Forest Health Technology
Enterprise Team

TECHNOLOGY
TRANSFER

Biological Control

Overview of the Forest Health Technology Enterprise Team Biological Control Program for Invasive Species – 1995 through 2007

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U.S. Department of Agriculture
Forest Service
FHTET

FHTET-2006-18
November 2006

The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry, USDA, Forest Service, to develop and deliver technologies to protect and improve the health of American forests. This book was published by FHTET as part of the technology transfer series.

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OVERVIEW OF THE FOREST HEALTH TECHNOLOGY ENTERPRISE TEAM BIOLOGICAL CONTROL PROGRAM FOR INVASIVE SPECIES – 1995 THROUGH 2007

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BACKGROUND

The number of non-native plants and animals in the U.S. is estimated at 50,000; many provide enormous benefits, escpecially in agriculture, and many others cause no problems. However, approximately 15% have been identified as causing economic losses exceeding $138 million per year (Pimentel et al. 2000).

In U.S. forests, about half of the 400 species of non-native (i.e., exotic, alien) insects and a relatively smaller number of non-native pathogens are regarded as pests, and 17 of those species cause severe economic and ecological impacts. Forest Health surveys in the northeastern U.S. indicated that more than 61% of forested acres have been damaged by non-native forest pests (insects and diseases).

Non-native invasive plants (i.e., exotic plant pests, noxious weeds) threaten the ecological integrity and biological diversity of forest and range ecosystems. Unfortunately, there are no accurate inventories of non-native invasive plants within the U.S. It is estimated that non-native invasive plants comprise 8 to 47% of all plant species in most states. On National Forest System lands alone, it is estimated that noxious weeds infest 20 million acres (D. Thomas, pers. comm. 1999).

National impacts from non-native invasive species and the inadequacies of federal programs to address existing and potential threats were documented in a 1992 Office of Technology Assessment Report (OTA 1993). Subsequently, the role of the federal sector was addressed in Executive Order 13112, "Invasive Species," released in February 1999. This Executive Order defined the criteria for a species to be considered invasive: 1) it is non-native to the ecosystem under consideration and 2) its introduction causes or is likely to cause economic or environmental harm or harm to human health. Also, this Executive Order required federal agencies to prevent the introduction and spread of invasive species and established the National Invasive Species Council to oversee implementation and prepare a National Invasive Species Management Plan that reviews current management programs and identifies how to minimize economic and ecological impacts of invasive species (completed on January 18, 2001). The Order also directed the Council to form a non-federal Invasive Species Advisory Committee (ISAC) to advise the Council on its work.

The risk of new introductions of invasive species into the U.S. will continue to increase due to increased interstate movement, either intentional or unintentional, and increased international trade. Continued spread of invasive species already established within the U.S. will require active management to reduce ecological, economic and social impacts and restoration of affected ecosystems.

ROLE OF THE U.S. DEPARTMENT OF AGRICULTURE AGENCIES

The Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine Division (PPQ), is the USDA agency authorized by the Plant Protection Act of 2000 and other acts to prevent the introduction of non-native invasive species into the U.S. This agency is also responsible for the detection and eradication of all non-native invasive species that are introduced into the U.S. However, other agencies, such as the Agricultural Research Service (ARS), Forest Service (FS), and agencies in the Department of the Interior (DOI), provide technical and financial assistance in APHIS's efforts to detect and manage non-native invasive species. **What is not defined is APHIS' role on forested lands.**

USDA Regulation 9500-10 stated the Secretary of Agriculture's direction pertaining to USDA leadership for non-native invasive species. It authorizes the Forest Service to directly respond, control, monitor, and conduct research on invasive species on approximately 190 million acres of National Forest System lands as well as providing technical and financial assistance for all of the nation's 731 million acres of forest lands, including urban, state, private, tribal, and forested lands managed by other federal agencies. The goal of the Forest Service Invasive Species Program is to reduce, minimize, or eliminate the potential for introduction, establishment, spread, and impact of invasive species across all landscapes and ownerships.

The Chief of the Forest Service has identified non-native invasive species as one of the four critical threats to our nation's ecosystems. In response to this national threat and in an effort to implement the 2004 Healthy Forests Restoration Act, which called for the development of a system to improve the Forest Service's ability to detect and respond to ecological disturbance nationwide, the Forest Service completed a National Strategy and Implementation Plan for Invasive Species Management, which focused on science-based prioritization of invasive species problems and improved collaboration on solution of those problems (FS-85, October 2004).

In 1994, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) was established by a Memorandum of Understanding and signed by representatives of seventeen federal agencies within five Departments. The Committee included representatives from Range Management, Forest Health Protection, and Research and Development. In November 1995, all USDA agencies with responsibility for noxious weeds were directed to develop strategies for addressing noxious weed issues in the USDA Noxious Weed Strategy. The Forest Service Strategy was approved in February 1996 and focused, in part, on the use of Integrated Pest Management (IPM) to manage weeds on National Forest lands. Included in areas of emphasis was recognition of the need to **develop biological control technology** to attack widespread infestations and, wherever possible, to **use biocontrol as a central feature in IPM efforts**.

Even though the Forest Service has the lead responsibility for non-native invasive plant management on forested lands, funding authorities are scattered within the Forest Service and no clear authority exists—except that the National Forest System's Range Management group

clearly has the funding authority to prevent, control, and eradicate noxious weeds in national forests and grasslands. It is not clear whether the Cooperative Forestry Assistance Act of 1978 authorizes the FS State and Private Forestry–Forest Health Protection Program (S&PF–FHP)—clearly established for addressing insects and diseases—to spend funds on treating invasive plants. In contrast, the Hawaii Tropical Forest Recovery Act does provide FHP the authority for treating noxious weeds in Hawaii. As a result, the Forest Service, through the State and Private Forestry Deputy Chief for Forest Health Protection, has maintained its role in protecting the health of U.S. forests and trees through the evaluation and suppression of insect and disease pests, and only more recently, engaged in detection and monitoring invasive plants and in providing technical assistance in releases of biological control organisms. **To continue to do so, Forest Health Protection needs the authority and additional funds to take a more active role in treating non-native invasive plants on forested land—especially on National Forest System lands.**

BIOLOGICAL CONTROL

Biological control—the reduction of an organism's population density through use of its natural enemies—has been recognized as being one of the most effective and cost-efficient long-term approaches for managing invasive species. Natural enemies (parasites, predators, herbivores, and pathogens) reduce the population of hosts; in turn, host abundance influences the population levels of natural enemies.

"Classical" biological control is the intentional introduction of non-native natural enemies for permanent establishment and long-term control of invasive species in the infested areas. It is a strategy that has been used extensively to control non-native invasive species. It is a long-term process: successful classical biological control programs tend to average 10 years from the discovery and evaluation of natural enemies to their release and establishment in an infested area. Successful weed biocontrol programs begin with localized damage to individual plants and finish with a sustained regional reduction in the plant population.

Biological control agents (except pathogens) are exempt from the Federal Insecticide, Fungicide and Rodenticide Act of 1996 and fall under APHIS jurisdiction. Pathogens, when used as biopesticides, require product registration from the U.S. Environmental Protection Agency. APHIS issues permits to release such pathogens when these are used as classical biological control agents. APHIS recently concluded that it has authority only to regulate natural enemies whose target hosts are plants (unfortunately designated "plant pests") and not natural enemies of arthropods. This has created much confusion among members of the biocontrol community because clearer regulations for natural enemy importation are needed. **The current APHIS system for processing permits to move "plant pests" into U.S. quarantine, between states, and release into the environment is not efficient and needs to be revised to be more time-sensitive to the biology of natural enemies and their hosts and responsive to their release history in the U.S.**

Existing biological control regulations are based mainly on the interpretation of five acts of legislation: 1) The Plant Quarantine Act of 1912, 2) The Federal Plant Pest Act of 1957, 3) The Federal Insecticide, Fungicide, and Rodenticide Act of 1947 (FIFRA), 4) The National Environmental Policy Act of 1969 (NEPA), and 5) The Endangered Species Act of 1973. These laws were not written with biological control agents in mind. Item 2 above is the law most often used for regulating classical biological control agents, though its purpose was to prevent the introduction of organisms that damage plants, not to provide a regulatory framework for importation of biological control agents. **Obviously, there is a need to develop a process and standards that are open, efficient, and scientifically based for regulating the introduction and release of biological control agents.**

FOREST HEALTH TECHNOLOGY ENTERPRISE TEAM

The Forest Health Technology Enterprise Team (FHTET) was created in 1995 by the Deputy Chief for State and Private Forestry to provide a focus within Forest Health Protection to develop and deliver technologies to protect and improve the health of America's forests. The FHTET Strategic Plan defines relationships with key cooperators and partners in three long-term strategic goals: 1) improve assessment of the health of America's forests, 2) protect and improve forest health through development and application of environmentally sound technologies, and 3) provide technical expertise and support to national programs. Goals 2 and 3, as well as the Forest Service strategy for dealing with invasive species, imply the need to develop biological controls as a central feature to an IPM approach to ecosystem restoration; therefore, biological control was identified as one of the major work emphasis areas within FHTET.

FHTET Biological Control Program

The FHTET biological control program (FHTET-BC) is part of the broader Forest Service's National Strategy and Implementation Plan for Invasive Species Management as well as regional plans dealing with invasive species (e.g., Forest Service Non-native Species Eastern Plan).

The focus of the FHTET-BC is to promote the development and implementation of biological control as a viable component for integrated programs to prevent, detect, and manage invasive species (arthropods, plants, and pathogens).

The FHTET-BC Program encompasses four program elements: 1) leadership and coordination, 2) communication, education, and public awareness via publications and sponsoring of symposia/meetings, 3) developing scientific information and technology for control and management (containing and reducing existing infestations), and 4) pilot or demonstration projects for established species and a rapid response for area-wide management of potential invasive species. Obviously, program element 3 is emphasized, with attempts to establish at least one effective natural enemy as an IPM component for area-wide management of each selected pest species. Because invasive species are associated with disturbed habitats, rehabilitation and restoration (reclaiming native habitats and ecosystems) are the desired outcome of our efforts.

The FHTET-BC program benefits forest managers by providing assistance in:

- Increased awareness, training, and use of biological control,
- More coordinated and focused funding for biological control,
- Up-to-date information on native and non-native natural enemies for established and potential pest species, and
- Recommendations on the restoration of native plant species.

The success of the FHTET-BC program is based on leveraging limited FHTET operational funds with those of Forest Health Protection, International Programs, Vegetation Management and Protection Research, state and local governments, universities, and industry cooperators.

FHTET-BC Program – 1995 through 1999

The initial five years (1995 through 1999) of the FHTET-BC Program were devoted to a comprehensive overview of the past history of biological control attempts for established invasive forest pests and documenting those recently introduced pests that were appropriate for biocontrol. These reviews were published as were the results of four sponsored meetings, all of which provided the initial basis for initiation of projects beyond 1999.

Projects

The extensive list of established invasive species on U.S. forest and rangelands as well as potential new invasions required the FHTET-BC program to focus its resources on a few priority insect and weed species that appeared to have the greatest potential for biological control. In the U.S., program staff focused on strengthening ongoing biocontrol programs for arthropod species established in limited geographical areas (e.g., hemlock woolly adelgid and beech scale) with the specific management objective of searching for and establishing additional natural enemies for each selected invasive species. Also, we were requested to provide assistance in biological control efforts for pink hibiscus mealybug in Puerto Rico and *Sirex* woodwasp in several regions in Brazil. Species of invasive plants were selected for biological control based on their distribution and invasiveness (e.g., preventing or depressing the regeneration of native species or outcompeting native species after natural disturbance). An effort was initiated to develop a biological control program for mile-a-minute, an invasive weed from China and Japan that has infested limited areas of ten states in the Northeast but has the potential to spread to an additional 15 states.

The overseas exploration efforts to locate natural enemies of mile-a-minute and conduct host range tests on them were coordinated with Forest Service International Programs. Gary Man (Asian Pacific Coordinator) was an active supporter of the classical biological control approach to managing invasive species and provided many opportunities through his financial support and contacts in China.

Publications

1. Proceedings of the First Hemlock Woolly Adelgid Review. FHTET-96-10. June 1996.
2. Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the U.S.: A Review and Recommendations. FHTET-96-19. December 1996.
3. Classical Biological Control of Pest Insects of Trees in the Southern U.S.: A Review and Recommendations. FHTET-96-20. June 1997.
4. The Gypsy Moth Fungus *Entomophagia maimaiga* in North America. FHTET-97-11. June 1998.
5. Weed Biocontrol: Extended Abstracts from the 1997 Interagency Noxious Weed Symposium. FHTET-98-12. June 1998.
6. Biological Control of Forest Pests in the Western U.S.: A Review and Recommendations. FHTET-96-21. July 1998.
7. Pathogens and Microbial Control of North American Forest Insect Pests. FHTET-97-27. August 1998.
8. Training in the Control of *Sirex noctilio* by the Use of Natural Enemies (Portuguese and English). FHTET-98-13. October 1998.
9. Pink Hibiscus Mealybug (Spanish and English). Institute of Tropical Forestry. October 1998.

Meetings

1995 - First Hemlock Woolly Adelgid Review

1997 – "Biological Control in Natural Areas" at national meeting of the Entomological Society of America

1997 - Oregon Department of Agriculture Interagency Noxious Weed Symposium

1998 – Training in the Control of *Sirex noctilio*, Colombo, Brazil.

FHTET-BC Program – 2000 through 2004

The next five years (2000 through 2004) of the FHTET-BC Program continued publishing documents, sponsoring meetings, continuing ongoing biological control projects, and initiating new projects to manage invasive species in forest ecosystems. One of the publications, Biological Control of Invasive Plants in the Eastern U.S., was a book dealing with a review of the history of biological control for 25 species of invasive plants in the eastern U.S.

Projects

Major progress was made in searching for, locating, and importing natural enemies of hemlock woolly adelgid to U.S. quarantine facilities, and then mass-rearing, releasing, and monitoring these natural enemies for establishment and impacts. Two species of coccinelids (*Sasajiscymnus tsugae* and *Scymnus sinuanodulus*) and a derodontid (*Laricobius nigrinus*) were released in the U.S. for control of hemlock woolly adelgid. These natural enemies were recovered from hemlock woolly adelgid populations in Japan, China, or British Columbia. Efforts to locate parasitoids of beech scale were not successful. Natural enemies of pink hibiscus mealybug and *Sirex* woodwasp were released and established in Puerto Rico and Brazil, respectively. Classical biological control efforts were initiated for emerald ash borer, ambermarked birch leafminer, and elongate hemlock scale.

Classical biological control efforts were initiated for four additional invasive plants: kudzu, Japanese knotweed, garlic mustard, and tree-of-heaven. A weevil from China, *Rhinoncomimus latipes*, that feeds on mile-a-minute was approved for release in the U.S. in 2003; releases of this weevil were made in New Jersey and Delaware in 2004. The weevil successfully established itself at all release sites and is spreading.

International Programs continued to provide much needed financial assistance in support of foreign exploration and host range testing at overseas institutions.

Publications

1. Host Specificity Testing of Exotic Arthropod Biological Control Agents - The Biological Basis of Host Range Testing, in Proceedings of the Xth International Symposium on the Biological Control of Weeds. FHTET-99-01. August 2000.
2. Guide to Common Natural Enemies of the Nantucket Pine Tip Moth. FHTET-2001-02. May 2001.
3. Biological Control of Invasive Plants in the Eastern U.S. FHTET-2002-04. August 2002.
4. Biology and Biological Control of Knapweed. FHTET-2001-07. Revised April 2003.
5. Proceedings of the First International Symposium on Biological Control of Arthropods. FHTET-2003-05. June 2003.
6. Biology and Biological Control of Yellow Starthistle. FHTET-98-17. Revised July 2003.
7. Hemlock Woolly Adelgid. FHTET-2001-03. September 2003.

8. Invasive Plants of the Eastern United States – Identification and Control. FHTET-2003-08. November 2003 – CD ROM only.
9. Emerald Ash Borer Research Review. FHTET-2004-02. January 2004
10. Hemlock Woolly Adelgid Biological Control Committee Meeting. FHTET-2004-08. April 2004.
11. Biology and Biological Control of Purple Loosestrife. FHTET-2004-12, August 2004.
12. Biological Control of Hemlock Woolly Adelgid. FHTET-2004-04. August 2004.
13. Assessing Host Ranges for Parasitoids and Predators used for Classical Biological Control: a Guide to Best Practice. FHTET-2004-03. September 2004.
14. Invasive plants of Asian origin established in the United States and their natural enemies–Vol 1. FHTET-2004-05. September 2004.

Symposia/Meetings

2002 – First International Symposium on Biocontrol of Arthropods–Hawaii

2002 – Second Hemlock Woolly Adelgid Review–New Brunswick, New Jersey

2003 – Emerald Ash Borer Research and Technology Development Meeting–Detroit, Michigan

2004 – Hemlock Woolly Adelgid Biological Control Working Group–Annapolis, Maryland

2004 – Emerald Ash Borer Research and Technology Development Meeting–Port Huron, Michigan

FHTET-BC Program – 2005 through 2007

The program focus continued publishing documents, sponsoring meetings, and implementing biological control projects. In 2007, two new biological control efforts were initiated for hawkweeds in Alaska and Chinese privet in the southeast U.S.

Publications

1. Emerald Ash Borer Research Review. FHTET-2004-15. January 2005.
2. Third Symposium on Hemlock Woolly Adelgid in the Eastern United States. FHTET-2005-01. June 2005.
3. Spatial Pattern Relationships between Emerald Ash Borer Larvae and Their Natural Enemies. 2005. *Chinese Journal of Applied Ecology* 16:1427-1431.
4. Proceedings of the Second International Symposium on Biological Control of Arthropods. FHTET-2005-08. September 2005.
5. Proceedings of the Garlic Mustard and Buckthorn Conference. FHTET-2005-09. September 2005.

6. Biology and Biological Control of Toadflax. FHTET-2005-07. October 2005.
7. Catalogue of Introductions of Pathogens and Nematodes for Classical Biological Control of Insects and Mites. FHTET-2005-05. October 2005.
8. First Recorded Parasitoid from China of *Agrilus planipennis*: a New Species of *Spathius* (Hymenoptera: Braconidae: Doryctinae). 2005. *Annals of the Entomological Society of America* 98:636-642.
9. Invasive Plants Found in Asia and Established in the United States and Their Natural Enemies–Vol 2. FHTET-2005-15. March 2006.
10. Biology and Biological Control of Leafy Spurge. FHTET-2005-07. September 2006.
11. Biological Control Agents of Noxious Weeds – Identification Cards. FHTET-2006-05. September 2006.
12. A New Species of Emerald Ash Borer Parasitoid from China in the Genus *Tetrastichus* Haliday (Hymenoptera: Eulophidae). 2006. *Proceedings of the Entomological Society of Washington* 108:550-558.
13. Relationships between the Emergence and Oviposition of Ectoparasitoid *Spathius agrili* Yang and its Host Emerald Ash Borer, *Agrilus planipennis* Fairmaire. 2006. *Acta Ecologica Sinica* 26:1103-1109.
14. Biological Control of Invasive Plants through Collabaration between China and the United States of America; a Perspective. 2006. Biological Invasions 8:1439-1450.
15. Parasites and Invertebrate Predators of Forest Pests in China (English and Chinese). China Forestry Publishing House. December 2006.

Planned Publications

1. Emerald Ash Borer and Asian Longhorned Beetle Research Review. FHTET-2005-16. January 2007.
2. Diseases of Forests in China (English and Chinese). China Forestry Publishing House. August 2007.
3. Control of Pests and Weeds Using Natural Enemies (Spanish and English). FHTET-2007. August 2007.
4. Biology and Biological Control of St. Johnswart. FHTET-2007. October 2007.
5. Invasive Plants of the Western United States – Identification and Control. FHTET-2007. December 2007 – CD ROM only.
6. Guide to the Species of *Spathius* in North America. December 2007.
7. Effects of Host Size on the Sex Ratio, Oviposition, and Size of *Spathius agrili*, an Ectoparasitoid of Emerald Ash Borer. 2007.

8. Determination of the Host Specificity of the Parasitoid *Spathius agrili* Yang (Hymenoptera: Braconidae). 2007.
9. Research on Cold Hardiness of Emerald Ash Borer and its Two Parasitoids, *Spathius agrili* Yang and *Tetrastichus planipennisi* Yang. 2007.
10. Biology of a New Parasitic Braconid, *Spathius agrili* Yang, in China. 2007.

Symposia/Meetings

2005 – Emerald Ash Borer Research and Technology Development Meeting – Pittsburgh, Pennsylvania

2005 – Second International Symposium on Biocontrol of Arthropods - Switzerland

2005 – Third Symposium on Hemlock Woolly Adelgid in the Eastern USA – Asheville, North Carolina

2006 – Mile-A-Minute Biological Control Research/Application Meeting – Newark, Delaware

2006 – Japanese Knotweed Workshop – Ithaca, New York

2006 – Emerald Ash Borer and Asian Longhorned Beetle Research and Technology Development Meeting – Cinncinati, Ohio

Planned Symposia/Meetings

2007 – Hemlock Woolly Adelgid Biological Control Working Group: January 2007, Annapolis, Maryland

2007 – Workshop on Invasive Species of Forests in the U.S. and the People's Republic of China (focus: biological control): September 2007, Beijing, China

2007 – Workshop on Biological Control of Invasive Species of Forests, as part of a meeting of Mexican Forest Pest Control group: November 2007, Agnascalientes, Mexico

Major progress was made in 2005 and 2006 in the continued search for natural enemies as well as in rearing, host range testing, and release of additional natural enemies.

Existing Projects–Arthropods

Amber-marked birch leafminer (*Profenusa thomsoni*) (Hymenoptera: Tenthredinidae)

The amber-marked birch leafminer, a sawfly, was accidentally introduced from Europe to North America early in this century. It is a serious pest of native and introduced birches (*Betula* spp.) in western Canada and, more recently, in the areas around Anchorage and Fairbanks, Alaska. A holarctic ichneumonid parasitic wasp, *Lathrolestes luteolator* was discovered attacking larval *P. thomsoni* in Alberta, Canada, and dramatically reduced populations of the sawfly. FHTET is assisting in establishment of this parasitoid in Alaska. Small numbers of this wasp were collected in Canada and released in 2004 and in 2005 at one site in Anchorage. The poor survival rate of the parasitoid in the overwintering leafminers has been the major impediment to collecting a sufficient number of wasps for release in Alaska.

In 2006, a University of Massachusetts graduate student was assigned to the project and stationed in Anchorage for the field season. Releases of *L. luteolator* were made at two new sites in Anchorage. Also, several new methods were used to increase survival of the overwintering parasitoids as well as for collection of larger numbers of parasitoid adults in Canada for direct release in Alaska. In 2007, the three release sites will be monitored for parasitoid establishment and impact on sawfly populations. Also, additional collections of parasitized larvae and adult parasitoids will be made in Canada.

Major cooperators: FHP R-10, Canadian Forest Service, University of Alberta, Alaska Department of Natural Resources, and the University of Massachusetts.

USDA Forest Service

Beech scale (*Cryptococcus fagisuga*) (Homoptera: Eriococcidoe)

The beech scale attacks the bark of American beech, *Fagus grandifolia,* introducing a pathogen causing beech bark disease that can result in significant beech mortality. This disease is a fungus complex consisting primarily of *Nectria coccinea* var. *faginata* and sometimes *N. galligena*. FHTET, in cooperation with the University of Massachusetts and CABI Bioscience, has surveyed China, Japan, Iran, Iraq, Turkey, Bulgaria, and India for parasitoids and pathogens of the scale. We have not located any parasitoids, and fungal pathogens collected over the past several years as well as the commercial mycopesticides Vertalac and Mycotal are being evaluated in laboratory trials. Endophytic *Trichoderma* isolates collected from beech are aggressive to both the North American and European isolates of the beech bark disease pathogen. In 2007, FHTET's contributions for continued evaluation of the pathogens will come to an end, but CABI-Bioscience will continue to pursue development of a viable control option.

Major cooperators: CABI-Bioscience and the University of Massachusetts.

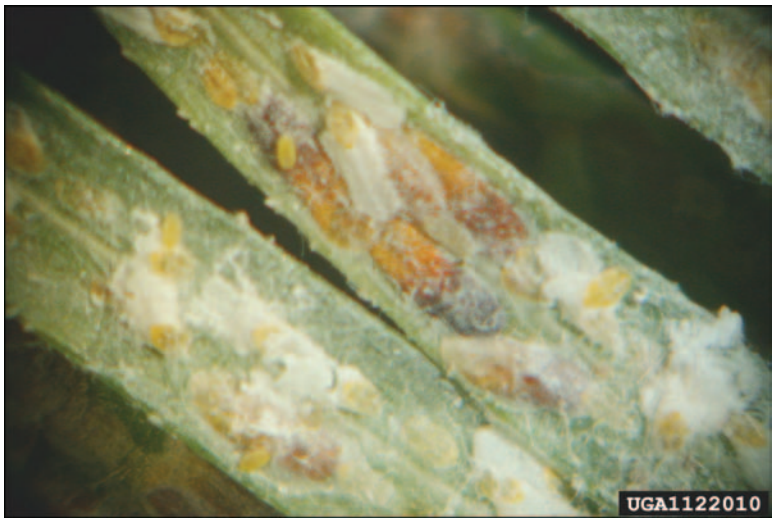
USDA Forest Service

Elongate hemlock scale (*Fiorinia externa*) (Hemiptera: Diaspididae)

The elongate hemlock scale (EHS) is an invasive pest of hemlock, *Tsuga* spp., and other coniferous species of ornamental and forest trees. The principal host plants include Canadian or eastern hemlock, *T. canadensis*; fir, *Abies* spp.; and spruce, *Picea* spp. This pest also feeds on cedar, *Cedrus* spp.; Douglas-fir, *Pseudotsuga menziesii*; pine, *Pinus* spp.; and yew, *Taxus* spp., but these are not preferred hosts. It is believed that this scale was unintentionally introduced into the United States from Japan. It was first observed in Queens, New York, in 1908. This pest occurs in Connecticut, Maryland, Pennsylvania, Massachusetts, New Jersey, New York, Ohio, Rhode Island, Virginia, North Carolina, and Tennessee.

A small parasitoid wasp (*Encarsia citrina*), a lady beetle (*Chilocorus stigma*), and several species of lacewings are natural enemies of this scale insect that provide some population reduction in the eastern U.S. Several studies were initiated to document the biology and life history of EHS, assess the status of EHS infestation in eastern North America, and determine whether a classical biological control program is merited. In addition, FHTET conducted surveys in Japan for natural enemies of this pest with help from The University of Massachusetts and the Osaka Museum in Japan. As a result, several species of parasitoids were identified, collected, and placed in quarantine facilities in the U.S. DNA of the most common species, *E. citrina*, from Japan is being compared to that of *E. citrina* from the U.S. to determine whether or not they are the same species.

Major cooperators: University of Massachusetts, University of Tennessee, University of Maryland, University of Vermont, and the Osaka (Japan) Museum of Natural History.



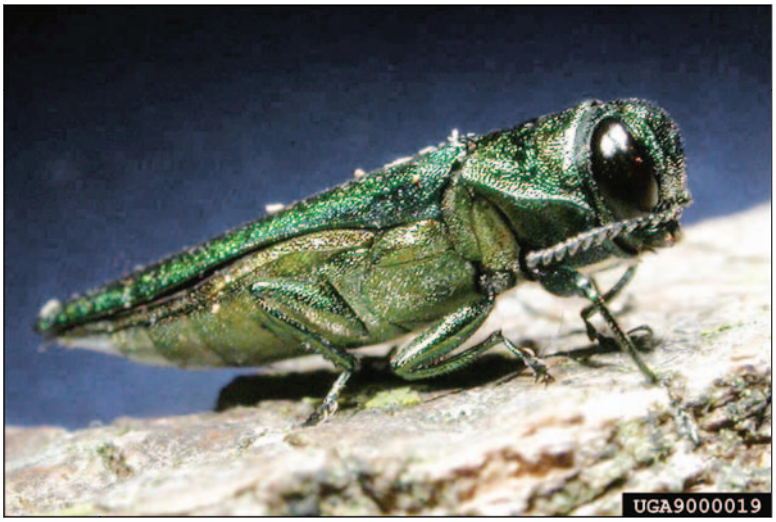
Eric R. Day

Emerald ash borer (*Agrilus planipennis*) (Coleoptera: Buprestidae)

The emerald ash borer (EAB) is a newly reported (summer 2002) pest from Asia that has killed 6-10 million ash (*Fraxinus*) trees in the U.S. It has expanded its range in Michigan, and populations are now established in Ohio, Indiana, Illinois, and Maryland. The EAB population in the U.S. has yet to be delimited as current infestations are the result of the movement of regulated articles.

The USDA Forest Service (FHTET) and APHIS are part of a cooperative effort with the Chinese Academy of Forestry to find natural enemies of this pest in China. Three species of parasitoids (*Spathius agrili*, *Tetrastichus planipennisi*, and *Oobius* sp.) have been collected in China and are in quarantine facilities in the U.S. Depending on the results of host range tests, all three parasitoids are planned for release in the U.S. in 2007 or 2008.

Major cooperators: USDA APHIS, Michigan State University, Chinese Academy of Forestry, and USDA Forest Service–Research and Development.



David Cappaert

Hemlock woolly adelgid (*Adelges tsugae*) (Homoptera: Adelgidae)

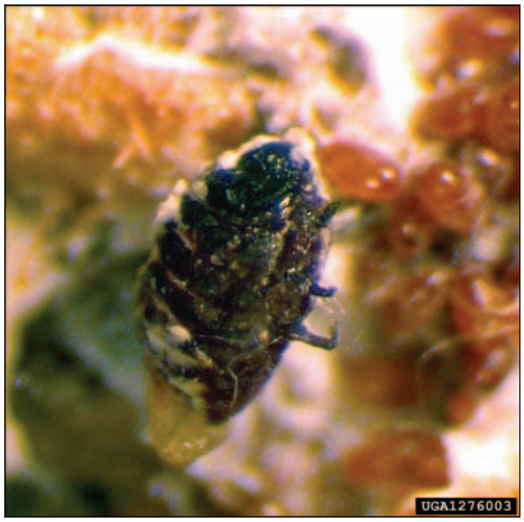
The hemlock woolly adelgid is believed to be a native of Asia (probably of Japan) and was first recorded in the United States in 1924. It is a serious pest of eastern and Carolina hemlocks. In the eastern United States, it is present from the Smoky Mountains north to the mid-Hudson River Valley and southern New England.

FHTET's cooperators are assisting in the evaluation and effectiveness of several predators in U.S. quarantine facilities and also in international exploration for additional predators of this pest in China and Japan. Predators that may prove useful include: *Laricobius nigrinus*, *Sasajiscymnus tsugae*, *Scymnus camptodromus*, *Scymnus sinuanodulus*, and *Scymnus ningshanensis*.

In 2005, another coccinalid (*Scymnus ningshanensis*) was released in the U.S. for ccontrol of hemlock woolly adelgid. In the same year, an accelerated cooperative effort was funded (Sino-U.S. Cooperative Project for Biological Control of the Hemlock Woolly Adelgid in the People's Republic of China–2005 through 2007) to collect additional predators in Asia. In 2006, an additional eight species of coccinelids were shipped from China to the quarrantine facility in Ansonia, Connecticut.

In 2006, a new species of *Laricobius* was recovered in Japan and a colony established at the quarantine facility at the Virginia Polytechnic Institute and State University. This species appears to be easier to rear and more cold-tolerant than *L. nigrinus*. In 2007, all predators will be reared and released at various sites in the eastern U.S.

Major cooperators: Virginia Polytechnic Institute and State University, University of Massachusetts, Forest Service–Forest Health Protection and Research and Development, Osaka (Japan) Museum of Natural History, Oregon State University, China State Forestry Administration, Chinese Academy of Agricultural Sciences, Beijing Academy of Agricultural and Forestry Sciences, and the Sichuan Academy of Forestry.



Michael Montgomery

Existing Projects–Plants

Garlic mustard (*Alliara petiolata*)

Garlic mustard was introduced from Europe for medicinal use in the 1800s and first escaped in 1868 on Long Island, New York. Garlic mustard is one of the most serious invaders in forested areas of the Northeast and Midwest and is able to invade and dominate the understory of North American upland and floodplain forests, both in shaded areas and in open woods and savanna, and not just disturbed areas.

Natural enemies collected in Europe are being evaluated in Europe and at the University of Minnesota quarantine facility to determine their host ranges. The most promising herbivores are four species of weevils: *Ceutorhynchus constrictus*, *C. alliariae, C. scrobicollis*, and *C. roberti*. The individual and combined impact of these species can increase rosette mortality and reduce seed output, stem height, and overall performance of garlic mustard. The host range testing for *C. scrobicollis* (a root feeder) is nearly complete, and the petition for its release is being reviewed by the Technical Advisory Group. The release of *C. scrobicollis* is planned for 2007. Two of the other species of weevils are being reared in quarantine at the University of Minnesota and host range testing is ongoing.

Major cooperators: University of Minnesota, CABI-Bioscience, Cornell University, and the New Jersey Department of Agriculture.

Chris Evans

Japanese knotweed (*Polygonum japonica*)

Japanese knotweed was introduced from Asia to North America in the late 19th century as an ornamental. It is a dense-growing shrub that reaches heights of 10 feet, spreads quickly, and forms dense thickets that exclude native species. It invades disturbed areas with high light, such as roadsides and stream banks. It is extremely difficult to eradicate due to its extensive rhizome system. The dense patches produce shade and displace other plant life and reduce wildlife habitat. This weed is having a major impact in riparian areas associated with salmon restoration.

Few natural enemies have been recovered from knotweed in the United States, while in Japan, there are at least 12 species of insect herbivores commonly found on this plant and many more species recorded. Surveys are continuing in Japan and several herbivores and pathogens are being reared at the CABI quarantine facility in England. In 2006, the leaf-feeding chrysomelid beetle *Gallerucida bifasciata* was shipped from the CABI quarantine facility to the quarantine facility at Oregon State University. Host range testing will begin for this promising species. In 2006, a limited survey for natural enemies of Japanese knotweed was initiated in China. Two herbivores causing extensive damage to knotweed were recovered. Host range testing will begin in China for these two species as well as a continuation of surveys throughout appropriate areas in China.

Major cooperators: Oregon State University, University of Washington, CABI-Bioscience, and Cornell University.

Leslie Seiger

Kudzu (*Pueraria montana* var. *lobata*)

Kudzu is a climbing deciduous vine capable of reaching lengths of 35 to 100 feet. Kudzu is easily identified when it grows as a large dense mat of vines, its usual growth form. It is found in open areas such as road sides, right-of-ways, forest edges, and old fields, where it grows over, smothers, and kills all other vegetation, including trees. Kudzu is native to Asia and was first introduced into America in 1876 at the Philadelphia Centennial Exposition as a potential forage plant. Later, it was widely planted throughout the eastern United States to control erosion.

Over 200 species of natural enemies have been recovered from kudzu in China. Various leaf-feeding beetles and sawflies have been collected and evaluated for host range in China. Two of the most promising species are being reared in quarantine facilities in the U.S. Unfortunately, the most promising species in quarantine (*Gonioctena tredecimmaculata*) also feeds on soybeans. Attempts to ship a previously recovered root feeder to quarantine facilities in the U.S. were unsuccessful, and efforts to transport the insect will be initiated again in 2007.

Major cooperators: North Carolina Department of Agriculture, University of Delaware, University of Tokyo (Japan), and the Chinese Academy of Sciences.

John D. Byrd

Mile-a-minute (*Polygonum perfoliatum*)

Mile-a-minute is native to eastern Asia and the Philippines and was introduced inadvertently several times into the United States from the late 1800s to the 1930s. Mile-a-minute is a vine that invades open, disturbed areas, such as fields, forest edges, roadsides, ditches, and stream banks, in the northeastern United States. Its rapid growth allows it to cover existing vegetation and restrict light availability, which can lead to plant death.

FHTET has sponsored surveys for native natural enemies of mile-a-minute at several sites in five states. By the end of the 2000 field season, more than 1,500 arthropods, representing 100 insect species in 50 families and seven orders, were recovered from mile-a-minute. None of the native species of natural enemies alone are effective in suppressing mile-a-minute populations. Insects that attack the seeds or roots have not been recovered.

A weevil, *Rhinoncominus latipes,* recovered from mile-a-minute in China was tested and then released in 2004 in Delaware, New Jersey, and West Virginia; the weevil has established populations at all release sites. In 2005 and 2006, the weevil was released in Pennsylvania, Delaware, Maryland, West Virginia, and New Jersey. In 2007, the weevil will be released at additional sites in these states and in Ohio and Connecticut. Monitoring for weevil presence and host damage will be conducted at all previous release sites.

Major cooperators: New Jersey Department of Agriculture, University of Delaware, Chinese Academy of Agricultural Sciences, University of Tokyo (Japan), Letterkenny Army Depot, and Codorus State Park (Pennsylvania).

USDA APHIS

Tree-of-heaven (*Ailanthus altissima*)

Tree-of-heaven, native to Asia, was first introduced into the United States in 1748 by a Pennsylvania gardener. It was widely planted tree in cities because of its ability to grow in poor conditions. It is extremely tolerant of poor soil conditions and thrives in disturbed forests or edges. Dense clonal thickets displace native species and can rapidly take over fields and meadows.

Surveys for natural enemies are ongoing in China. Two species of weevils are important natural enemies of tree-of-heaven and have been damaging trees planted in cities as part of China's beautification program. In 2005 and 2006, the weevil *Eucryptorrhynchus brandti* was shipped to the quarantine facility at Virginia Polytechnic Institute and State University (VPI) and the other weevil (*E. chinensis*) will be shipped in 2007. A laboratory colony of *E. brandti* was established and host range testing initiated at VPI. In 2006, a plant list for host range testing was submitted to the Technical Advisory Group.

Major cooperators: Virginia Polytechnic Institute and State University and the Chinese Academy of Agricultural Sciences.

Chuck Bargeron

New Projects–Plants

In 2007, a new initiative will determine the potential for development of a biocontrol program for hawkweeds in Region 10 (Alaska). The project will initially focus on a review of the biocontrol literature and identification of the most effective natural enemies as well as identification of the various habitats in Alaska occupied by hawkweeds. Plots for monitoring hawkweeds and their native natural enemies will be established in at least two regions of Alaska.

Another new initiative will be the continuation of an IPM program for Chinese privet initiated by the Southern Research Station in the southeastern U.S. The project will focus on expanding the biocontrol component, including additional searches for natural enemies in China as well as host range testing and laboratory rearing of natural enemies already in laboratories in China. Plots for monitoring Chinese privet have been established by the Southern Research Station.

SUMMARY

There are numerous organizations and regulations in place to deal with non-native invasive species and much progress is being made in identification of introductive pathways, preparation of risk maps, and attempted identification of the "worst" invasive species threatening North America. Unfortunately, there are no accurate scientifically-based methods to determine which species will be the "worst" invasive in North America. Also, there is only minimal funding available for developing management tactics for these non-native invasive species once they are established in North America.

The Forest Health Technology Enterprise Team biological control program for invasive species was initiated in 1995. From 1995 through 1999 the program was devoted to reviewing the past history of biological control attempts for invasive forest pests and documenting which new pests were appropriate candidates for biocontrol. The program from 2000 through 2004 focused on publishing documents, sponsoring meetings, and continuing classical biological control efforts for insect and weed pests. In 2005 and 2006, the program continued to develop publications and continue existing classical biological control efforts.

The release of the weevil *Rhinoncominus latipes* for mile-a-minute has been a huge success, as the weevil has established overwintering populations at all release sites, spread to nearby sites, and affected plant populations. Also, laboratory rearing of the weevil and the collection of adults from field insectaries continues to provide weevils for release at additional sites.

The pending release of three species of natural enemies for emerald ash borer and a weevil for garlic mustard are major steps toward possible biocontrol of these pest species. The establishment of the wasp *Lathrolestes luteolator* in Alaska is a major success, and it is hoped that the wasp will spread and impact birch leafminer populations. Unfortunately, our efforts for beech scale and kudzu have not been productive and probably will be terminated in 2007, respectively.

In 2007, two workshops are planned: the first workshop in China will focus on cooperative efforts to use biocontrols to manage invasive species both in China and in the USA. The second workshop will be held in Mexico and will focus on the use of biological controls for forest pests and a Spanish and English version of a FHTET biological control handbook will be distributed at the meeting. The handbook will also be available to biological control scientists, pest managers, etc. throuout Spanish-speaking countries.

REFERENCES

Office of Technology Assessment (OTA). 1993. Harmful non-indiginous species in the United States. United States Congress, Washington D.C.

Pimentel, David, Lori Lach, Rodolfo Zuniga, and Doug Morrison. 2000. Environmental and Economic Costs Associated with Non-Indigenous Species in the U.S. *BioScience* 50:53-65.