Incorporating Photoperiod in the Prediction of Biocontrol Agent Phenology and Voltinism

Co-Principal Investigators

    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. She will be responsible for field surveys and chamber experiments and will contribute to model development and implementation.

    Leonard B. Coop, Assistant Professor (Senior Research), Integrated Plant Protection Center and Department of Botany and Plant Pathology, Oregon State University. Dr. Coop will take lead on the technical aspects of the model and produce maps and tools for predicting phenology and voltinism in biological control organisms.

Cooperators and Other Participating Institutions

    Eric Coombs, Biological Control Entomologist, Noxious Weed Control, Oregon Department of Agriculture, 635 Capitol St. NE, Salem, OR 97301. Mr. Coombs will suggest field survey locations, share records of *Galerucella* releases made in Oregon, help with field surveys, and contribute to publications. His time on the project has been committed as cost share.

    Peter McEvoy, Department of Botany and Plant Pathology, Oregon State University. Dr. McEvoy will contribute technical advice toward the project and allow use of environmental chambers located in his laboratory.

    Other collaborators: We plan to recruit numerous other collaborators across U.S. to help with rapid assessment for presence or absence of second generation in *Galerucella* spp.

BCIP Contact

    Lia Spiegel, Entomologist, USDA Forest Service, Forest Sciences Lab, 1401 Gekeler Lane, LaGrande, OR 97850. Dr. Spiegel will serve as the Forest Service technical contact and will be responsible for monitoring the progress of the cooperative agreement.

Project Goals and Supporting Objectives

The overall goal of this project is to increase the effectiveness of biological control of weeds by developing methods and tools that can be used to predict and measure phenology and voltinism (number of generations) of introduced biological control agents. Unique to our approach is the incorporation of photoperiod as the cue for induction of hibernal diapause. Common among insects, reliance on a photoperiod cue can have important consequences for insects introduced into locations with climates or latitudes that differ from the source location to which they are adapted. The model that we develop will be generally applicable to nearly all introduced insects and will be tested extensively for two leaf beetles (*Galerucella* spp.) that were introduced into North America over a wide geographic range against purple loosestrife (*Lythrum salicaria*).

Our specific objectives are as follows:

1. Develop and implement a combined phenology/voltinism model that incorporates continent-wide degree-day and photoperiod data with biocontrol agent development rates and photoperiod response. An online version of the model will be made available as a tool for producing voltinism maps for introduced insects.
2. Using the model, develop standardized methods for rapid assessment of the presence or absence of a second generation in *Galerucella* beetles and use these methods, with help of collaborators, to assess patterns of voltinism at sites across the continent.
3. Compare field observations of voltinism to model predictions and assess possible explanations, including adaptation, where field observations do not align with predictions.
4. Using selected field-collected populations of *Galerucella*, carry out environmental chamber experiments to test the hypothesis that the critical photoperiod and/or development rates have evolved since their introduction in correspondence with the selective pressures of their new environment.

Project Justification and Background

Consequences of photoperiod-cued diapause in biocontrol agents

Many insects, if not most, use the indirect cue of photoperiod to synchronize their life cycle with the timing of favorable seasonal conditions (Tauber et al. 1986; Danks 1987; Denlinger 2002). This response often takes the form of termination or induction of a diapause state when the insect is exposed to a photoperiod that lengthens (or shortens) beyond a critical threshold (the critical photoperiod). Diapause is a physiological state of dormancy in which development and reproduction cease and energy is conserved until conditions or resources once again become favorable. Most temperate zone insects diapause during the colder months and emerge in the spring or summer when their food resources become available. Photoperiod serves as an indirect predictor of near future conditions that is more reliable than direct cues such as temperature and moisture, which can be highly variable. Since both photoperiod and climate vary geographically, the particular critical photoperiod used by a population to synchronize its life cycle to the seasons is specific and adaptive to a particular location. In their native ranges, insects that cue on photoperiod exhibit clinal variation in the critical photoperiod length corresponding with gradients of climate and latitude (e.g. Danilevski 1965; Masaki 1961, 1999; Gomi 1997). In addition, there may be corresponding variation in rates of development, with faster development occurring where degree-days are limited and slower development where they are not (Masaki 1967, 1978; Mousseau and Roff 1989; Blanckenhorn and Demont 2004).

In classical biological control, natural enemies are usually collected from a single source location in the native range and introduced into many locations across a climatically variable target range. These introduced populations will suddenly find themselves in a climate that differs to varying degrees from the one in which they evolved. Traditionally, estimation of the suitability of the new climate (if done at all) is carried out using a direct climate matching approach (e.g. Climex ®) without regard to photoperiod response. However, because climate and photoperiod are not likely to align in the same way in the introduced location as in the source location, an insect's reliance on a photoperiod can lead to asynchrony of the life cycle with the seasons and rather extreme shifts in the duration of the reproductive phase of its life cycle. Two recent field studies of biocontrol agents reveal the potential effects of photoperiodicity for the outcomes of

biological control introductions. Bean et al. (2007) showed that the tamarisk leaf beetle (*Diorhabda elongata deserticola*), normally a multi-voltine species, was unable to establish south of 38 º N latitude because the day length was never long enough to allow a second generation. Instead adult beetles entered diapause early in the summer and were unable to survive the extended period of diapause to the following spring. In another study, Grevstad et al. (2012) found that populations of the planthopper *Prokelisia marginata* that were collected from four different source locations and introduced into Willapa Bay, WA for control of *Spartina alterniflora* emerged out of synchrony with the new climate, but consistent with a photoperiod cue that was adaptive for their respective source locations. These two cases illustrate that the effect of photoperiod response on phenology and voltinism in the new range is predictable. Needed are conceptual models and tools to help biocontrol researchers understand and predict these outcomes.

The ecological response for introduced populations that are sensitive to photoperiod can be counter intuitive. For example, it is often assumed that insects with the potential for multiple generations will have more generations when introduced into warmer southern locations and fewer generations in the north where heat accumulation is limited. However, the opposite is likely to be true when insects rely on photoperiod as their cue for entering diapause. While degree-day accumulation tends to increase from north to south, photoperiod during the summer decreases from north to south. This means that introduced insects adapted to a certain latitude/climate may have fewer generations when introduced into more southern locations, which have shorter day lengths, even though the degree-days are sufficient for more. The case of the tamarisk leaf beetle mentioned above is a published example of this. A similar situation appears to be present in the loosestrife leaf beetles (*Galerucella calmariensis* and *G. pusilla*). Early reports suggest only one generation in southern latitudes such as Virginia (McAvoy et al. 1997), a partial second generation at mid-latitidudes (Matos and Obrycki 2007), and 2 full generations in several northern locations such as Michigan, Ontario, Manitoba, and British Columbia (Dech and Nosko 2002; Lindgren et al. 2002; Landis et al. 2003). A second generation can mean greater impact on the weed, but a second generation could also be detrimental if there are insufficient degree-days to support it. Cueing on the long days of northern latitudes, a late second generation of *Galerucella* could fail to survive the onset of cold fall weather and senescing host plants.

It is reasonable to expect that populations that are not well adapted to their new climates would eventually adapt, as has been shown in some introduced pest species (Riedl and Croft 1978; Gomi and Takeda 1996). Demonstrations of evolved adaptation to climate in weed biocontrol agents are rare, but perhaps only because few researchers have looked. Three very recent studies appear to be the first to do so. The tamarisk leaf beetle evolved a shorter critical photoperiod in just 7 years, allowing it to expand its range further south than its original limit (Bean et al. 2012). Two biocontrol agents introduced against tansy ragwort, the moth *Tyria jacobaeae* (McEvoy et al. 2012) and the flea beetle *Longitarsus jacobaeae* (Szűcs et al. 2012) were found to have evolved shorter generation times allowing them to occupy high elevation habitats.

Need for improved effectiveness of biological control of purple loosestrife

While our research will have broad implications for improving classical biological control in general, it will have the most immediate and direct implications for improving effectiveness of the biocontrol program against purple loosestrife, the system that we have chosen to focus on. Purple loosestrife is an aggressive invader of wetlands, occurring in 44 states and 10 Canadian provinces. It is officially designated as noxious in 33 states. Invasion by purple loosestrife leads to decreased native plant diversity (Gabor et al. 1996; Schooler et al. 2006) and a reduction of the quality of nesting and foraging habitat for a variety of specialized wetland bird species (Rawinski and Malecki 1984; Hickey and Malecki 1997; Whitt et al. 1999; Lor 2000). Purple loosestrife also alters decomposition rates and nutrient cycling, thus altering the ecosystem services provided by wetlands (Emery and Perry 1996; Barlocher and Biddiscombe 1996; Grout et al. 1997; Templer et al. 1998).

Four insects have been introduced as biocontrol agents against purple loosestrife: the two leaf beetles *Galerucella calmariensis* and *G. pusilla*, a root feeding weevil *Hylobius transversovittatus*, and a seed feeding weevil *Nanophyes marmoratus*. Of these, the two *Galerucella* beetles have been the most widely released and have had the most visible impact to the weed. However, the biological control program against purple loosestrife has been only partially successful (Denoth and Myers 2005; Grevstad 2007). Control of purple loosestrife appears to be greater where there are two beetle generations. For example, stem count reductions of 90 to 100% have been reported in central Canada (Lindgren et al. 2002), compared to no significant decline in stem density in New York State where one generation is typical (Grevstad 2004). Our research will help identify locations where populations are not reaching their potential and where they are having just one generation but could be having two. It will also help identify sources of adapted agents in similar climates that could be redistributed to sites where the existing population was not effective.

<u>*Galerucella* spp. biology</u>

Galerucella pusilla and *Galerucella calmariensis* are leaf beetles (family Chrysomelidae) originating from 2 locations in Northern Germany: Gelnhausen at 50.2° N and Meggerdorf at 54.3° N. Beginning in 1992, they were released across North American from central California to British Columbia in the West and from Virginia to Maine in the East (Hight et al. 1995). The beetles are host-specific to purple loosestrife with both larvae and adults feeding on the leaves and stems of the plant. Both *Galerucella* species overwinter as adults and emerge to mate and reproduce in direct response to warming temperatures. Based on local and published phenological reports, emergence timing corresponds to approximately 150 accumulated degree-days, which is followed by a pre-oviposition period of approximately 50 degree-days. They have one to two full generations per year depending on location and require 473 (*G. calmariensis*) and 490 degree-days (*G. pusilla*) to complete development from egg to eclosed adult (lower threshold 7.9 and 8.0° C, respectively) (McAvoy and Kok 2004). During late summer or early fall, diapause is induced by short photoperiod experienced by newly eclosed adults (Velarde et al. 2002), with a critical threshold likely to be somewhere between 15.2 and 15.3 hours (Bartelt et al. 2008).

The two leaf beetles (*Galerucella* spp.) introduced against purple loosestrife make up an ideal system for investigating the ecological and evolutionary consequences of a photoperiod response for insects moved into a new climate. First, development rates, degree-day requirements, and critical photoperiod details are available (McAvoy and Kok 2004; Velarde et al. 2007; Bartelt et al. 2008) making it possible to parameterize models of phenology. Second, they have been introduced over a very wide geographic range with varying observable responses. Third, as a wetland system, the plant and insect phenologies are largely dependent on seasonal temperatures and not complicated by variation in moisture levels. Fourth, for many of the release sites, we know both the source and the year of release, which will allow us to determine rates at which adaptation may have occurred. Finally, with this biocontrol system we will be able apply the model to two beetle species at once, helping to validate the model as a general predictive tool for introduced insect species that use photoperiod to induce diapause.

Preliminary observations and results from the west coast

Recent observations have motivated our hypothesis that *Galerucella* populations have already evolved toward adaptation to local conditions. In California, populations were initially very difficult to establish. This is likely due to the fact that the short day lengths trigger diapause early in the summer after just one generation. However, in recent years, the beetles near Palermo, CA are reported to have at least two generations per year (B. Villegas, personal communication), which is only be possible if there has been a change to a shorter critical photoperiod. Our second line of evidence comes from a preliminary experimental test of divergence in the rates of development. We collected adult *G. calmariensis* from Palermo (California), Sutherlin (Oregon), and Bellingham (WA) and reared their offspring on each of 6 replicate caged plants in a common environmental chamber. Beetles from the most northern site (Bellingham) developed 2 days faster on average than beetles from the Sutherlin or Palermo sites (Fig. 1). Selection for faster development may have occurred because individuals that developed faster were able to fit in a second generation whereas those that developed slower would confront the declining conditions and reduced host quality in the late second generation.
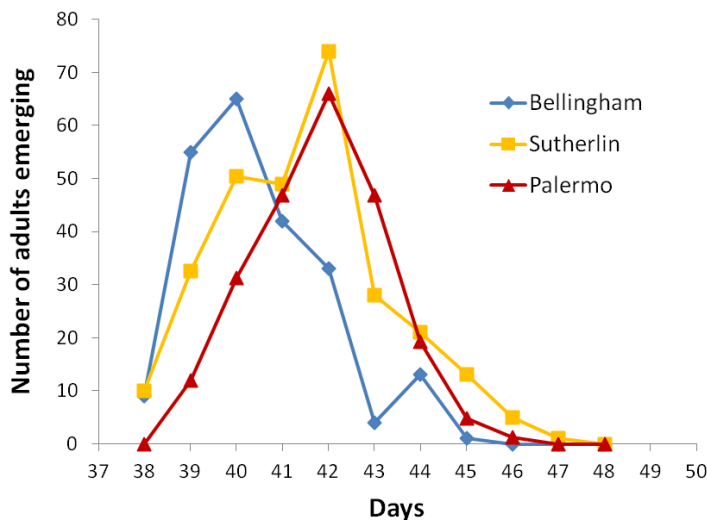

Figure 1. Timing of adult emergence for three geographic sources of *Galerucella calmariensis* when reared from eggs in a common environmental chamber. The beetles from the northernmost location (48.8° N lat.; Bellingham) developed significantly faster than the central (43.4° lat.) and southern (39.4° lat.) locations (ANOVA on mean eclosion date per plant: $F = 4.24$, $p = 0.039$). The faster development could allow this northern population to fit in a second generation.

Approach

Model and online tool

We propose to integrate available spatial and temporal climate data with development rates and photoperiod response into a model that can be used to predict both the timing of life cycle events and the number of generations for newly introduced insect populations. The model will be similar to standard degree-day phenology models, but will incorporate delay of reproduction (induction of diapause) in response to photoperiods that are shorter than the population-specific critical photoperiod. With recent advances in spatial climate modeling technology (Daly et al. 2008, Coop 2010), degree-day maps (both 30-year normal and near-realtime) can be produced for any location in the contiguous US (CONUS) plus southern Canada to 52º N. One version of this technology, the Oregon State University IPPC degree-day mapping calculator (http://uspest.org/cgi-bin/usmapmaker.pl), will be modified to include photoperiod response via user-input critical photoperiods. The current degree-day mapping tool is written in the Perl and GRASS GIS languages, and the submodels needed for this new product have been similarly built and tested as prototypes. In the simplest form of the model, input parameters will include the minimum and maximum threshold temperatures for development, the development time to the sensitive stage (in degree-days) and the critical photoperiod (hrs) that induces diapause. Outputs will include detailed (800m) maps of expected voltinism for all CONUS regions. Following peer review and testing, the proposed model will be integrated within existing on-line IPPC services and made freely available to support a wide array of collection, release, survey, and assessment strategies. The IPPC services have been in continuous operation since 1997 supported by OSU with additional grants and contracts.
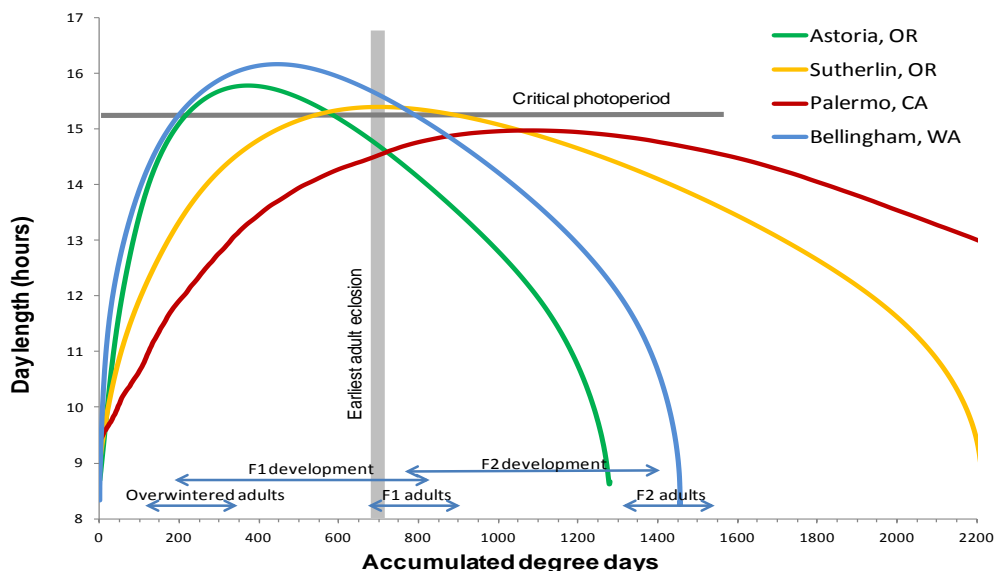
Figure 2. Predicting the consequence of a population's reliance on photoperiod as a cue for diapause. If the day length is longer than the critical photoperiod (horizontal gray line) at the time when adults eclose (vertical gray line), the insects remain reproductively active for a second generation. If it is shorter, they enter diapause. The critical photoperiod and timing of adult eclosion are estimated for the original populations of *Galerucella* introduced from Germany. Evolution of these population-specific traits (seasonal adaptations) would be represented by a change in position of the horizontal and vertical lines, potentially resulting in a change in the number of generations per year. Photoperiod calculations were made following Forsythe et al. (1995).

For illustrative purposes we can make initial model predictions for *Galerucella* spp. based on 4 point locations in the western U.S. (Fig. 2). The eventual model will do the same over continuous space. By plotting seasonal photoperiod on a degree-day scale, we can directly compare photoperiods between geographic locations at the time when the F1 adults are expected to eclose (the photoperiod sensitive stage (Velarde et al. 2002)). The number of degree-days to adult eclosion is estimated to be 690 based on the development rates of McAvoy and Kok (2004) and published and personal observations of spring emergence timing. Plotting on a degree-day scale also allows us to gauge whether there is sufficient heat accumulation for a second generation following the emergence of the F1 adults. Using the four point locations as examples, we demonstrate four possible outcomes for introduced *Galerucella* populations that will eventually be mapped as geographic zones (see Table 1).

	Photoperiod at emergence < CP		Photoperiod at emergence > CP	
	Ecological	Evolutionary	Ecological	Evolutionary
Degree-days sufficient for one generation	One generation, good winter survival (e.g. Astoria, OR)	Little or no change	Two generations, late diapause/fall mortality (e.g. Bellingham, WA)	Longer CP leading to one generation **OR** faster development for two generations
Degree-days sufficient for two generations	One generation, poor winter survival (diapause too early) (e.g. Palermo, CA)	Shorter CP leading to 2 generations **OR** Slower development, later diapause	Two generations, good winter survival (e.g. Sutherlin, OR)	Little or no change

Table 1. Predicted ecological and evolutionary responses of introduced populations with short-day diapause induction. The introduced range can be divided into 4 zones, each with a different ecological and evolutionary response from the introduced population.

Phenology and voltinism field surveys

We will carry out two types of field surveys. For a limited number of field sites that have differing climates but still convenient to Oregon State University, we will carry out weekly surveys of life stages to obtain detailed plant and insect phenology that can be used with already published phenology reports to help calibrate our model. In these surveys, the number of individuals in each stage (egg, larva, adult) will be counted weekly on 10 focal loosestrife plants at each site between April and October, 2013. In addition, the stage of plant development will be recorded for 20 randomly selected plants per site.

The second type of survey is a rapid assessment intended only to confirm the presence or absence of a second generation of *Galerucella* spp. at sites across the continent. Our model can be used to determine the best timing for such a survey in various geographic regions. Survey timing is critical because the adults are active on the plants for only a couple weeks before descending into the soil to diapause and we intend that the confirmation of a second generation will require only one visit to the site. The standardized methods will be used in our own surveys in the western U.S. and will also be sent to colleagues familiar with the biocontrol system who will help gather data points on the number of generations in different regions. The P.I. will take at least one trip to the Eastern or Midwestern U.S. to help fill regions where collaborators might

be lacking. These rapid assessment methods will also be made available to land managers who want to troubleshoot a *Galerucella* population that has not been effective at controlling purple loosestrife. Where only one generation occurs, it may be possible to move insects from another source location to increase the number of generations and have a greater impact on the weed.

Testing for evolution of development rates and critical photoperiod

Where the number of generations observed in the field does not match the model prediction based on parameters from the original source populations, we can hypothesize that adaptation to local climate may have occurred. We will select at least one *G. calmariensis* population from each of the four zones identified in Table 1, including (if available) at least two populations that show evidence for adaptation based on divergence from model predictions. Adult beetles will be collected shortly after they emerge from overwintering and reared for a generation in the laboratory to eliminate maternal effects. In the first experiment, we will compare rates of development from egg to adult among the four populations when reared at a common temperature. Our hypothesis is that populations occurring in regions where degree-days are limited will have evolved faster rates of development. In the second experiment, we will determine and compare the critical photoperiod used by each population to induce diapause using methods similar to Verlarde et al. 2002. Newly eclosed adults will be exposed to four light:dark treatments selected to bracket the reported initial critical photoperiod of approximately 15.25 hours (Bartelt et al. 2008). Two additional treatments will be used to test whether the photoperiod response varies with temperature as has been found in some cases (e.g. Gomi 1997). Our hypothesis is that photoperiods will have evolved in a direction to allow the optimal number of generations for the available degree days. This experiment requires 6 environmental chambers which are available to us in the lab of Dr. Peter McEvoy at Oregon State University.

Expected Products and Outcomes

1. Concept/theory paper describing the implications of photoperiod-cued diapause for biological control agents and other introduced insects.
2. Publicly accessible online tool for generating maps to predict phenology and voltinism for biological control agents and other introduced insects that have life-cycles cued to photoperiod.
3. Technology transfer document describing methods for rapid assessment of the presence or absence of second generation in *Galerucella* and its implications for biocontrol effectiveness.
4. Paper on observed patterns of the number of generations of *Galerucella* populations at sites throughout the continent.

This research will produce concepts and tools intended to improve approaches to selection and release of biocontrol agents leading to greater success in establishment and effectiveness. Lack of attention to photoperiod-regulated voltinism has likely led to failures in the past; we intend to improve on this record with the proposed combined phenology/voltinism mapping tools and survey timing guidelines. These "expert assist" tools can help biocontrol researchers and practitioners better understand and predict the ecological and evolutionary implications of introductions of organisms into new climates and at varying latitudes.

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Time Table

Task	Winter 2013	Spring 2013	Summer 2013	Fall 2013	Winter 2014	Spring 2014	Summer 2014	Fall 2014
Build model and incorporate into USPest.org website	X	X	X					
Update and improve model based on user feedback					X	X	X	
Write concept/theory paper	X	X						
Start plants from seed in greenhouse		X						
Field phenology surveys		X	X	X				
Recruit volunteers for voltinism survey			X					
Field voltinism surveys				X				
Compare field voltinism to model					X			
Write paper on observed voltinism in *Galerucella*					X	X		
Start plants from seed in greenhouse						X		
Beetle collections from selected field sites						X		
Environmental chamber experiments							X	X

Fritzi S. Grevstad

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EDUCATION

1998   **Ph. D.** Cornell University, Ithaca, New York
              Field of Ecology and Evolutionary Biology
              Dissertation Title: The Colonization Ecology of Two Loosestrife Leaf Beetles, *Galerucella calmariensis* and *G. pusilla*

1989   **Bachelor of Science.** University of Washington, Department of Zoology
              Graduated *Magna Cum Laude* with Distinction.

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.

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

Sept.1998-   **NSF Postdoctoral Fellow.** Department of Entomology, Oregon State University, Corvallis,
Dec. 1999   OR. Conducted research on the interactions among biocontrol agents introduced against purple loosestrife and carried out an analysis of release and recovery records for weed biocontrol programs in Oregon.

SELECTED PUBLICATIONS

Grevstad, F.S., R. H. Shaw, R. Bourchier, P. Sanguankeo, G. Cortat, and R. Reardon. 2012. Host specificity and efficacy of two biotypes of the psyllid *Aphalara itadori*, a candidate for biological control of invasive knotweeds in North America. ***Biological Control*** (in press)

Grevstad, F.S., E.M. Coombs, and P.B. McEvoy. 2012. Revisiting release strategies in biological control of weeds: are we using enough releases? **Proceedings of the XIII International Symposium on Biological Control of Weeds**, Sept. 11-16, 2011, Waikoloa, HI. (in press)

Grevstad, F.S., C. O'Casey, and M.L. Katz. 2012. A comparison of four geographic sources of the biocontrol agent *Prokelisia marginata* (Homoptera: Delphacidae) following introduction into a common environment. ***Environmental Entomology*** 41: 448-454.

McIver, J. and F. Grevstad. 2010. Natural Enemies of Invasive Knotweeds in the Pacific Northwest. Technology Transfer Publication FHTET 2010-02. U.S.D.A. Forest Service Forest Health Technology Enterprise Team, 39 pp.

Grevstad, F.S. 2006. Ten-year impacts of the biological control agents *Galerucella pusilla* and *G. calmariensis* (Coleoptera: Chrysomelidae) on purple loosestrife (*Lythrum salicaria*) in Central New York State. ***Biological Control*** 39: 1-8.

Grevstad, F.S. 2005. Strategies for controlling a spatially structured plant invasion: *Spartina alterniflora* in Pacific Coast estuaries. ***Biological Invasions*** 7: 665-677.

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.

Grevstad, F. S. 1999a. Experimental invasions using biological control introductions: the influence of release size on the chance of population establishment. ***Biological Invasions*** 1: 313-323.

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

Grevstad, F.S. and A.L. Herzig. 1997. Quantifying the effects of distance and conspecifics on colonization: experiments and models using the loosestrife leaf beetle, *Galerucella calmariensis.* ***Oecologia*** 110: 60-68.

Leonard B. Coop – 1 page C.V.
Integrated Plant Protection Center & Botany Plant Pathology Dept.
Cordley 2040 Oregon State University, Corvallis, OR 97331-2907
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Education and Training:
Ph. D. Entomology (IPM) 1987. Dissertation: Management of Variegated Cutworm in Peppermint. Oregon State University, Corvallis, Oregon
M. S. Entomology (IPM) 1983. Thesis: Orange Tortrix: Parasitoid Complex and Thermal Constants for Egg Hatch. Oregon State University, Corvallis, Oregon
B. A. Biology 1979. Baker University, Baldwin City, Kansas
GIS I & II. 1992 & 1994. Central Washington University, Ellensburg, Washington

Professional Experience & Areas of Expertise:
Assistant Professor (Senior Research), Nov. 2002 to present. Oregon State University, Integrated Plant Protection Center and Botany & Plant Pathology Dept. Expertise in phenological modeling, GIS modeling, life history modeling, climate modeling, decision support systems in agriculture, biological control, plant disease risk modeling. Coop is chief developer and supervisor of OSU IPPC's website "IPM Pest and Plant Disease Models and Forecasting for Agricultural, Pest Management, and Plant Biosecurity Decision Support in the US", http://uspest.org/wea which serves thousands of users in agricultural and pest management decision support in the U. S. The site integrates real time weather data from 17,000+ weather stations, PRISM climate data, GRASS GIS, spatial interpolation of weather data and models, 99+ pest and disease models, and gridded and site-specific forecasts from Fox Weather, LLC and the National Weather Service.

Teaching Experience:
Developed and taught the course, Computers and Modeling for Integrated Pest Management, OSU Entomology Taught numerous laboratory exercises, OSU Entomology ENT 443/444, based on material from the course.

Grants - total awarded to date: $4,502,179; Recent:
Oct 2009-Apr. 2012. Sustainable grape pest management for California using weather data, models, and cultural controls. Calif. Dept. Food and Agri. SCBGP. Coop, L. (PD of subcontract); Gubler, W.D. (PD). $154,359.
Jan 2010 – Dec 2012. Automated mesoscale pest risk forecast maps for agricultural production and potential plant biosecurity threats. USDA AFRI Plant Biosecurity. Coop, L (PD), Gent, D, Mahaffee, D., Gubler, W.D. $996,112.
Sept 2009 – Aug 2011. IPM Disease Risk Forecasts and Virtual Weather for Western States. USDA WRIPM Specialty Grants. Coop, L.B. (PD), Jepson, P., Gent, D., Grove, G. $179,221.

Recent Relevant Publications:
1.   Pfender, W., Gent, D., Mahaffee, W., Coop, L., Fox, A. 2011. Decision aids for multiple-decision disease management as affected by weather input errors. Phytopathology. 101:644-653.
2.   Coop, L. B. and J. K. Stone. 2010. Climate models for predicting distribution and severity of Swiss Needle Cast. In: D. Shaw, Ed. Swiss Needle Cast Coop. Annual Report, 2010. College of Forestry, Oregon State University. pp. 68-82. http://www.cof.orst.edu/coops/sncc/pdfs/sncc10.pdf
3.   Walton, V.P., A.J. Dreves, L.B. Coop, G.V. Jones and P.A. Skinkis. 2010. Developmental parameters and seasonal phenology of Calepitrimerus vitis (Nalepa 1905) (Acari: Eriophyidae) in wine grapes of Western Oregon. Environmental Entomology: 39:2006-2016.
4.   Kim, K. S., S. E. Taylor, M. L. Gleason, F. W. Nutter, Jr., L. B. Coop, W. P. Pfender, R. C. Seem, P. C. Sentelhas, T. J. Gillespie, A. D. Marta, S. Orlandini. 2010. Spatial Portability of Leaf wetness models based on Empirical Approaches. Agric. and Forest Meteor. 150:871-880.
5.   Stone, J. K., L. B. Coop, and D. K. Manter. 2008. Predicting effects of climate change on Swiss needle cast disease severity in Pacific Northwest forests. Canadian Journal of Plant Pathology. 30:169-176.
6.   Coop, L. B. 2010. U. S. degree-day mapping calculator. Version 4.0. Oregon State University Integrated Plant Protection Center Web Site Publication E.10-03-1: <http://uspest.org/cgi-bin/usmapmaker.pl>
7.   Coop, L. B. 2008. Daily and interactive degree-day maps for the USA. Oregon State University Integrated Plant Protection Center Web Site: <http://pnwpest.org/wea/indextable.html>

Budget

January 1, 2013 - December 31, 2014

		Year 1	Year 2	Both Years
Salaries				
	F. Grevstad, 25% FTE for 2 years	18,786	19,537	38,323
	L. Coop, 18% FTE for 2 years	11,336	11,789	23,125
	(salaries include 4% cost of living increase per year)			
Benefits				
	F. Grevstad, rate=49% (year 1), 50% (year 2)	9,205	9,573	18,778
	L. Coop, rate = 53.73%	6,090	6,334	12,424
Supplies	Web server support (web hosting costs)	400	200	600
	Supplies for collecting and rearing *Galerucella* beetles	200		200
Equipment				
Travel	Travel to field sites within the western U.S.	1,200	1,200	2,400
	Travel to field sites on East Coast		1,500	1,500
	Travel to International Symposium on Biological Control of Weeds March 2014		2,500	2,500
	Total Requested:	**47,217**	**52,634**	**99,851**

Matching Contributions	Year 1	Year 2	Both Years
Oregon State University unrecovered indirect costs at 46%	21,720	24,212	45,931
Participation by Eric Coombs, Oregon Department of Agriculture	10,000	5,000	15,000
Total Match:	**31,720**	**29,212**	**60,931**

Oregon

John A. Kitzhaber, MD, Governor

October 26, 2012

Dr. Fritzi Grevstad:

Please accept this letter as my intention to contribute to your USFS grant application to conduct biological control research on purple loosestrife (*Lythrum salicaria*) leaf beetle (*Galerucella* sp.) phenology and voltinism.

My contribution will consist of In-Kind services to consist of: field surveys, travel, beetle collection, assisting in propagation, data consultation, reviewing manuscripts, and project maintenance. I will be able to contribute an equivalent of $10K in my time and expenses during the first year and $5K for each of the following years.

This research is critical in helping us to better understand the purple loosestrife biocontrol system and how to better manage the biocontrol agents and improve efficacy. I appreciate your willingness to seek funding and conduct a project that is important to helping to protect Oregon's precious natural resources and agricultural economy.

Sincerely,

Eric M. Coombs
Biological Control Entomologist
Plant Division / Weed Control
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