

Knotweed Biological Control Program FY2016: Phenology and Voltinism Modelling, Permits, and Release Preparation

Principal Investigator

Fritzi Grevstad, Assistant Professor (Senior Research), Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331. Dr. Grevstad will oversee the completion of all objectives of this proposal and will provide progress and final reports.

Cooperators and Other Participating Institutions

Eric Coombs, Oregon Department of Agriculture will help in the planning and preparing for biocontrol agent releases and will provide space for mass rearing insects at the Oregon State Department of Agriculture Greenhouse.

Jennifer Andreas, Washington State University Extension will assist in release and monitoring efforts in the State of Washington.

Amount Requested: Year 1: \$42,515

Project Leveraging: Year 1: \$42,557

(leveraging sources Oregon State University, Washington State Department of Agriculture)

Total Project Cost: \$85,072

Project Goals and Supporting Objectives

The overall goal of this project is to improve forest health and fish and wildlife habitat by providing an ecological, cost-effective, environmentally safe, and sustainable form of control for invasive knotweeds. The supporting objectives include:

- 1) Experimentally determine the critical photoperiod that induces diapause in the knotweed psyllid and incorporate this information into a phenology and voltinism model that will predict regions where psyllid performance will be highest.
- 2) Facilitate the completion of the release permit process, including addressing any future questions or concerns raised by the regulatory agencies.
- 3) Continue to maintain colonies of both biotypes of the knotweed psyllid in the Oregon State University Quarantine and, when appropriate, expand rearing operations in preparation for release.
- 4) If permitted, coordinate and monitor releases in the Northwest and supply insects to cooperators for releases in the Northeast.

Project Justification/Urgency

Invasive knotweeds in North America are a complex of 3 closely related species in the family Polygonaceae that were introduced from Japan during the late 19th century (Barney 2006). They

include *Fallopia sachalinensis* (giant knotweed), *F. japonica* (Japanese knotweed), and the hybrid between the two *F. x bohemica* (Bohemian or hybrid knotweed). These large herbaceous perennials have spread throughout much of North America with the greatest infestations in the Pacific Northwest (Oregon, Washington and British Columbia), the northeast of the United States, and eastern Canada. Knotweeds are present in at least 41 U.S. states and eight Canadian provinces and are classified as noxious in ten states ((USDA-NRCS 2011). Knotweeds have also invaded Europe, New Zealand, and Australia and are listed among the “world’s worst invasive species” by the World Conservation Union (Lowe et al. 2000). While capable of growing in diverse habitats, the knotweeds have become especially problematic along the banks and floodplains of rivers and streams, where they crowd out native plants and potentially affect stream nutrients and food webs (Beerling and Dawah 1993; Maerz et al. 2005; Gerber et al. 2008; Urgenson et al. 2009; McIver and Grevstad 2010). Dense knotweed thickets displace native plants through a combination of shading (Siemens and Blossey 2007), nutrient competition, and allelopathy (Murrell et al. 2011; Urgenson et al. 2012). The inability of tree seedlings to grow along invading stream banks is potentially detrimental to fish and other stream inhabitants that benefit from the shade of trees. In restoration projects, knotweeds must be fully removed before native plantings are successful. The dense stands have no known value for wildlife.

Many federal, state, and local agencies have active control programs against knotweeds. However, the large scale of the knotweed invasion in North America, the inaccessibility of some of the infestations, and the difficulty with which the plants are killed, all suggest that complete eradication of this plant is unlikely. Classical biological control has the potential to provide widespread and sustained reduction in knotweed abundance at a very low cost. Without a biological control program, chemical and mechanical inputs are likely to be needed on a permanent basis with variable to limited success.

An eagerly awaited biological control program against Japanese and Giant knotweeds (*Fallopia* spp.) using the knotweed psyllid (*Aphalara itadori*) from Japan is currently under review for permitting by APHIS. The psyllid has been fully tested and was recommended for release by the Technical Advisory Group in November 2013. In 2014, APHIS requested additional testing to confirm no effect of adult stages on certain Threatened and Endangered plant species. We completed this additional testing in 2015, finding no measurable effects of adult stages on the non-target plants. A report of these results was submitted to APHIS in September 2015. With this information, APHIS can now complete the Biological Assessment to be reviewed by the US Fish and Wildlife Service for compliance with the Endangered Species Act.

Two biotypes of the knotweed psyllid are being maintained in the Oregon State University Quarantine. The two biotypes differ in their preference and performance on the various genetic types of knotweed. Both biotypes will be needed for the diversity of knotweed infestations that occur in North America. The northern biotype, from Hokkaido, Japan, performs best on giant knotweed (*Fallopia sachalinensis*) and is expected to be most effective as a biocontrol agent against this plant species. The southern biotype, from Kyushu, Japan, performs best on Japanese knotweed (*F. japonica*) and on hybrid knotweed (*F. x bohemica*).

An important factor that may influence the performance of insects introduced to new regions is their genetic based response to photoperiod. Many species, including the knotweed psyllid exhibit a short-day diapause response where diapause is induced when days shorten beyond a critical threshold. In their native locations, this response is adapted to providing optimal timing of the life cycle to favorable seasonal conditions and resources. However, when introduced to a new climate and/or latitude the photoperiod response may cause phenological asynchrony or an inappropriate number of generations. In a previous project supported by this funding program, we developed a model to predict the consequences of a short-day diapause response for newly introduced biocontrol agents (Grevstad and Coop 2015). Depending on details, the photoperiod response can influence whether they enter diapause too early or too late in the season, either of which could be detrimental. Populations of the knotweed psyllid previously released into the United Kingdom in 2010 have been difficult to establish and slow to expand and have not yet had impacts on knotweed. A likely problem is the difference in climate and latitude between the source of the insects (they used the southern biotype) and the U.K., which spans from 51 - 59° N. In North America the differences will not be so severe, but there may still be phenological mismatches to take into account in choosing release locations. Also, we expect that the two psyllid biotypes, which originate from different latitudes in Japan (43° N, and 33° N), will differ in the critical photoperiod that trigger diapause. We plan to use a simple chamber experiment to determine the critical photoperiod in both biotypes of the psyllid and incorporate these into our model along with available parameters for development rate and developmental thresholds (Myint et al. 2012). The model will produced maps of expected voltinism and degree of phenological mismatch. These can be used to select initial release sites that have the best chance for establishing thriving populations early in the control program.

Approach

Objective 1: Critical photoperiod and phenology-voltinism model

A phenology-voltinism model was developed by Grevstad and Coop (2015) and applied to a different insect (the loosestrife leaf beetle *Galerucella californiensis*) as part of a previous FHP/FHTET project. In order to use the model to predict phenology and voltinism in the knotweed psyllid, we need to determine the critical photoperiod used that triggers diapause. We know from previous observations that diapause occurs will occur in response to short days, but the specific critical photoperiod is unknown. With a limited number of environmental chambers in the quarantine facility, we will use a two stage approach to determine the critical photoperiod.

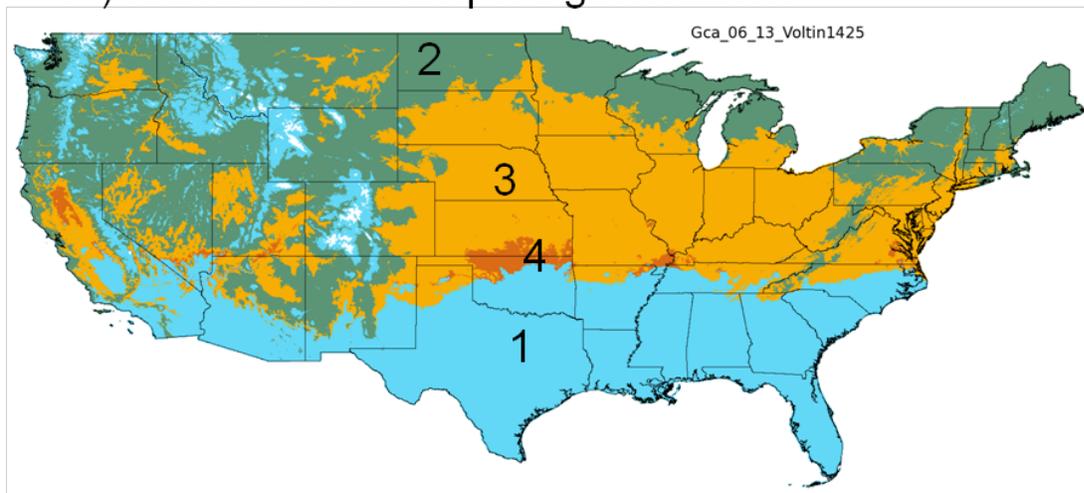
In the first experiment, psyllids of each biotype will be reared separately on each of 5 replicate caged plants in two environmental chambers. Temperatures will be fixed at 21° C. In one of the chambers, the photoperiod will be gradually reduced over the course of several months (similar to seasonal change through the late summer and fall) and in the other chamber the photoperiod will remain constant. On a weekly basis, adult psyllids will be sampled and scored as to whether they are in a reproductive or diapause state. Conveniently, *A. itadori* adults change coloration from the medium tan color of reproductive individuals to a dark brown/black in diapausing

individuals. Behavioral differences are also present. From this experiment, we will get a rough approximation of the critical photoperiod that can be further defined in the next experiment.

For the second experiment, we will use two chambers with two different photoperiods chosen to straddle the approximate critical photoperiod determined in the first experiment. Cohorts of each of the two biotypes will be reared in each chamber. After the adults emerge and have had time to feed and mature for ~2 weeks, they will be individually scored as to whether they are reproductive or diapausing. Logistic regression analysis will be used to determine the critical photoperiod as defined as the day length where 50% of the population enters diapause.

The critical photoperiod will be plugged into our model along with development parameters already available (Myint et al. 2012) to produce maps of expected voltinism and phenological synchrony (Fig. 1).

A) Number of attempted generations



B) Degree of phenological mismatch

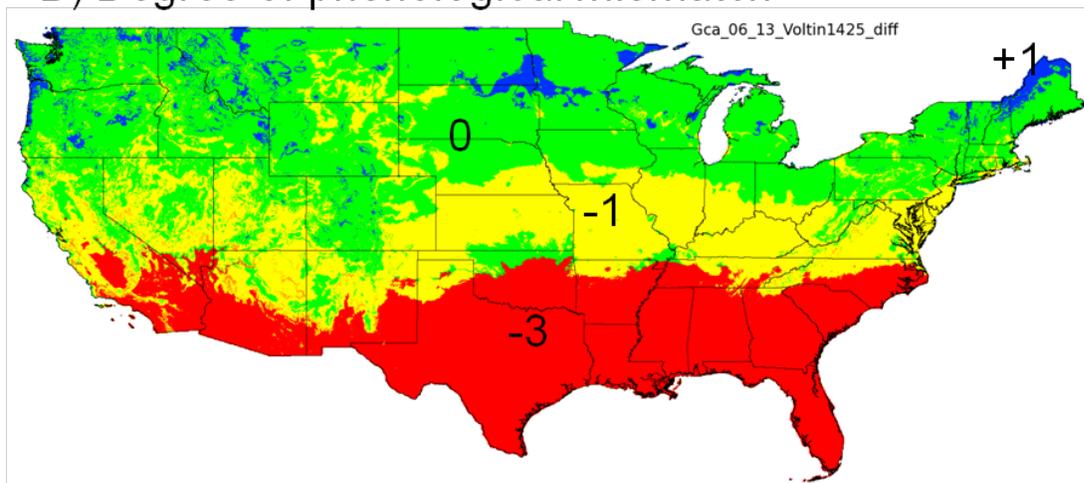


Figure 1. Example of the type of map output that will be created for the knotweed psyllid (see Grevstad and Coop 2015 for details).

Objective 2: Completion of the permitting process

At the time of submission of this proposal, APHIS should be in the process of finishing the Biological Assessment (BA) for the knotweed psyllid and incorporating new test results that were completed last year and submitted as a report to APHIS in September 2015. The project investigator will periodically check in with APHIS during the course of the year to encourage progress in the permit review and to assist them with any needed details for preparation of the review documents. When the BA is completed, it will be forwarded to the U.S. Fish and Wildlife and additional concerns of that agency may need to be addressed.

Objective 3: Maintain quarantine colonies and expand rearing

Throughout the project period, we will maintain healthy colonies of both biotypes of the psyllid. This requires maintaining a steady supply of knotweed plants--field collection of knotweed rhizomes, potting up the plants, watering, and controlling greenhouse pests. The plants are transferred into the quarantine colonies where they support development of one to two generations of psyllids. Dead or depleted plants are removed from the cages as needed and disposed through the autoclave.

Objective 4: Coordinate and monitor releases

Although it is difficult to know when release permits will be issued, we are planning for a release in the summer of 2016. In anticipation of releases, we will begin to increase our rearing operations in the quarantine. The goal will be to maintain 10,000-20,000 psyllids (as can be accomplished in the limited greenhouse space in the quarantine) through spring months so that releases can be made soon after permits are issued. Once permits are issued, depending on timing, we will make initial field releases into Oregon and Washington field sites and provide insects to East Coast collaborators where further rearing/releases will occur. At this point we will also transfer populations to a larger, non-quarantine greenhouse at the Oregon Department of Agriculture in Salem, Oregon where rearing can occur on a much larger scale.

Expected Products and Outcomes

If approved for release, the knotweed psyllid will be an extremely valuable control tool that will eventually be available for release into all locations where in North America where knotweeds are a problem. At best, the psyllid populations will expand to reach high densities wherever knotweed occurs, causing a substantial decline in its abundance and impacts. In the least, the psyllid will provide an added stress to the plant that will reduce its aggressiveness, slow its rate of spread, and make it easier to eliminate using integrated control tools. Either way the psyllid is likely to provide large economic and environmental benefits.

References

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- Urgenson, L.S., S.H. Reichard, and C.B. Halpern. 2012. Multiple competitive mechanisms underlie the effects of a strong invader on early- to late-seral tree seedlings. *Journal of Ecology* 100: 1204-1215.

Budget

Project Period: May 1, 2016 -- April 30, 2017

Cost Elements	Details	Forest Service Contribution
Direct Costs:		
Salaries		
Principal Investigator	27% FTE for 12 months	\$21,527
Fringe Benefits		
Principal Investigator	O.S.U. benefits rate = 49% of salary	\$10,548
	Total Salaries and Benefits:	\$32,075
Travel		
	Travel costs for the P.I. to attend one national meeting	\$1,600
	Driving costs for collecting plants from field sites and attending meetings in Pacific Northwest (~1200 miles x \$0.575/mile)	\$690
	Total Travel:	\$2,290
Supplies (expendable)		
	Supplies for growing plants and rearing insects: pots, soil, fertilizer, cage material, light bulbs for environmental chamber	\$350
Other Direct Expenses		
	Quarantine costs: 52 weeks @ \$150 per week	\$7,800
Total Requested		\$42,515

Matching Contributions

Source	Details	
Oregon State University	Unrecovered indirect expenses (46% of requested total)	\$19,557
Washington State Department of Agriculture	Committed for May 1, 2016 - April 30, 2017	\$23,000
Total Match		\$42,557

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EDUCATION

1998 **Ph. D.** Ecology and Evolutionary Biology. Cornell University, Ithaca, NY
1989 **Bachelor of Science.** Zoology. University of Washington, Seattle, WA

PROFESSIONAL APPOINTMENTS

Current **Assistant Professor of Senior Research.** Department of Botany and Plant Pathology, Oregon State University. Research interests include invasive species ecology, insect and plant population ecology, and biological control of weeds. Lead scientist for developing biological control programs for knotweeds and gorse.

Jan. 2000-
Sept. 2010 **Biological Control Specialist.** Olympic Natural Resources Center, College of Forest Resources, University of Washington, Seattle, WA 98195. Lead scientist for the development and implementation of a biological control program for introduced cordgrasses *Spartina spp.* in Washington State.

1998-1999 **NSF Postdoctoral Fellow.** Department of Entomology, Oregon State University, Corvallis.

SELECTED PUBLICATIONS

Grevstad, F.S. and L.B. Coop. 2015. The consequences of photoperiodism for organisms in new climates. *Ecological Applications* 25: 1506-1517.

Gaskin, J.F., M. Schwarzlander, F.S. Grevstad, M.A. Haverhals, R.S. Bouchier, and T.W. Miller. 2014. Extreme differences in population structure and genetic diversity for three invasive congeners: knotweeds in western North America. *Biological Invasions* 16:2127-2136

Grevstad, F.S., R. H. Shaw, R. Bouchier, P. Sanguaneko, G. Cortat, and R. Reardon. 2013. Efficacy and host specificity compared between two populations of the psyllid *Aphalara itadori*, candidates for biological control of invasive knotweeds in North America. *Biological Control* 65: 53-62.

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Grevstad, F.S., D.R. Strong, D. Garcia-Rossi, R.W. Switzer, and M.S. Wecker. 2003. Biological control of *Spartina alterniflora* in Willapa Bay, Washington using the planthopper *Prokelisia marginata*: agent specificity and early results. *Biological Control* 27: 32-42.

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Grevstad, F. S. 1999b. Factors influencing the chance of population establishment: implications for release strategies in biological control. *Ecological Applications* 9: 1439-1477.

REPORT SUBMITTED TO THE TECHNICAL ADVISORY GROUP

Grevstad, F.S., R. Bouchier, R. Shaw, P. Sanguaneko, G. Cortat, and R. Reardon. 2012. A petition for field release of *Aphalara itadori* into North America for biological control of invasive knotweeds. Submitted to the Technical Advisory Group on Biological Control of Weeds. 54 pp.