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Hemlock Woolly Adelgid (HWA) ***Adelges tsugae* Annand**



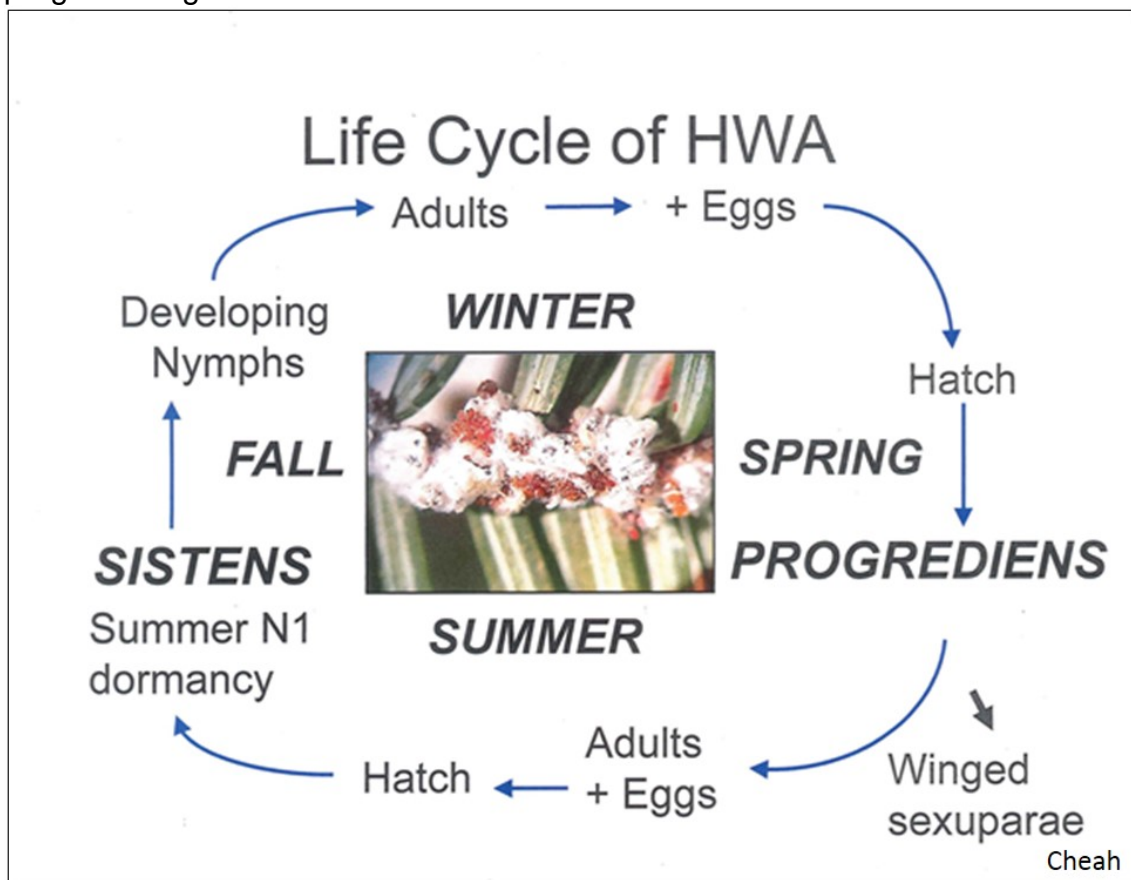
Introduction and Overview

Adelgids are conifer-feeding insects, related to aphids, belonging to the SubOrder Homoptera. Hemlock woolly adelgid, *Adelges tsugae* Annand, (HWA), feeds on hemlock species and was first described in Oregon by P. N. Annand in 1924. In the eastern United States, this non-native insect pest was initially

reported at a private estate in Richmond, Virginia in the early 1950s. HWA infestations have since spread widely to attack eastern hemlock, *Tsuga canadensis*, and Carolina hemlock, *Tsuga caroliniana*, and can now be found in 20 eastern states, from the southern Appalachians in the Carolinas and Georgia, through the Mid-Atlantic States, westwards to Ohio and Michigan and northwards to northern New England. Most recently, HWA was found in southern Nova Scotia in Canada. In Connecticut, HWA was first reported to the Connecticut Agricultural Experiment Station in New Haven in 1985 and by 1997, was found throughout the state, in all 169 Connecticut towns. Hemlock tree mortality from HWA attack can occur in a few years, often in conjunction with other pests, especially on stressed, drought-prone sites. But infested hemlocks can also survive HWA infestations if regularly controlled, especially in the garden landscape. To date, Connecticut has been dealing with HWA for 33 years.

Life Cycle of HWA

HWA is an unusual parthenogenetic [all female] insect, largely sessile, that actually thrives and feeds on hemlocks during the fall and winter when temperatures are mild. The insect secretes a waxy wool covering for protection. A generalized life cycle on eastern hemlock is shown below, and consists of 2 generations: the winter or sistens generation, and the shorter summer or progrediens generation:



The winter or sistens generation in Connecticut generally begins to lay eggs in early spring [March-April]. Each egg mass, hidden within the wool of the overwintering generation can contain 100-300 eggs by late April. These eggs hatch over an extended period in April and May to produce the second damaging summer **progreiens** generation in late May and June, characterized by a much shorter generation time and smaller egg masses. Both generations of HWA are similar in appearance. Eggs and mobile crawlers of both generations are spread by wind, birds and other wildlife, humans and infested plant material movement from spring through summer. In more northerly latitudes and higher elevations, this period for potential dispersal can be extended due to cooler temperatures.

HWA Stages Damaging to Hemlock



Crawlers of the new sistens generation hatch in the summer, settle and cease feeding until the fall. During this dormant period, there is no wool production. This settled first instar stage is inconspicuous and easily escapes detection.

When HWA feeding and development resume in the fall, usually in late September-mid October in the Northeast, the first instar sistens swell and molt, and start to produce the characteristic wool in the second instar. Adelgid growth continues throughout the winter into early spring, with increasing production of

wool which is most prominent on adults in late March through May, especially on the undersides of hemlock branch tips. Eggs are protected by the woolly secretions and populations can quickly explode to infest a tree.

HWA prefers to feed on the newest most nutritious growth available, especially on healthy trees. Feeding by the adelgid depletes the tree's storage reserves and results in a decline or cessation in new foliage production, needle drop, twig dieback and thin crowns.

In Connecticut and the Northeast, winter populations of HWA can also be dramatically reduced by extreme winter temperatures and research at the Station has shown that HWA from more interior regions are more cold tolerant than coastal populations. A predictive model was developed, based on the absolute minimum daily winter temperature occurring between December and February [link] and is helpful in determining the need for chemical treatment of HWA for Connecticut homeowners in the relevant climate divisions [link]. In the past 20 years, extremely high HWA mortality was recorded during severe Connecticut winters in 2000 [link], 2003 [link], 2004 [link], 2009 [link], 2011 [link], 2014 [link], 2015 [link], 2016 [link] and 2018 [link].

Thorough coverage with horticultural oil or soap sprays can be used on accessible trees in the garden landscape to kill HWA but is costly and impractical for large scale control in the forest. Chemical control with neonicotinoids has been widely utilized in some other states for control of HWA but in Connecticut, this is now restricted to licensed use (CT Public Act No. 16-17 An Act Concerning Pollinator Health).

With mounting environmental concerns for honeybees, other pollinators and wildlife, biological control remains the safest strategy for managing HWA in the natural landscape. Several other predator species have also been introduced in other parts of the HWA range.

Other serious hemlock pests

Trees can also suffer decline from another serious non-native pest, elongate hemlock scale, *Fiorinia externa* Ferris (EHS) which occurs as the major hemlock pest or in combination with HWA.



In recent years, EHS has spread to very damaging levels in western Connecticut and has started to spread east of the Connecticut River. Decline in hemlock health is indicated by the widespread loss of needles and a reduction in new shoot production on infested branches which all result in reduced, grayish thin crowns. During extended extreme drought periods, stressed, weakened hemlocks are also targeted by the native hemlock borer, *Phaenops* or *Melanophila fulvoguttata* Harris, a buprestid beetle, which in large numbers, often overwhelm and eventually kill the trees. Woodpeckers strip the bark of infested trees exposing the reddish inner bark riddled with larval tunnels.



Biological Control of HWA in Connecticut

In Connecticut, biological control of HWA has focused exclusively on mass releases of the tiny Japanese coccinellid, *Sasajiscymnus* [formerly *Pseudoscymnus*] *tsugae*. This tiny ladybeetle, about 2mm in length, was the first non-native HWA predator species imported into the US from southern Honshu island, Japan. A federal permit was issued after an environmental assessment and the first release of this species was in Connecticut in 1995. *Sasajiscymnus tsugae* is the first predator species introduced into the U.S. for biological control of HWA and several million have since been released throughout eastern USA. It is the only HWA predator that is reared commercially and is available to the public from Tree-Savers, a company from Pennsylvania (<http://tree-savers.com/>).

***Sasajiscymnus* (formerly *Pseudoscymnus*) *tsugae* (Coleoptera: Coccinellidae: Scymninae)**



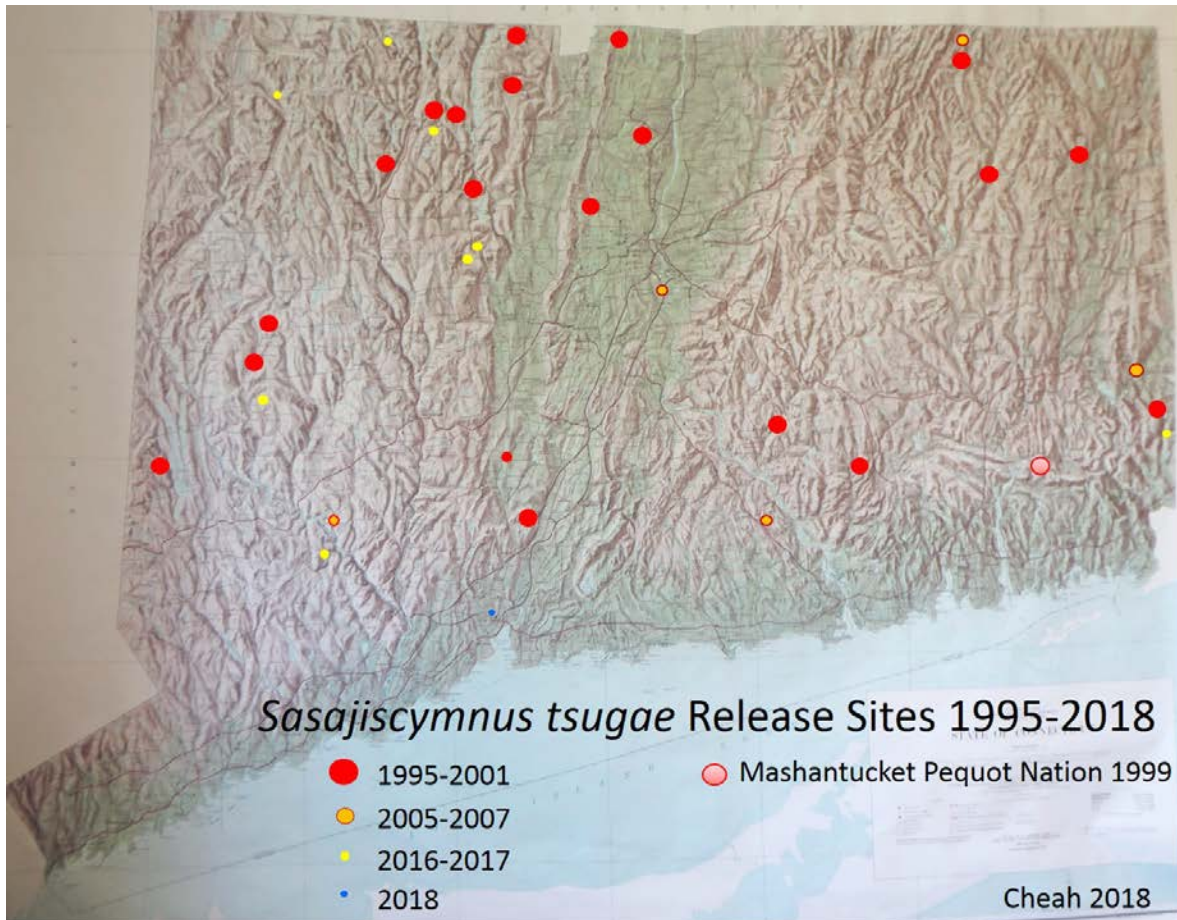


Biology and Synchrony with HWA

This tiny ladybeetle only measures 2mm in length but it is a specialized, long-lived adelgid feeder which highly prefers HWA. Both larva and adult stages feed voraciously on all stages of HWA, including the dormant HWA first settled instars in the heat of summer. In Connecticut, two field generations are possible and adults overwinter. Adults are highly mobile and fly readily to disperse. Female *S. tsugae* beetles are highly fecund. The life cycle of this species is highly synchronized to that of its prey, HWA, and it has a long season of predation and impact from mid-spring to late fall [link] [link] [link]

Rearing and Releases of *S. tsugae* in Connecticut

Between 1995-2007, >176,000 adult *S. tsugae* were reared at the Valley Laboratory in Windsor and released at 26 sites on state lands, town and private forests and open space. The majority of forest sites received several thousand (2,000- 10,000) mated adult *S. tsugae*. More recently, this biological control program with *S. tsugae* was revived in 2017 through the generous donation and cooperation of the sole commercial producer of *S. tsugae*, Tree-Savers of Greentown, PA, (www.tree-savers.com). Two thousand beetles were released in 7 new forest sites in June 2017 in small groups of 100-300 to control small pockets of resurgent HWA in new areas of Connecticut. As of 2018, a total of 178,442 *S. tsugae* have been released at 35 sites throughout Connecticut since 1995: 22 on state lands, 5 in town/city parks, 7 on private forests/land trusts and 1 on tribal land at the Mashantucket Pequot Tribal Reservation. Assessments in Connecticut release sites from 1995-2001 showed that *S. tsugae* had reproduced and overwintered successfully in many locations [link].



The large, colorful and exotic Halloween ladybeetle, *Harmonia axyridis* Pallas occasionally feeds on HWA but its preferred prey are aphids.



Hemlock trees at selected Connecticut *S. tsugae* release sites have been assessed annually for HWA winter mortality, crown conditions, pests and general health for many years since the initial releases. Summary posters from Plant Science Day on the HWA biological control program in Connecticut are available below:

Link: 2013

Link: 2014

Link: 2015

Link: 2016

Link: 2017

Research at the Connecticut Agricultural Experiment Station, supported by the USDA Forest Service from 1994-2009, has documented the life history, biology, mass rearing potential, establishment and suitability as a biological control agent (Further Reading)

Currently, an integrated assessment of the efficacy of these biocontrol implementations of *S. tsugae* in Connecticut at older sites is underway, funded by the USDA National Institute of Food and Agriculture. Field release sites are being revisited and reassessed 12-20 years after release.

Links to recent talks and interviews:

Plant Science Day 2018

Climate impacts on hemlocks and hemlock woolly adelgid in the Northeast

<http://www.ct.gov/caes/cwp/view.asp?a=2824&Q=602278&PM=1>

The Holistic Nature of Us

All New Podcast from Judith Dreyer 2018

<https://www.judithdreyer.com/podcast/podcast-carole-cheah-entomologist-eastern-hemlock-and-wooly-adelgid/>

Biological control of invasives: hemlock woolly adelgid

The University of Connecticut Hot Topics series for the Master Gardeners

Program June 20, 2018

<https://www.youtube.com/watch?v=IkTj2EzAXxs&feature=youtu.be>

2018

Connecticut Post: John Burgeson

[Cold snap gives hemlocks a fighting chance; Jan 26, 2018](#)

https://www.ctpost.com/local/article/Cold-snap-gives-hemlocks-a-fighting-chance-12528892.php?utm_campaign=email-tablet&utm_source=CMS%2520Sharing%2520Button&utm_medium=social#photo-14948007

Yale Daily News: William Langhorne

[An Invasion Intervention; Mar 6, 2018](#)

<https://yaledailynews.com/blog/2018/03/03/an-invasion-intervention/>

The Day: William Hobbs

[Nature Notes: Cold snaps and special beetle help combat hemlock woolly adelgids; Mar 9, 2018](#)

<https://www.theday.com/article/20180309/NWS01/180309691>

2017

Danbury New Times Bob Miller

<http://www.newstimes.com/news/article/Robert-Miller-The-one-two-punch-to-hemlocks-11509832.php>

2016

<http://www.newstimes.com/news/article/Robert-Miller-The-pluses-and-minuses-of-the-cold-7251890.php>

2014

<http://www.newstimes.com/news/article/Robert-Miller-Winter-s-toll-on-insects-and-a-bird-5430553.php>

2013

<http://www.newstimes.com/news/article/Robert-Miller-Hemlocks-are-losing-ground-4793633.php>

2004

<http://www.newstimes.com/news/article/Weather-beetles-help-kill-bug-that-threatens-45236.php>

2014

NPR Patrick Skayhill

<http://www.wnpr.org/post/invasive-bugs-connecticut-may-be-adapting-extreme-winters>

CAES Publications on hemlocks, hemlock woolly adelgid and biological control of HWA, elongate hemlock scale:

Hemlock

Olson, J.S., Stearns, F. W. and Nienstaedt, H. 1959. Eastern Hemlock Seeds and Seedlings Response to Photoperiod and Temperature Bulletin 620

<http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b620.pdf>

Nienstaedt, H. and Olson, J.S. 1955. Heredity and Environment: Short-cut study shows how both affect hemlock growth

http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_7.2.pdf

Hicock, H. W. 1958 Hemlock seedlings

http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_11.1.pdf

Stephens, G. R. 1981 Heavily defoliated white pine has lower mortality than hemlock

http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_37.1.pdf

Life cycle, impacts and control of HWA

McClure, M.S. 1987 Biology and control of hemlock woolly adelgid
<http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b851.pdf>

McClure, M.S. 1995 Managing hemlock woolly adelgid in ornamental landscapes
<http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b925.pdf>

McClure, M.S. 1987 Hemlock woolly adelgid may also attack spruce
http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_39.2.pdf

McClure, M.S. 1991. Pesticides will protect ornamentals from hemlock woolly adelgid
http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_44.1.pdf

McClure, M.S. and Cheah, C.A. S-J. 1998
Released Japanese ladybugs are multiplying and killing hemlock woolly adelgids
http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_50.2.pdf

Cheah, C. 2010 Connecticut's Threatened Landscape: Natural Enemies for Biological Control of Invasive Species
http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/frontiers_vol_57_num_2_spring_2010.pdf

Scales on hemlocks

McClure, M.S. 1987 Controlling hemlock scales with least environmental impact
<http://www.ct.gov/caes/lib/caes/documents/publications/bulletins/b844.pdf>

Other hemlock pests

Chris T. Maier, Carol R. Lemmon, Ronald M. Weseloh, and Theodore G. Andreadis 1993. Spring hemlock looper returns to attack hemlock forests in Connecticut
http://www.ct.gov/caes/lib/caes/documents/publications/frontiers/fps_45.2.pdf

Further reading:

Cheah, C.A.S.-J. 2017. Predicting winter mortality of hemlock woolly adelgid in Connecticut by climatic divisions. *Northeastern Naturalist* Volume 24, Special Issue 7, 2017 B90-118

Link:

Cheah, C.A.S.-J. 2017. Climate change impacts in the Northeast on HWA and its coccinellid predator from Japan, *Sasajiscymnus tsugae*. Abstract for an oral presentation at the 2017 NorthEast Natural History Conference, 22–23 April 2017, Cromwell, CT Available online at:

https://www.eaglehill.us/NENHC_2018/archives/NENHC2017-oral-abstracts.pdf

Cheah, C.A.S.-J. 2016. Predicting winter mortality of hemlock woolly adelgid in Connecticut. Abstract for an oral presentation at the 2016 NorthEast Natural History Conference, 22–24 April 2016, Springfield, MA. Available online at:

<https://www.eaglehill.us/NENHC-archives/NENHC2016-oral-abstracts.pdf>

Cheah, C. 2011. Chapter 4. *Sasajiscymnus* [= *Pseudoscymnus*] *tsugae*, a ladybeetle from Japan. In: Implementation and Status of Biological Control of Hemlock Woolly Adelgid. Tech.Coar. Onken, B. and Reardon, R. USDA Forest Service FHTET Publication FHTET-2011-04 pp. 43-52.

Link:

Cheah, C. 2008. The case for *Sasajiscymnus tsugae*: Biological control has helped save Connecticut's hemlocks. Abstract for a poster in Proceedings of the Fourth Symposium on Hemlock Woolly Adelgid in the Eastern United States. Hartford, CT. Feb. 12-14, 2008. B. O. Onken and R. Reardon [Compilers] FHTET 2008-01. pp. 279-280.

Link:

Cheah, C.A. S.-J. & McClure, M.S. 2010. *Sasajiscymnus* [formerly *Pseudoscymnus*] *tsugae* [Coleoptera:Coccinellidae]. In: Biological Control: A Guide to Natural Enemies in North America. A. Shelton. Cornell University College of Agriculture and Life Sciences, Department of Entomology website. Online at:

<https://biocontrol.entomology.cornell.edu/predators/sasajiscymnus.php>

Cheah, C.A. S-J. & McClure, M.S. 2002. *Pseudoscymnus tsugae* in Connecticut forests: the first five years. Proceedings of the Hemlock Woolly Adelgid Symposium, East Brunswick, NJ, February 5-7, 2002. Eds. Onken, B., Reardon, R. Lashomb, J. p. 150-165 Available online at: http://hiro.ento.vt.edu/hwa/wp-content/uploads/publications/2002proceedings/first_five.pdf

Link:

Cheah, C.A. S-J. & McClure, M.S. 2000. Seasonal synchrony between the exotic predator, *Pseudoscymnus tsugae* [Coleoptera:Coccinellidae] and its prey, the hemlock woolly adelgid, *Adelges tsugae*. Agriculture and Forest Entomology 2, 241-251

Link:

Cheah, C.A.S-J. & McClure, M. S. 1998. Life history and development of *Pseudoscymnus tsugae* [Coleoptera:Coccinellidae], a new predator of the hemlock woolly adelgid [Homoptera: Adelgidae]. Environmental Entomology, 27, 1531-1536.

Link:

Cheah, C.A.S-J. & McClure, M. S. 1996. Exotic natural enemies of *Adelges tsugae* and their potential for biological control. Proceedings of the First Hemlock Woolly Adelgid Review [ed. by S. Salom, T. Tigner and R. C. Reardon], pp. 103-112. USDA Forest Service Forest Health Technology Enterprise Team 96-10.

Link:

Cheah, C, Montgomery, M. Salom, S. Parker, B. L., Costa, S. and Skinner, M. 2004. Biological control of hemlock woolly adelgid. USDA Forest Service. FHTET-2002-04, Reardon, R. and B. Onken [Tech. Coordinators], 22 pp.

Link:

Cheah, C.A. S-J., Mayer, M. A., Palmer, D., Scudder, T. and Chianese, R. 2005. Assessments of biological control of hemlock woolly adelgid with *Sasajiscymnus tsugae* in Connecticut and New Jersey. In: Proceedings of the Third Symposium on the Hemlock Woolly Adelgid in the Eastern United States, Feb.1-3, 2005, Asheville, North Carolina. Onken, B. and Reardon, R. [Compilers] FHTET 2005-01 pp. 116-130.

Link:

Cohen, A.C. and Cheah, C. 2010. Packaging and Presentation of Artificial Diets for Hemlock Woolly Adelgid Predators In: Proceedings of the Fifth HWA Symposium in the Eastern United States, Asheville, NC August 17-19, 2010. Compilers Onken, B. and Reardon, R. USDA Forest Service FHTET-2010-07. p 33-35.

Link:

Cohen, A.C. and Cheah, C. 2011. Chap. 14. Development of artificial diets for predators of hemlock woolly adelgids. In: Implementation and Status of Biological Control of Hemlock Woolly Adelgid. Tech. Coord. Onken, B. and Reardon, R. USDA Forest Service FHTET Publication FHTET-2011-04 pp. 148 – 160

Link:

Cohen, A. C and Cheah, C. A.S.J. 2015. Interim Diets for Specialist Predators of Hemlock Woolly Adelgids. Entomol Ornithol Herpetol 4:153
doi: 10.4172/2161-0983.1000153
Open access available online at <https://www.omicsonline.org/open-access/interim-diets-for-specialist-predators-of-hemlock-woolly-adelgids-2161-0983-1000153.php?aid=52757>

Cohen, A.C., Cheah, C., Kidd, K. and Hodgson, T. 2011. Chap. 13. Defining PC/QC standards of mass-rearing HWA predators. In: Implementation and Status of Biological Control of Hemlock Woolly Adelgid. Tech. Coord. Onken, B. and Reardon, R. USDA Forest Service FHTET Publication FHTET-2011-04 pp. 139-147

Link:

Cohen, A.C., Cheah, C.A.S-J., Strider, J., and Hain, F. 2008. Diet development for hemlock woolly adelgids and their predators In: Proceedings of the Fourth Symposium on the Hemlock Woolly Adelgid in the Eastern United States, Feb.12-14, 2008, Hartford, Connecticut.. Onken, B. and Reardon, R. [Compilers] FHTET 2008-01 p. 150-156.

Link:

McClure, M.S. and Cheah, C. A. S-J. 2002. Important mortality factors in the life cycle of hemlock woolly adelgid, *Adelges tsugae* Annand [Homoptera:Adelgidae] in the Northeastern United States. Proceedings of the Hemlock Woolly Adelgid Symposium, East Brunswick, NJ, February 5-7, 2002. Eds. Onken, B., Reardon, R. Lashomb, J. p. 13-22.

Link:

McClure, M. S., Cheah, C.A.S-J. and Tigner, T. 2000. Is *Pseudoscymnus tsugae* the solution to the hemlock woolly adelgid problem? An early perspective. Proceedings of a Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America 1999. [eds. K. McManus, K. Shields and D. Souto] p. 89-95. USDA Forest Service General Technical Report NE-267.

Link:

Ward, J. S., Cheah, C. A. S-J., Montgomery, M.E., Onken, B. P. and Cowles, R.S. 2004
Eastern Hemlock Forests: Guidelines to minimize the impacts of hemlock woolly adelgid
http://www.ct.gov/caes/lib/caes/documents/special_features/MinimizingimpactsofHWA.pdf