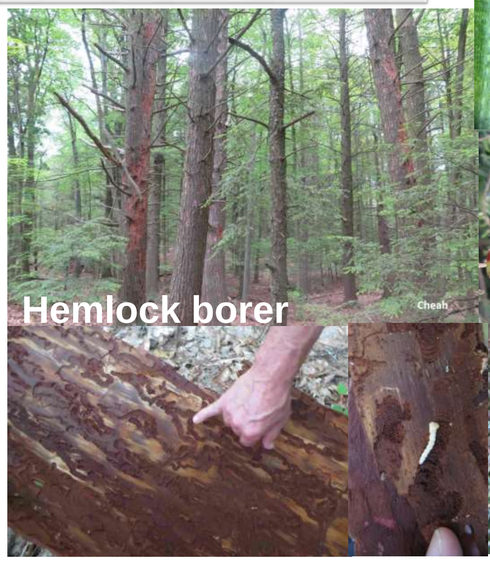


PATTERNS OF HWA WINTER MORTALITY BY CLIMATIC DIVISIONS



•Subzero winter temperatures (< 0 °F) result in high HWA winter mortality to different degrees in CT's 3 climate divisions. Coastal populations are more susceptible to winter extremes while northern HWA are more cold hardy. But in 2016, the warmest winter on average since 1895, a cold snap of only a few hours, due to an extreme polar vortex outbreak resulted in the highest mean HWA winter mortality (97%) in CT since 2000. Polar vortex outbreaks in CT have strongly reduced HWA and spread in 2014, 2015, 2016 & 2018. But a non-winter in 2020 = patchy resurgence of HWA especially in southern CT.

•Urban heat sinks, proximity to large bodies of water and snow cover can protect HWA. Isolated populations can rebound from winter survivors in the summer, or are re-introduced from other infested regions. To counter this resurgence, a collaborative program of augmentative biocontrol releases in 2020 is in progress.



Biological Control of HWA in CT 1995-2020
with *Sasajiscymnus* (=*Pseudoscymnus) tsugae*

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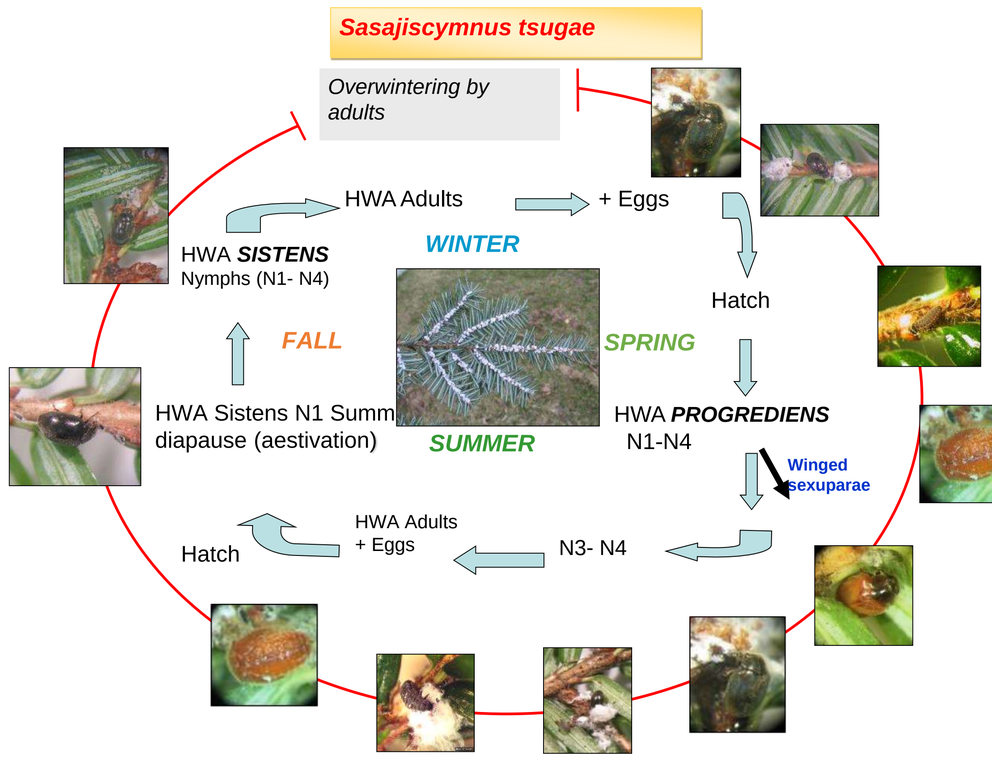
Synchrony of life cycles between HWA and *S. tsugae*

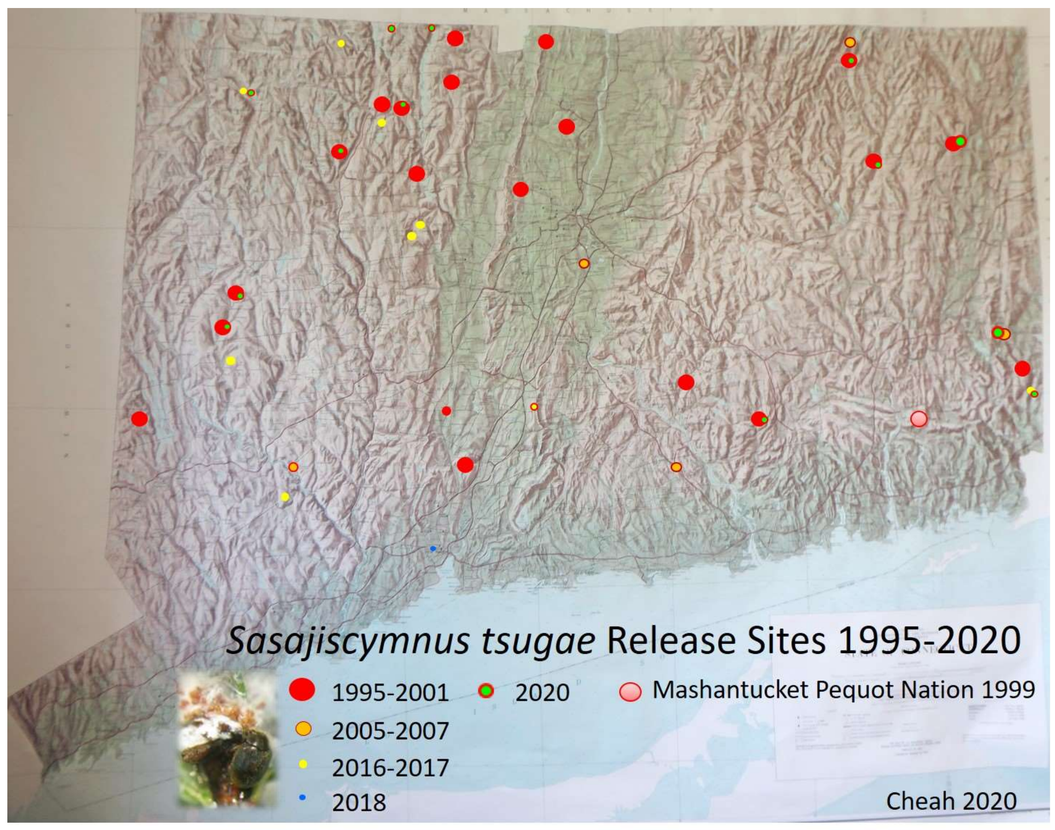


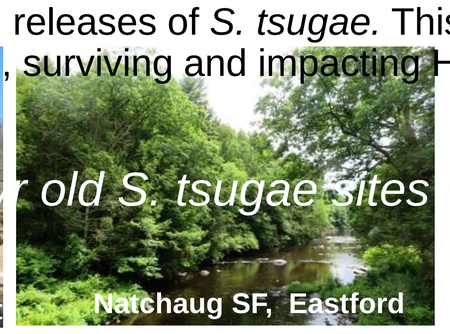
S. tsugae adults and larvae feed on all stages of HWA, including the second progrediens generation and dormant first instars of the sistens, throughout the hot summers in CT. Each adult can feed on >1200 HWA N1 just in the summer and fall.

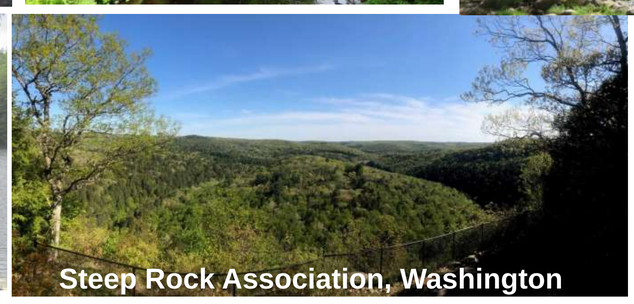
- This tiny black specialist HWA ladybeetle, *Sasajiscymnus* (= *Pseudoscymnus*) *tsugae* was discovered by CAES and introduced into Connecticut in 1995 from southern Honshu, Japan. It is the first HWA biological control agent introduced in the US. Several million have been released to combat HWA in eastern USA.
- The life cycle of *S. tsugae* is well synchronized with HWA with 2 generations of beetles/year; adults and larvae feed on all stages of HWA and other adelgids, with continual adult feeding on dormant HWA during the hot summers. Research in CT confirmed its field establishment and overwintering survival 1996-2005.
- It is the only HWA biocontrol species reared commercially and is available to the public at https://tree-savers.com/
- *Connecticut & Tree-Savers continue to partner to save hemlocks statewide.*
- More than 176,000 were reared at the Valley Lab. CAES and released throughout CT from 1995-2007. In 2017, 2,000 *S. tsugae* were donated by Tree-Savers, and released in new forest sites. In 2020, a combination of purchases and donations have resulted in >6,500 released on state lands, land trust and private preserves and MDC watershed lands.
- Assessments of biological control efficacy are complicated by sampling challenges + episodes of severe winter mortality of HWA in 2003-04, 2009, 2011, 2014-16, 2018. Major drought events (especially in 2016--2017), concurrent heavy EHS infestations, have also contributed to periodic decline of hemlocks. But long term annual data on hemlock stand health are encouraging.

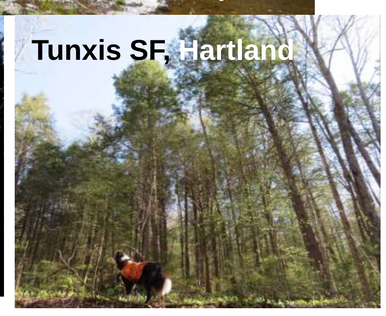
Evidence of the efficacy of *S. tsugae* biological control strategy in CT: release sites were compared with non-release sites in 2003, 2005 and annually with non-infested, healthy baseline sites. Hemlocks in release sites exhibited greater recovery & refoliation than in non-release sites in 2005 and were comparable to hemlocks in non-infested baseline sites from 2006-2009, 2019, 2020.

- Annual field assessments of hemlock health statewide resumed in 2016 under funding from USDA NIFA. In 2009, 70% of release sites had exhibited recovery and healthy crowns with little tree mortality since 2001. After severe winters, great hemlock recovery was also recorded in 2015-2016. But the extreme, extended drought in 2016-2017 caused heavy decline in marginal ridgetop sites with tree mortality resulting from hemlock borer outbreaks in 20% of sites assessed in early 2017. But from 2017-2020, abundant precipitation has enabled remarkable hemlock recovery, mitigation of borer attacks, with abundant new growth even in poor sites. A very warm winter in 2020 (6th warmest) has seen the patchy return of HWA. Emerging HWA outbreaks in CT after warm winters are the target of strategic augmentation releases of *S. tsugae.* This beetle is proving to be an effective predatory tool, surviving and impacting HWA , even in the hottest summers.









2020 Releases of *S. tsugae* targeting HWA rebound and reinvasion in CT

ACKNOWLEDGMENTS: USDA NATIONAL INSTITUTE OF FOOD AND AGRICULTURE (NIFA) 2015 – 2019; USDA FOREST SERVICE NORTHEASTERN AREA STATE & PRIVATE FORESTRY FUNDING 1994-2009. *Many Thanks to Great Mountain Forest; Mt. Riga, Inc.; CT DEEP Forestry Division, CT DEEP State Parks; Friends of American Legion and People's State Forests; Andy Hubbard and Phil Rogers, Metropolitan District Commission (Natural Resources); Ann Astarita, Roxbury Land Trust; Brian Hagenbuch & Rory Larson, Steep Rock Association; Dave Soleck, Town of Monroe; John Winiarski (retired CAES), Dr. Allen Cohen; NCSU, for CC diet, and Jayme Boniewicz, Tree-Savers, PA. All photos by Carole Cheah.*

Biological Control of Mile-a-Minute Weed (MAM) in CT

Carole Cheah[1] and Donna Ellis (*retired*)[2]

Assisted by Emmett Varricchio 2015-2017

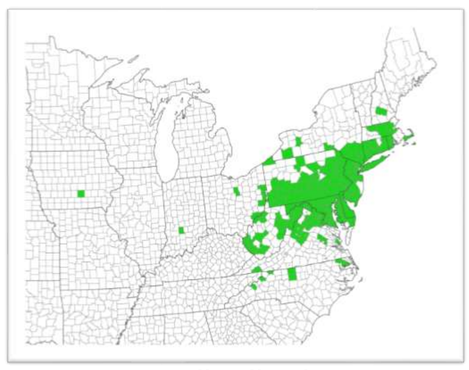
[1]The Connecticut Agricultural Experiment Station; [2]University of Connecticut

Identifying MAM, *Persicaria perfoliata* (L.) H. Gross (formerly *Polygonum perfoliatum*)

Origin: Asia
Family Polygonaceae

- Triangulate leaves
- Recurving barbs
- Blue fruit when ripe
- Saucer-shaped leaves encircling stem (ocrea)

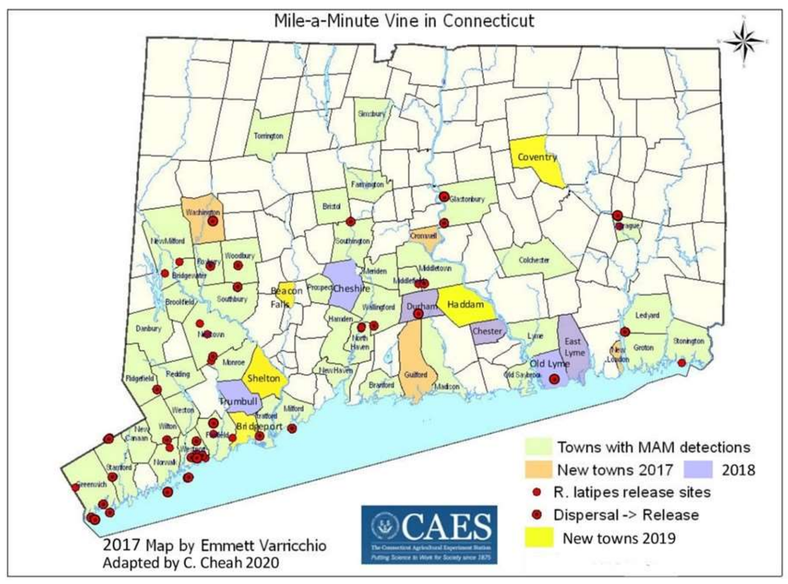
Tolerates beach conditions**!**



U.S. distribution

EDDMapS. 2020. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed July 6, 2020.

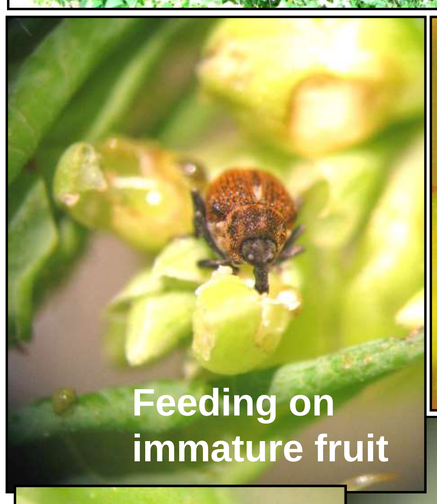
Distribution of MAM, location of weevil release sites and dispersal 2009-2019 in CT

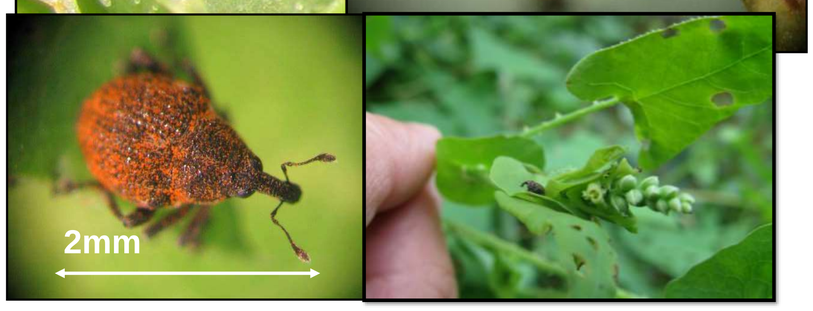


- First confirmed in Greenwich, 2000
- Annual vine with exponential growth + huge seed bank, viable for 6-7 years
- Colonizes disturbed soil, forest openings, wetlands; riparian corridors; persistent seed bank is a challenge
- Threat to forest regeneration
- Outcompetes + overwhelms native plants
- Dispersed by man, water, wildlife, birds

Rhinoncomimus latipes (Coleoptera:Curculionidae)

- Federally screened for biological control; first introduced in CT in July 2009
- Adult weevils feed on youngest leaves, flowers and buds of MAM and are very host specific; in time, feeding may delay and reduce overall fruiting and maturation
- Eggs are laid on undersides of leaves and on the stem, preferentially on plant capitula (flower heads) of MAM
- Larvae hatch, bore into first node in stem and enter stem to feed and develop; cannot develop on other related species
- Mature larvae leave the stem; drop to soil to pupate
- New adults emerge from the soil as black adults which turn orange with feeding; Generation time is approx. 26 days; >2 generations in CT
- Adults overwinter and can live >1yr
- Adults fly and readily disperse to find new MAM populations, even dispersing to off shore islands in Long Island Sound



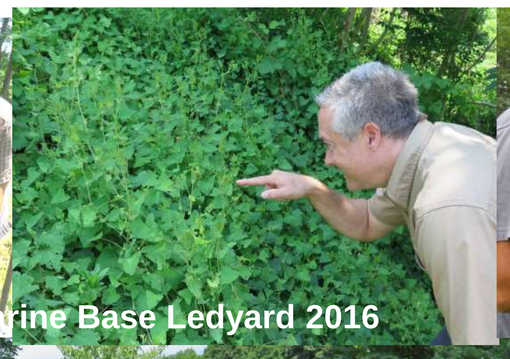


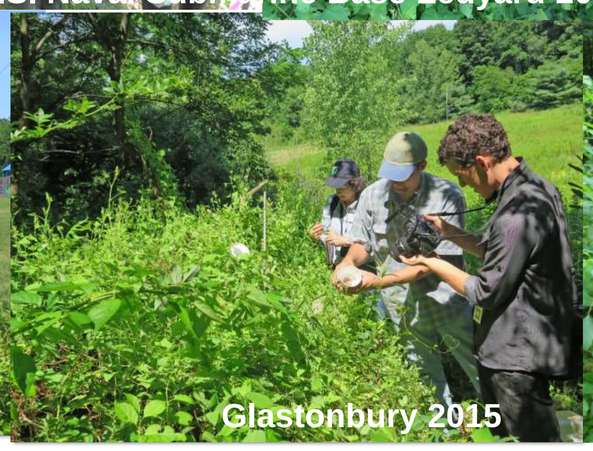
Origin: Central China; introduced into the US by the USDA Forest Service and University of Delaware in 2004

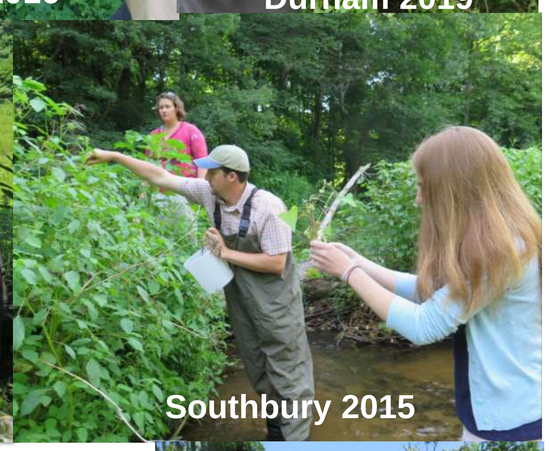
R. latipes Releases in CT 2009 - 2019 and Field Assessments

- Weevils reared & supplied by NJDA PABIL (2009-2019) & URI (2012-2014)
- 500-1000 adults released per site at a central location
- Monitoring over time for weevil survival and dispersal, activity and MAM damage, timing of fruiting
- Annual visits in late summer to >30 selected sites initiated in 2014

CT Releases 2014-2019

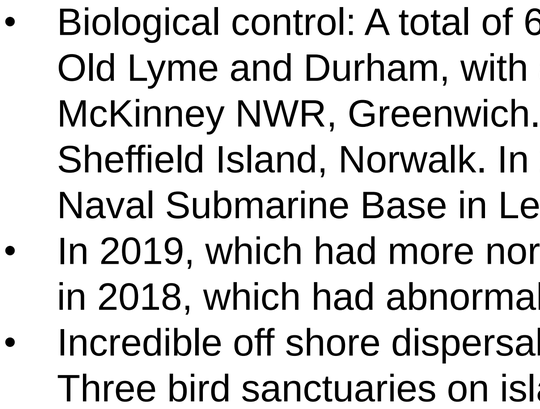


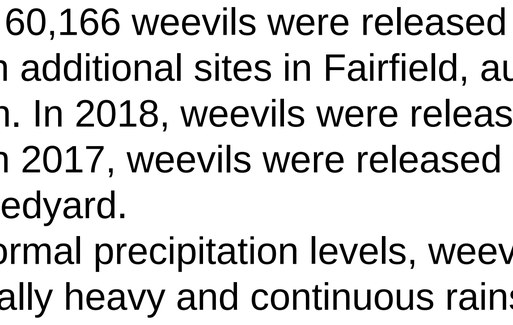


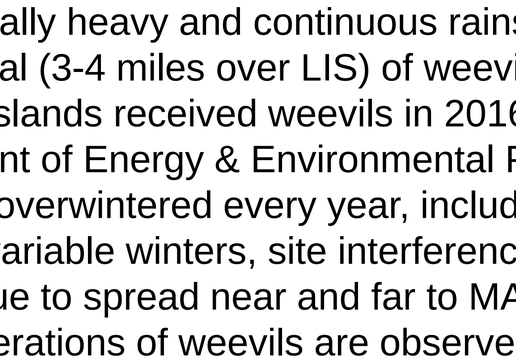


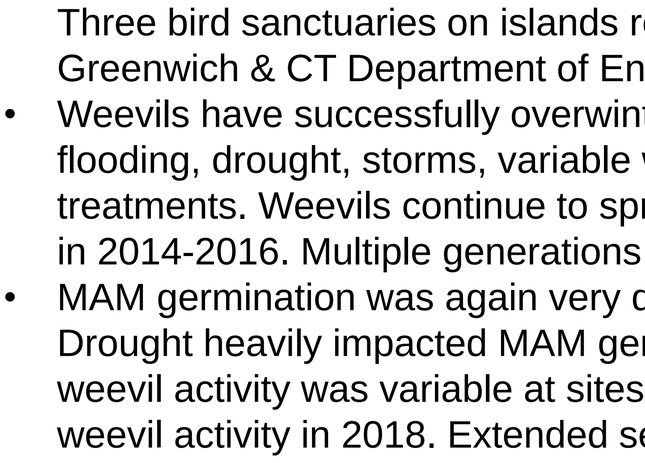
Progress in 2015-2019

- 59 CT towns (34.9%) have confirmed reports of MAM to date in 2019 (*www.mam.uconn.edu/);* with plentiful rains and hot temperatures, MAM has continued to spread*: 5 new towns in 2018, 5 new in 2019, but so have the weevils.*
- Biological control: A total of 60,166 weevils were released in 27 towns (45 sites) in CT from 2009-2019: New in 2019: Old Lyme and Durham, with additional sites in Fairfield, augmentations on Calf and Sheffield Islands, Stewart B. McKinney NWR, Greenwich. In 2018, weevils were released in Washington, with augmentations in Westport and Sheffield Island, Norwalk. In 2017, weevils were released in Glastonbury Meadows and in 2016, at the New London Naval Submarine Base in Ledyard.
- In 2019, which had more normal precipitation levels, weevil damage and activity was much higher in more sites than in 2018, which had abnormally heavy and continuous rains, which affected weevil activity while benefiting MAM.
- Incredible off shore dispersal (3-4 miles over LIS) of weevils and MAM to islands was recorded in 2015 and 2016. Three bird sanctuaries on islands received weevils in 2016, partnering with US Fish and Wildlife, Towns of Westport, Greenwich & CT Department of Energy & Environmental Protection.
- Weevils have successfully overwintered every year, including the most severe winter of 2015; survived severe flooding, drought, storms, variable winters, site interference from mowing, tree felling, vegetation clearance, herbicide treatments. Weevils continue to spread near and far to MAM infestations,14-29 miles from nearest earlier release sites in 2014-2016. Multiple generations of weevils are observed yearly. New weevils seen in mid-late Sep. 2019.
- MAM germination was again very delayed (late April) in 2020, as in 2014, 2016-2019 due to cool spring temperatures. Drought heavily impacted MAM germination in 2016. Early feeding by weevils seen on MAM seedlings. In 2016, weevil activity was variable at sites; maturation of fruit was very late, reduction of MAM at some sites, with or without weevil activity in 2018. Extended severe drought, competition from natives possibly limited MAM growth and seed set in 2016. Heavy and continuous precipitation in 2018 favored rampant MAM growth but affected weevil feeding on MAM (very light in 59% of sites). In 2019, better damage was recorded in drier weather conditions.



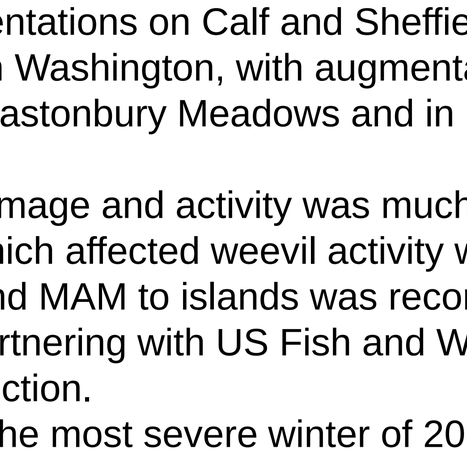






All photos by Carole Cheah

2019 weevil damage



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USDA APHIS PPQ

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Joe Blank, Ani Adishian, Greenwich
Pat and Sheldon Corrow, Southington
Ray Purtell and Greg Foran, Town of Glastonbury
Mark Austin, Ed Edelson, Sandy Ingelllis, Town of Southbury
Carol Haskins, Pomperaug River Watershed Coalition
Kris Vagos, U.S. Fish and Wildlife, Stewart B. McKinney National Wildlife Refuge
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Michael Brown, Tracey McKenzie, Rich Massad, Jane Urban, Naval Submarine Base, New London
Tim Rosa, Stephen Roth, SBA Communications Corporation
Jeff Hammond, Town of Washington Parks and Recreation; Amy Richardson, Westport
Sandy Downing, Bonnie Reemsynder ,Town of Old Lyme;
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