The Elongate Hemlock Scale, *Fiorinia externa* Ferris (Homoptera: Diaspididae): A New Look at an Old Nemesis

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Abstract

The elongate hemlock scale, *Fiorinia externa* Ferris, and a circular one, *Nuculaspis tsugae* (Marlatt) (Homoptera: Diaspididae) attack eastern hemlock, *Tsuga canadensis* Carriere in the eastern United States. They often co-exist with hemlock woolly adelgid, *Adelges tsugae* Annand, and hasten the decline of hemlock. *Aspidiotiphagus citrinus* Craw (Hymenoptera: Aphelinidae) was the only parasitoid species recovered from emergence cages or observed during microscopic examination of samples taken from five hemlock forests in Connecticut and one in New York during 2001. Parasitization rates of *F. externa* by *A. citrinus* were highly variable at all six sites. In Connecticut, parasitization on new needles (indicative of 2001 parasitoid activity only) averaged 6.3% (range 3.4% to 9.4%) and on old needles (indicating cumulative parasitoid activity during the past two years) averaged 16.2% (range of 10.2% to 24.2%). Parasitization rates of *F. externa* were substantially higher at the site in New York (18.6% and 40.6% for scales on new and old needles, respectively). These levels of parasitization are similar to those reported in Connecticut decades ago and are insufficient for biological control of *F. externa*. Larvae and adults of *C. stigma* and unidentified lacewing species were collected at each site, but in insufficient numbers to suggest their importance in biological control at this time.

No pathogens of *F. externa* or *N. tsugae* have previously been reported. Microscopic examination of samples collected from 20 trees along a 2.5 km transect through the hemlock forest at Mianus River Gorge Preserve in Bedford, New York on 31 October 2001 revealed that an unknown fungal pathogen has established an epizootic on *F. externa* and on *N. tsugae*. The highest infection rates observed for *F. externa* on the new needles (indicative of 2001 fungal activity only) and the old needles (indicating cumulative fungal activity during the past two years) were 13% and 27%, respectively. Infection rates for *N. tsugae* were 7.5% and 43.0% on new and old needles, respectively.

Keywords:

Elongate hemlock scale, *Fiorinia externa, Nuculaspis tsugae,* natural enemies.

Introduction

The elongate hemlock scale (*Fiorinia externa* Ferris) and a circular one, *Nuculaspis tsugae* (Marlatt)(Homoptera: Diaspididae) attack eastern hemlock, *Tsuga canadensis* Carriere in the eastern United States. *Fiorinia externa* was first discovered in Queens, New York in 1908 (Sasscer 1912) and now occurs in at least 10 states from Virginia to Massachusetts and west to Ohio (Kosztarab 1996). *Nuclaspis tsugae* was introduced into the United States on hemlock shipped to New Jersey from Japan (Weiss 1914) and is now known to occur in Connecticut, Maryland, New Jersey, Rhode Island (Kosztarab 1996) and New York (McClure, this study). Both scales feed on the undersides of hemlock needles by sucking cell fluids from the mesophyll. Their densities often increase rapidly to levels that cause needles to discolor and drop prematurely and branches to die. Although these insects are not nearly as destructive as hemlock woolly adelgid (*Adelges tsugae* Annand) (Homoptera: Adelgidae), they can kill trees in about 10 years if their populations are not controlled (McClure 1980). In addition to eastern hemlock, *F. externa* also can develop and reproduce on at least 42 other conifer species representing seven different genera; *N. tsugae* does the same on at least eight other species in four genera (McClure 1977a).

In Japan, their homeland, *F. externa* and *N. tsugae* usually occur at low, innocuous densities on native and exotic hemlocks, including *T. canadensis*, even though their populations have the potential to be as high as those in North America (McClure 1986). Outbreaks seldom occur because a parasitoid, *Aspidiotiphagus citrinus* Craw (Hymenoptera: Aphelinidae) and predators, including *Chilocorus kuwanae* Silvestri (Coleoptera: Coccinellidae), are effective enemies of both scales (McClure 1986).

Aspidiotiphagus citrinus regularly kills more than 90% of both scale species in Japan (McClure 1986). This same parasitoid occurs throughout the scale-infested area of the eastern United States, but has been ineffective, especially against *F. externa*. In Japan, *A. citrinus* and both scales have two generations each year and the occurrence of adult parasitoids and vulnerable stages of both scale species are highly synchronous (McClure 1986). This results in high parasitism rates and stable population regulation in Japan. In the northeastern United States, however, *F. externa* usually is able to complete only one generation each year (McClure 1978). *Aspidiotiphagus citrinus* completes two generations each year throughout the eastern United States and, as a result, the occurrence of adult parasitoids and vulnerable stages of *F. externa* are highly asynchronous. This results in parasitism rates fluctuating between 2% and 55% from generation to generation. However, in the South and during relatively mild winters in the North, *F. externa* may complete two generations, which should improve the effectiveness of *A. citrinus* (McClure 1986). Because *N. tsugae* completes two generations each year in the Northeast, its life cycle is more synchronous with *A. citrinus* and parasitism rates hold consistently near 55% (McClure 1986).

The coccinellid beetle, *Chilocorus stigma* (Say) and various species of lacewings that are native to the eastern United States also attack hemlock scales. Although these predators and *A. citrinus* have not been effective biological control agents of *F. externa* in the United States, they do contribute a significant degree of mortality, indicated by a rapid resurgence in scale populations following elimination of these enemies with chemical pesticides (McClure 1977b).

Nuclaspis tsugae is far less abundant and important than *F. externa*. Studies in the greenhouse and in hemlock forests in Connecticut established that *F. externa* and *N. tsugae* compete for food and space, and that *F. externa*, the superior competitor, quickly excludes *N. tsugae* (McClure 1980). The host-finding behavior of *A. citrinus* also hastens the decline of *N. tsugae* populations in mixed infestations (McClure 1980).

Initial observations suggested that as *A. tsugae* invaded hemlock stands previously occupied by *F. externa*, the latter species might eventually be displaced (McClure 1997). However, in recent years populations of *F. externa* have increased dramatically and have contributed significantly to hemlock decline throughout much of the *A. tsugae*-infested area. The ecology of *F. externa* in the eastern United States, including interactions with its community of native and introduced enemies, has not been examined in more than 20 years. During that time, *F. externa* has significantly expanded its geographical range; the climate in the East has moderated, perhaps allowing *F. externa* to become bivoltine, thereby affecting its interaction with *A. citrinus;* and *A. tsugae* has become widely established. In spring 2001, I initiated a re-examination of the interrelationships between *F. externa*, *A. tsugae*, and their enemies; the role of *F. externa* in the decline of eastern hemlock; and the potential for biological control of these pests. Here I report the initial findings of this ongoing investigation.

Methods

To determine recent levels of parasitization of *F. externa* by *A. citrinus* and/or other species, I sampled five sites in Connecticut where the presence of *A. tsugae* and *F. externa*, and hemlock health, have been monitored for up to 7 years, and where *Pseudoscymnus tsugae* Sasaji and McClure (Coleoptera: Coccinellidae) has been released for biological control. Between 5 June and 15 August 2001, 25 branches (~1 m long) were removed randomly from the lower crowns of a number of eastern hemlocks at each site. No more than two branches were sampled from any one tree. Parasitization was monitored using emergence cages and microscopic techniques described by McClure (1977c). For each site, 150 g of youngest growth from each tree were placed in emergence cages and held at room temperature in the laboratory for two weeks. Adult parasitoids were then collected, identified, and counted. Parasitization rates were determined by examining the first 100 scales encountered on the youngest foliage and on the one-year-old foliage on each branch, and by counting parasitoids within scales and exit holes on the dorsum of the scale cover (McClure 1977c).

On 12 October 2001, I received a sample of *T. canadensis* infested with *F. externa* from Jason Denham of the New York State Department of Environmental Conservation, which had been taken from Mianus River Gorge Preserve (MRGP) in Bedford, New York. He had observed that some scales were covered with a black substance. On 31 October 2001, I sampled four branches (~0.5 m long) from the lower crown of each of 20 hemlock trees along a 2.5 km, SSE: NNW transect through MRGP. Microscopic examination of branches in the laboratory revealed that an unknown fungal pathogen has established an epizootic on *F. externa* and on *N. tsugae* at MRGP. Samples have been sent to experts for identification. Counting the number of scales that were infested and not infested on 100 new and 100 one-year-old needles on each branch determined infection rates

by the fungus. Percent parasitization of *F. externa* at MRGP was determined for each branch as previously described.

Results and Discussion

Aspidiotiphagus citrinus was the only parasitoid species recovered from emergence cages or observed during microscopic examination of samples during this study. Parasitization rates of *F. externa* by *A. citrinus* were highly variable at all six sites (Table 1). At the Connecticut sites, parasitization on new needles (indicative of 2001 parasitoid activity only) ranged from 0% to 30% with means ranging between 3.4% to 9.4%. Parasitization on old needles (indicating cumulative parasitoid activity during the past two years) ranged from 0% to 67% with means ranging between 10.2% to 24.2%. Parasitization rates were substantially higher at the site in Bedford, New York (Table 1). However, these levels of parasitization are similar to those that occurred throughout Connecticut decades ago and are insufficient for biological control of *F. externa* (McClure 1977c).

Table 1. Parasitization (%) of *Fiorinia externa* by *Aspidiotiphagus citrinus* at Five Sites in Connecticut and One in New York, 2001.

	New Needles			Old Needles		
Site	%	Range	N	%	Range	N
Connecticut						
East Haddam	4.2	0–10	2,500	11.4	1–26	2,500
New Fairfield	9.4	0-31	2,500	23.0	1-67	2,500
Washington (1)	5.4	0-13	2,500	10.2	0-29	2,500
Washington (2)	9.0	0-30	2,500	24.2	9-48	2,500
Windsor	3.4	0-8	2,500	12.2	0-41	2,500
New York						
Bedford	18.6	6-28	7,256	40.6	24-63	8,000

Larvae and adults of *C. stigma* and unidentified lacewing species were collected at each site, but in insufficient numbers to suggest their importance in biological control at this time. However, future studies will evaluate the impact of these predators working together and with *A. citrinus* on the population dynamics of *F. externa*.

Infection rates of *F. externa* and *N. tsugae* at MRGP revealed an epizootic by an unknown fungal pathogen (Table 2). Although the fungus occurred on all 20 trees sampled, there were clearly foci of activity along the 2.5 km transect. The highest infection rates observed for *F. externa* on the new needles (indicative of 2001 fungal activity only) and the old needles (indicating cumulative fungal activity during the past two years) of a single branch were 13% and 27%, respectively. Infection rates of 100% were observed for *N. tsugae* on some trees. However, because of the relatively small number of *N. tsugae* sampled, the 7.5% and 43.0% infection rates determined across the entire sample of new and old needles, respectively, is more valid. These preliminary data suggest that *N. tsugae* may be more susceptible to the unknown fungus than *F. externa*.

Table 2. Infection Rate (%) of *Fiorinia externa* and *Nuculaspis tsugae* by an Unknown Fungus in Bedford, New York, 2001.

	New Needles			Old Needles		
Species	%	Range	N	%	Range	N
F. externa	3.4	0-8.9	2,764	11.7	1.6-21.1	27,093
N. tsugae	7.5	1-100	161	43.0	0-100	278

No pathogens of *F. externa* or *N. tsugae* have previously been reported. The discovery of an apparent fungal pathogen at epizootic levels in a hemlock forest infested with *F. externa*, *N. tsugae*, and *A. tsugae*, and where *A. citrinus, P. tsugae*, and other natural enemies are established, offers exciting new possibilities for biological control and for managing our hemlock forests.

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References

Kosztarab, M. 1996. *Scale insects of northeastern North America: Identification, biology, and distribution*. Special Publication Number 3. Virginia Museum of Natural History, Martinsville, Virginia.

McClure, M.S. 1977b. Resurgence of the scale, *Fiorinia externa* (Homoptera: Diaspididae), on hemlock following insecticide application. *Environmental Entomology* 6: 480-484.

McClure, M.S. 1977c. Parasitism of the scale insect, *Fiorinia externa* (Homoptera: Diaspididae) by *Aspidiotiphagus citrinus* (Hymenoptera: Eulophidae) in a hemlock forest: Density-dependence. *Environmental Entomology* 6: 551-555.

McClure, M.S. 1978. Seasonal development of *Fiorinia externa*, *Tsugaspidiotus tsugae* (Homoptera: Diaspididae), and their parasite, *Aspidiotiphagus citrinus* (Hymenoptera: Aphelinidae): Importance of parasite-host synchronism to the population dynamics of two scale pests of hemlock. *Environmental Entomology* 7: 863-870.

McClure, M.S. 1980. Competition between exotic species: scale insects on hemlock. *Ecology* 61: 1391-1401.

McClure, M.S. 1986. Population dynamics of Japanese hemlock scales: a comparison of endemic and exotic communities. *Ecology* 67: 1411-1421.

McClure, M.S. 1997. Biological control in native and introduced habitats: Lessons learned from the sap-feeding guilds on hemlock and pine, pp. 31-52. In Andow D.A., D.W. Ragsdale, and R.F. Nyvall (eds.). *Ecological Interactions and Biological Control*. Westview Press, Boulder, Colorado.

McClure, M.S. and M.B. Fergione. 1977a. *Fiorinia externa* and *Tsugaspidiotus tsugae* (Homoptera: Diaspididae): Distribution, abundance, and new hosts of two destructive scale insects of eastern hemlock in Connecticut. *Environmental Entomology* 6: 807-811.

Sasscer, E.R. 1912. The genus *Fiorinia* in the United States. *USDA, Bureau of Entomological Technical Service* 16: 75-82.

Weiss, H.B. 1914. Notes on three imported insects occurring in New Jersey. *Journal of Economic Entomology* 7: 250-251.