12 Oct2000

Special Technology Development Program
New Project Proposal

PROJECT NUMBER: NA-2001-05 New Proposal

PROJECT TITLE: Field evaluation and establishment of the lady beetle, *Scymnus ningshanensis*, for biological control of the hemlock woolly adelgid

PROJECT STATUS: New-not previously funded

EXPECTED PROJECT DURATION: 2 years

EXPECTED COMPLETION DATE OF THE PROJECT: Sept 30, 2002

SUBJECT: (mark all that apply using 1 for primary category and 2 for secondary categories):
Biological Control_1_ Invasive Species_1_ Methyl Bromide Alternatives___ Models___ Monitoring___ Organism Biology___ Pesticides: Microbial ___ Pesticides: Synthetic___ PTIPS___ Population___ Risk and Hazard___ Remote Sensing___ Semiochemicals___ Silvicultural Technology___ Social Values___ Spray Technology___
Other_____

STATUS OF SUBJECT SPECIES: The hemlock woolly adelgid is a non-native noxious pest, currently spreading and causing increasing mortality of eastern hemlock.

PROJECT OBJECTIVES: (1) Define an optimal strategy for release of *Scymnus ningshanensis*; **(2)** define the effectiveness of this lady beetle under various environmental conditions; **(3)** produce sufficient numbers of predators for mass releases in 2003.

BRIEF DESCRIPTION OF PROJECT: In Spring 2001, *S. ningshanensis* will be caged on HWA-infested hemlock branches to determine the impact of the predator on different densities of HWA. The laboratory colony of beetles will be increased 10-fold. In the Fall, adult beetles will be placed in large screen cages to evaluate overwintering and the onset of activity and oviposition in Spring 2002. In 2002, additional lady beetles will be released to determine optimal release timing and conditions. Mass rearing in the laboratory will be initiated, including producing an additional generation during the winter. Mass releases for the purpose of establishing this predator of HWA are anticipated in 2003, but this is not part of this proposal because specific resource needs are not defined at this time.

FHP LEAD CONTACT:

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Dennis Souto	S&PF, NA, FHP, Durham	603-868-7717, dsouto@fs.fed.us

PRINCIPAL INVESTIGATOR(S):

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Michael Montgomery	FS Research, NERS, Hamden	203-230-4331, memontgomery@fs.fed.us

COOPERATORS:

Name	Affiliation (Office or Dept.)	Phone, E-mail, Fax
Joseph Elkinton	Univ. of Mass, Amherst	413-545-4816 elkinton@ent.mass.edu

COOPERATOR INVOLVEMENT:

Name	Role	Time Commitment
Joseph Elkinton	data collection, numerical impact analysis	10%, student 50%

JUSTIFICATION: Biological control is considered by the Strategic Plan of the S&PF Hemlock Woolly Adelgid Working Group as the best option for reducing the mortality of hemlocks in the eastern U.S.

caused by the hemlock woolly adelgid. Also, the working group recognizes that a multiple species complex will be necessary to achieve desirable management of the adelgid.

URGENCY: The hemlock woolly adelgid currently infests ten eastern states and has potential to spread to the entire range of the eastern hemlocks. Hemlock mortality in heavily infested stands ranges from 36 to 86 percent and impacts on hemlock forests will intensify and spread unless effective management is implemented.

NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITY (check one):

Priority 1: __ Priority 2: __ Priority 3: __ Priority 4: __

TECHNICAL COMMITTEE DEVELOPMENT PRIORITY (check one):

Priority 1: __ Priority 2: __ Priority 3: __ Priority 4: __

Priority 5: __ Priority 6: __ Priority 7: __ Priority 8: __

SCOPE OF APPLICATION: Establishment will first be made in MA in newly infested areas. Once established, the control will remain forever. Eventually, through natural means or augmentation, the control will spread through the entire area of HWA infestation.

RESEARCH BASIS: Several predators have been described in China that attack the hemlock woolly adelgid (HWA) (Wang et al. 1997, Montgomery et al. 2000). Lady beetles are the most diverse and abundant predators of HWA in China; 54 species were collected, of which 26 were new to science (Yu et al. 2000). Three of these lady beetles have been imported and studied extensively.

Considerable information has been gathered for one species, *Scymnus sinuanodulus*, including its host range (Montgomery et al. 1997) and biology (Lu and Montgomery in press). Field evaluations (Havill and Montgomery 2000) indicate that it can significantly reduce HWA populations. This research, sponsored in part by STDP (NA-1997-01), has developed and tested methods of quantifying the numerical impact of predators on HWA, which will be used and refined in the project. Unfortunately, *S. sinuanodulus* has been extremely difficult to mass rear. Work is continuing to solve the rearing problem and hopefully it can be mass released in 2002.

Scymnus ningshanensis, the subject of this proposal, was imported from China only two years ago. Its biology is similar to *S. sinuanodulus*, but its larvae develop faster and it has a stronger numerical ovipositional response to prey density. Both traits are advantageous in biological control organisms. It has been easier to rear and maintain laboratory colonies of this species. Moreover, we have induced it to oviposit in the fall after a short cold-period; hence, we may be able to rear two generations per year even though it is univoltine.

More than 400,000 of the lady beetle, *Pseudoscymnus tsugae*, from Japan have been released since 1995 at more than 20 locations for control of HWA. This beetle is considered established in several areas and has reduced local HWA populations (McClure et al. 2000), but the overall impact is difficult to quantify and may be insufficient. Based on the diversity of predators that attack HWA and other *Adelges* spp. in their native ranges, it is likely that a complex of several predators will be needed to reduce HWA to innocuous levels in eastern forests (NA-FHM Strategic Plan for HWA Biological Control).

The cost to date to establish *P. tsugae* is estimated to be more than $1 million. This proposed project will evaluate *S. ningshanensis* in field cages to establish optimal release conditions and to document its efficacy. Using this information, fewer well-timed and well-placed releases can be made to establish this predator and documentation can be obtained to verify the desired results.

METHODS: Field studies of numerical response will confine individual, mated female beetles in sleeve cages on HWA-infested branches using techniques previously developed. Treatments will be placed over a range of HWA densities per 1 m^2 branch. Each treatment and appropriate controls will be replicated 25 times. Data analyses will range from simple one-way analysis of variance to multiple regressions with covariates such as tree condition and number of beetle progeny per female. This experiment will tell us the

range of densities at which the predators are effective to help target future releases to maximize beetle impact.

In fall 2001 (mid-October) beetles will be placed in large screen houses covering individual small hemlock trees for overwintering. Twenty-five or 50 beetles will be placed in each of 10 screen houses. Beginning very early in the spring (end of February 2002), they will be checked weekly for onset of beetle feeding and ovipositional activity. This experiment will tell us what time of year future beetle releases should be made. A free release of 5,000 beetles will be made in Spring 2002 to validate release protocols.

Mass rearing capability will be increased by producing beetles during the winter as well as the spring. In the past we have produced only one generation per year because adult beetles require a cold period before laying eggs. In addition, newly hatched larvae of this lady beetle require HWA eggs for development and adult beetles will only oviposit if fresh HWA eggs are present. Because of this, a nearly constant supply of hemlock foliage with HWA eggs is required for mass rearing but HWA only lays eggs at two distinct times in early spring and mid-summer. We can remedy this by bringing infested foliage indoors in the spring and storing it at 5° C for up to 6 months and by collecting foliage in the fall and winter and holding it at 10 or 15° C to stimulate HWA to produce eggs. New adult beetles will be stimulated to produce eggs in both spring and fall by giving them sufficient cold treatments. Supplemental artificial diet will be provided to increase survival of new adults. Beetles will be monitored for disease and measures taken to reduce possible disease transmission. Adult beetles can be held for long periods at 10° C by supplementing their natural food and water with artificial diet. These improvements in our methods will allow us to produce sufficient numbers of beetles for mass releases.

MEASURES OF SUCCESS:

Standard of Success: (1) Methods developed and information obtained for optimal release strategy; (2) Sufficient predators reared for future work and establishment.

Expected Outcomes: (1) Reliable methods to release predators for establishment; (2) Three thousand predators for release in 2002; (3) Additional predators reared for distribution to others in 2003.

Implementation of Products/methods: (1) Methods and information on numerical response will be reviewed by the scientific community and published; (2) Methods for release and establishment will be transferred to forest protection through demonstration and written protocols; (3) Predators will be transferred to other rearing facilities for rearing and to forest protection personnel for release.

PRODUCTS AND DUE DATES: Environmental Assessment completed and reviewed by public, FONSI issued – February 2001; Methods development progress – October 2001; Methods for release finalized – September 2002; Distribution of predators/release methods – March 2003.

PUBLICATIONS: There will be 2 or more publications in scientific journals on the numerical response and feeding effectiveness of the predator. At least one presentation will be given each year at a joint meeting of research and forest protection personnel.

TECHNOLOGY TRANSFER: The initial release will be a joint effort in which we physically participate (hands-on, one-on-one transfer). Additionally, written protocols are provided. We will assist in initial survey and evaluation of predator releases. Rearing technology will be transferred by written protocols and demonstration at our insect rearing facility.

LONG-TERM BUDGET REQUEST:

	Item	Requested FHP STDP Funding	Other-Source Funding	Source
FIRST YEAR				
Administration	Salary	$22,000	$52,000	NE-4501 OP
	Overhead		$11,928	NE-4501
	Travel	$ 4,000		
				NE-4501 OP
Procurements	Contracting			
	Equipment			
	Supplies	$ 1,000	$ 4,000	NE-4501 OP
Year Totals		**$27,000**	**$67,928**	
SECOND YEAR				
Administration	Salary	$50,000	$20,000	NE-4501 OP
	Overhead		$ 7,668	NE-4501
	Travel		$ 4,000	NE-4501 OP
Procurements	Contracting			
	Equipment			
	Supplies		$ 4,000	NE-4501 OP
Year Totals		**$50,000**	**$43,668**	
PROJECT TOTALS		**$77,000**	**$111,596**	

Other sources represent contributions from NE-4501 operating budget and do not include research unit base funding for permanent salaries and operation of the insect rearing facility.

BENEFIT AND COST: Very favorable, 35:1

(See attached Production Function worksheet.)

LITERATURE, CITATIONS, ATTACHMENTS, etc.:

Havill Nathan P, Montgomery Michael E. 2000. Impact of a Chinese lady beetle on hemlock woolly adelgid: initial field cage study. p. 19 *In* Fosbroke SLC and Gottschalk KW, eds., Proceedings, USDA interagency research forum on gypsy moth and other invasive species; January 18-21, 2000; Annapolis, MD. General Technical Report NE-273. U.S. Department of Agriculture, Forest Service, Northeastern Research Station; Newtown Square, PA.

McClure Mark S, Cheah, Carol A SJ, Tigner, Timothy C. 2000. Is *Pseudoscymnus tsugae* the solution to the hemlock woolly adelgid problem?: An early perspective. p. 89-96 *In* McManus KA, Shields, KS, and Souto DR, eds., Proceedings: Symposium on sustainable management of hemlock ecosystems in eastern North America; June 22-24, 1999; Durham, NH. General Technical Report NE-267. U.S. Department of Agriculture, Forest Service, Northeastern Research Station; Newtown Square, PA.

McWilliams William H, Schmidt Thomas L. 2000. Composition, structure, and sustainability of hemlock ecosystems in eastern North America. p. 5-10 *In* McManus KA, Shields, KS, and Souto DR, eds., Proceedings: Symposium on sustainable management of hemlock ecosystems in eastern North America; June 22-24, 1999; Durham, NH. General Technical Report NE-267. U.S. Department of Agriculture, Forest Service, Northeastern Research Station; Newtown Square, PA.

Montgomery Michael E, Defu Yao, Wang Hongbin. 2000. Chinese Coccinellidae for biological control of the hemlock woolly adelgid: description of native habitat. p. 97-102 *In* McManus KA, Shields, KS, and Souto DR, eds., Proceedings: Symposium on sustainable management of hemlock ecosystems in eastern North America; June 22-24, 1999; Durham, NH. General Technical Report NE-267. U.S. Department of Agriculture, Forest Service, Northeastern Research Station; Newtown Square, PA.

Montgomery Michael E, Lyon Suzanne M, Lu Wenhua, Defu Yao, Wang Hongbin. 1998. Developing biological technology: evaluation of the feeding range of predaceous beetles. p. 28-34 *In* Resource technology 1997: Beijing international symposium proceedings. China Forestry Publishing House, Beijing.

Wang Hongbin, Defu Yao, Li Guangwu, Zhang Changhai, Li Li, Guo Hengxiao, Zhao Dingquan. 1998. Investigation on hemlock woolly adelgids and its natural enemies in China. p. 41-46 *In* Resource technology 1997: Beijing international symposium proceedings. China Forestry Publishing House, Beijing.

Van Driesche Roy G, Bellows Jr., Thomas S.1996. *Biological Control.* Chapman and Hall, New York. 539 p.

Yu Guoyue, Montgomery Michael E, Yao Defu. 2000. Lady beetles (Coleoptera: Coccinellidae) rom Chinese hemlocks infested with the hemlock woolly adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae). The Coleopterists Bulletin 54(2): 154-199.

Enclosure 2a

STDP PRODUCTION FUNCTION

PROJECT NUMBER: NA-2001-New Proposal

PROJECT COST: $188,596 (STDP request $77,000 + $111,596 other)

PROJECT OBJECTIVE: The objective of this project is to develop efficient methods to evaluate and establish biological controls for the hemlock woolly adelgid. A secondary objective is to produce predators for mass release. The goal of this project is to establish and document the impact of imported biological controls. The benefit that will be used in the economic analysis is reduced mortality of hemlock caused by HWA. Other benefits not included in the economic analysis are reduced costs of implementation and procedures to quantify efficacy.

ASSUMPTIONS: Thirty percent of hemlock growing stock is at risk (= 2.4 million acres or 3.8 cu. ft.). Hemlock is valued at $450/acre as pulpwood and $550/acre wildlife and recreation value (total = $1,000/acre). Initial treatments will be made on 5 one-acre plots and in 10 years the protected acreage will naturally increase to 36,917 (see table below for alternative calculation of benefit). A worst-case scenario is that only partial control is achieved and tree mortality is reduced from 100% to 75%. A 4%/year inflation factor is used to show cost at the end of the 10-year projection.

BACKGROUND DATA: Excluding the Lake States, 2.4 million acres of eastern forests are classified as hemlock, 80% of which is sawtimber size (McWilliams and Schmidt 2000). The stumpage value as timber averages only $450/acre. Intrinsic values for wildlife, water quality, and recreation are much higher. Less than 30% of the total acreage is currently infested by HWA. Mortality occurs gradually in infested stands but eventually all the hemlock dies. Once released and established, classical biological controls spread naturally across the entire infested area. Once established, biological controls are permanent. Historically, only about 16% of all biological control projects resulted in complete control, but at least partial control was achieved in 48% of the projects, but since cost/benefit ratios are high (3:1 to 100:1), classical biological control is considered a highly effective use of public funds (Van Driesche and Bellows 1996).

CALCULATIONS

EXPENDITURE & OUTPUT VALUES (EOV) WITHOUT PROJECT:

100% loss of 36,917 unprotected acres = $36, 917,000

EXPENDITURE & OUTPUT VALUES (EOV) WITH PROJECT:

75% loss of 36,917 protected acres = $27,687,000

BENEFIT (CHANGE IN EOV) ATTRIBUTABLE TO PROJECT:
B = $(with) - $(without) -- $9,230,000
($36,917,000 - $27,687,000 = $9,230,000)

BENEFIT/COST RATIO: 35:1
B/C = $(with) - $(w/o)
$(STDP cost) + $(treatment cost, where applicable)
$77,000/0.73 = $109,594 STDP + $111,596/0.73 = $152,871 other = $262,465
$9,230,000/$262,465 = 35.17

BENEFIT ATTRIBUTABLE TO STDP:
Benefit attributable to STDP funds = $(STDP cost) x (B/C)

$77,000 x 35.17 = $2,708,090

PNV OF PROJECT:
PNV of project = $(Benefit) - $(cost)

$9,230,000 - $262,465 = $8,967,535

PNV OF STDP:
PNV of project = $(Benefit attributable to STDP) - $(STDP cost)

$2,708,090 - $109,594 = $2,598,49

ADDITIONAL CALCULATION:

COST PER ACRE PROTECTED:
Benefits (acreage of hemlock protected from mortality caused by HWA) will increase yearly as the predator range spreads. The predators will spread at 1000 ft./year. Initial treatments will be done on a one-acre plots releasing 3,000 predators. The following table gives the yearly increase in acreage protected and the cost/acre adjusted at 4% inflation rate.

Year	Protected Acres	Cost/Acre
1	5	$188,596.00
2	450	$2,179.35
3	1,615	$631.55
4	3,505	$302.65
5	6,115	$180.40
6	13,495	$85.00
7	18,270	$65.30
8	23,760	$52.25
9	29,985	$43.05
10	36,917	$36.35

This cost/acre is comparable to the cost of aerial applications with conventional pesticides. However, this cost also includes the cost of developing the technology and documenting efficacy. The predators can be produced and released at a cost of about $1.00 each. Thus, the cost of subsequent releases would be $3,000 or $0.58/acre at year 10. Assuming that tree mortality is reduced only 25% by the release of the biological control would be 43:1.