Enhancing Biological Control in Western Orchards

enhancedbiocontrol.org

A USDA-NIFA Specialty Crop Research Initiative Project

A collaborative project between Washington State University, University of California at Berkeley, Oregon State University, USDA-ARS, USDA-NIFA, and the apple, pear and walnut industries in California, Oregon, and Washington.

Project Directors

Washington State University:

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Canada: Dr. Gary Judd (Agriculture and Agri-Food Canada, outside scientist)

Project Goals

- *Improve the long-term sustainability of the apple, pear and walnut industries in the western US by enhancing biological control (BC) of pest insects and mites.*
- *Synthesize the information developed in this project along with existing information to provide the outreach tools needed to bring about change in grower practices.*

Objectives

1. *Evaluate the sublethal effects of newer pesticides on key natural enemies in laboratory and field assays in apple, pear, and walnut orchards.*
2. *Characterize natural enemy phenology, including timing of emergence from overwintering areas, entry into orchard, and development within the orchard.*
3. *Evaluate attractants as natural enemy monitoring tools and compare them to traditional methods.*
4. *Develop molecular and video methods to monitor predation of codling moth (CM).*
5. *Conduct economic analyses to determine long-term costs associated with IPM programs with and without various levels of biological control.*
6. *Survey clientele to identify optimal ways to present information that will lead to quicker adoption of new technologies; synthesize existing and new information to provide real-time support for pest control decisions by stakeholders.*

Over, but not done

Our project officially ended on 31 August. However, the official end is not the end of the project and we have leveraged the SCRI funding well beyond the initial 1:1 match, with at least an additional $1.8 M in new grant funds to expand on the original objectives and also to bolster the outreach efforts.

For this progress report, we will provide a short overview of the accomplishments for each objective, as well as showing some of the exciting new research and extension directions that have been taken by some of our project directors. We also provide a comprehensive list of publications, presentations, leveraged grants, and the training opportunities that this SCRI grant has helped fund or that is an outcome of the leveraged funding. We think that our productivity has been extraordinary, with 92 presentations, 31 additional symposia presentations (with 9 more coming in 2014), 21 popular articles, 26 peer-reviewed articles in print or in press, and a special issue of the journal *Biological Control* that will have 14 additional peer-reviewed articles, a two-day short course presented at 3 locations over video conference, more than twelve 2-4 hour training courses on natural enemies and a state of the art web site that pulls all this together (enhancedbiocontrol.org).

We hope you enjoy the report and find our results and new directions to be a clear indication of our passion for both basic and applied research, the excellence of our team, and the importance of taking a broad and fresh approach to integrating biological control into normal orchard management programs.

For more information on this project and our accomplishments, please visit our web site (enhancedbiocontrol.org) and feel free to contact our project directors.

Lacewing larva eating aphid.

Convergent ladybird beetle

Western predatory mite and mite eggs

Pesticides Influence Biocontrol Success

I. Pesticide Effects

Mills, Beers, Shearer, Unruh

This objective has successfully characterized the potential disruptive effects of seven different pesticides used for management of codling moth and diseases on a set of natural enemies that contribute to the management of secondary pests in western apple, pear and walnut orchards. Detailed laboratory tests designed to integrate both acute and sublethal effects of pesticides on natural enemies led to the development of a simple visual chart summarizing the relative compatibility of each pesticide with natural enemies (*top next page; enhancedbiocontrol.org/pe.html*). Follow-up studies in apple, pear and walnut orchards were used to confirm the strongest disruptive effects seen in the laboratory tests on the ratio of natural enemies to secondary pests, which is a useful index of biological control activity in the field. This information has already been incorporated into the decision making of a number of leading pest managers throughout the region, and is being used in educational programs associated with the project. We anticipate this information will result in enhanced conservation of biological control agents in western orchards and reduce the need for pesticide applications against secondary pests in these crops.

Benefits to Science and the Agricultural Industries

The accomplishments from the project include significant advances in both science and industry application. From a science perspective, the project has generated the first larger scale application of life table statistics to the laboratory assessment of pesticide risk to natural enemies and provides a framework of standardized protocols for rigorously testing pesticide selectivity. Benefits to the tree crop industries have been twofold: First, growers and pest managers have become increasingly aware of the importance of the biological control services that natural enemies can provide if not disrupted by indiscriminate use of pesticides. Secondly, this awareness has encouraged them to question whether changes in pesticide registration in these crops could be responsible for the novel secondary pest complexes that have arisen in recent years. Consequently, this has led to a series of new industry-sponsored research projects in all three states that are geared toward enhancing the role of biological control in the management of secondary pests such as aphids, pear psylla, and spider mites.

Percentage change in the population size of treated populations compared to untreated controls after one generation, estimated from laboratory life table bioassays. Green cells show <25% reduction, yellow have 25-75% reduction, and red have >75% reduction

NE tested	Altacor	Cyazypyr	Delegate	Rimon	Warrior	Kumulus	Kocide/ Manzate
Woolly apple aphid parasitoid, *Aphelinus mali*	-4.2	-56.8	-84.5	-26.9	-72.8	3.7	12.2
Walnut aphid parasitoid, *Trioxys pallidus*	-58.7	-88.5	-83.2	-7.0	-90.7	-89.1	-23.5
Pear psylla predator, *Deraeocoris brevis*	5.0	10.4	-76.8	-98.2	-99.2	-65.9	-31.8
General predator, *Chrysoperla carnea*	-99.8	-99.9	-96.5	-94.4	-99.9	-26.1	-39.0
Aphid predator, *Hippodamia convergens*	-87.3	-84.1	-21.1	-86.5	-99.8	-4.4	-10.5
Mite predator, Western predatory mite *Galendromus occidentalis*	-12.4	-36.1	-97.5	-73.9	-98.5	-90.7	-77.1

Knowing Phenology Improves Management Options

2. NE Phenology Models

Jones, Mills, Shearer, Horton, Unruh

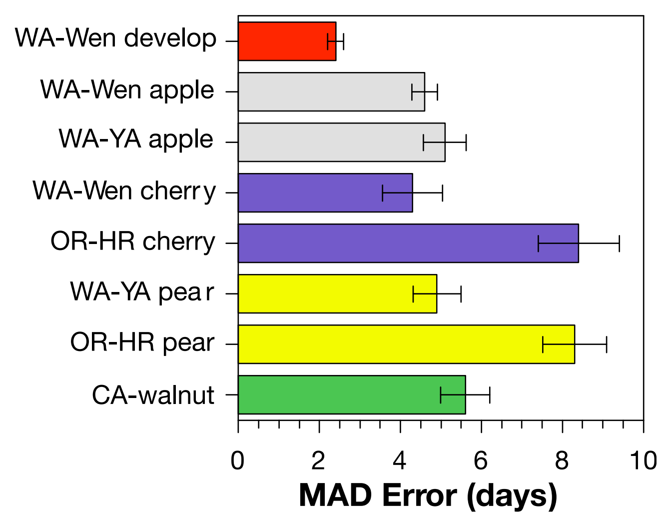
Phenology models have been developed for two lacewings (*Chysopa nigricornis, Chrysoperla plorabunda*) and a syrphid fly (*Eupeodes fumipennis*), and we are working on at least two more. There is more data from apple orchards than all other crops, so we developed the models using a subset of the apple data, and then validated the model using the remainder of the apple data. The apple models were then tested in cherry, pear, and walnut orchards to check for significant departure. Our average error with the models for the lacewing *Chrysopa nigricornis* was similar in the two different areas of Washington tested, and California, but were roughly 40% higher in Oregon (HR, *figure on right*). We are not sure why the Oregon data had higher errors, but it is not related to differences in crops, since both cherry and pear orchards in Washington fit the apple data similarly to the apple validation data. We are currently evaluating the different spray programs to see if that explains the differential errors in Oregon.

Benefits to Science and the Agricultural Industries

The phenology models for natural enemies are merely extensions of the theory used to to develop phenology models for pest insects. However, they are an advance in the sense that we found that the phenology in our systems could be predicted solely by temperature accumulations, and did not require information on the host or prey populations levels. We also found that a single model for each natural enemy had similar accuracy in all crops, except in situations where pesticide use was excessive.

The models provide the industries precise information on when different natural enemies occur. In particular, we found that the lacewing, *Chrysoperla plorabunda* and the syrphid flies (*Eupeodes fumipennis* and *Eupeodes volucris*) occur much earlier in the season than previously expected. Our data suggest that we need to re-consider the pesticides used, timing, and the particularly the delayed dormant sprays in all three crops. Ultimately, we expect that we can use our data from this and leveraged projects to generate at least five phenology models that are important to a range of our key pests in western orchards. These models will be be delivered through the WSU-Decision Aid System and provided to the researchers in Oregon and California for implementation in those states.

Mean absolute deviation error for the *C. nigricornis model*. Wen develop (red bar) is the Wenatchee apple data (2009) used to develop the model, all other data is completely independent and used to validate the model. YA - Yakima, HR-Hood River, Wen - Wenatchee.



Improved Monitoring Tools Make Biocontrol Visible

3. NE Monitoring Tools

Jones, Mills, Shearer, Horton, Unruh

The work performed in this objective makes our project the best source of information for the effect of a wide range of floral volatiles and herbivore-induced plant volatiles on natural enemies on different crops in widely separated locations. In addition, the factorial design of our experiments allowed us to evaluate how different potential attractants work together and give us a much more complete picture of how to combine several different volatile components together to make lures that are not only more attractive, but also more selective for different natural enemy groups. We found that 2-phenyl-ethanol (PE) was highly attractive to several species of syrphid species, and some selectivity between species was possible by adding either methyl salicylate (MS) or geraniol (GER). Lacewings (*Chrysoperla plorabunda*) responded strongly to a variety of volatiles and optimal attraction required lures combining three different volatiles. However, because of interactions between the different volatiles, there were multiple combinations that provided the same response. Acetaphenone (AP) was important for *C. plorabunda*, but only when mixed with other components. A broad range of Hymenopteran taxa responded to virtually any lure combination that contained phenylacetaldehyde (PAA) as one component.

Benefits to Science and the Agricultural Industries

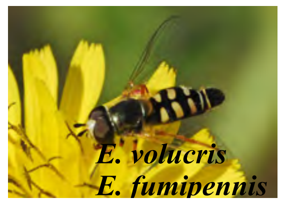
Our studies showed an astonishing variety of natural enemies could be found at various times and abundances in agro-ecosystems. For example, in apple we regularly monitored >120 different natural enemies. The traps are very sensitive indicators of species presence and abundance that may change our basic understanding of population interactions. Our studies also showed that particular lure combinations work regardless of the crop system, which means that our research should translate to other crop systems which often share similar generalist natural enemies. The discovery that PAA was attractive to all hymenopterans (including honey-bees) makes that compound a particularly powerful tool for studying ecosystem function because of the importance of the parasitic Hymenoptera in regulation of a wide range of insect pests.

From the standpoint of benefit to the industries, we now have sensitive traps that work for monitoring a range of natural enemy groups important in apple, cherry, pear, and walnut orchards in the western region. These traps can provide the information on natural enemy abundance throughout the season (useful in model development (objective 2)), and for understanding the effects of different control tactics on natural enemy population dynamics. Our research also showed that syrphid flies and lacewings could be used as indicator species to help simplify trap use for pest management purposes.

Which lures work best?

Squalene

AA+MS+PE
AA+AP+PE
AA+AP+PAA



PE

PE+GER

MS+PE

PAA+PE+AP

Any lure with PAA

Three Predator Groups are Dominant

4. Predation On Codling Moth

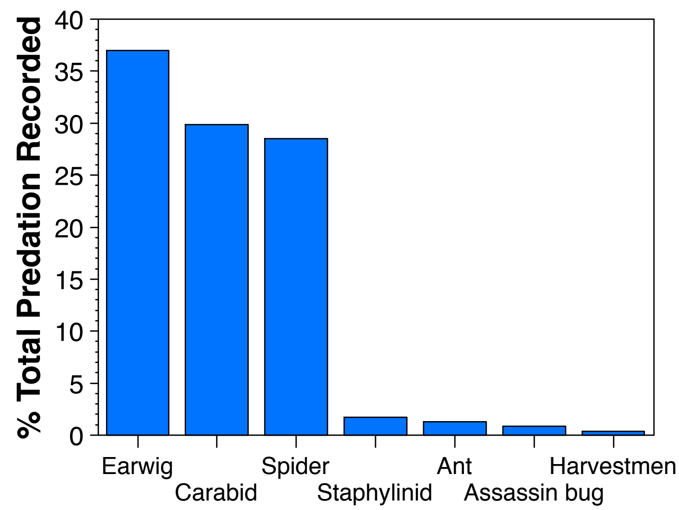
Unruh

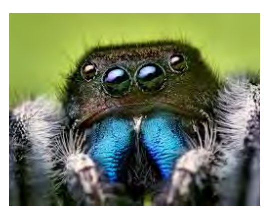
Previous studies suggested that predation rates on mature codling moth larvae were 30 – 40% when pesticide use was moderate. Here we designed a study to identify which predator groups contribute most to codling moth mortality. Molecular gut content analysis was chosen because predators usually eat their prey and leave little visual trace of their activities. Our detection of codling moth DNA in predators provided a semi-quantitative measure of what proportion of each predator group had recently fed on codling moth. The results are conservative because digestion of the codling moth (and consequently their DNA) within the predator limits detectability to just a few days. Even so, we found earwigs, spiders, and carabid ground beetles were important due to their abundance and high feeding rates on codling moth (*right*).

Benefits to Science and the Agricultural Industries

Molecular gut content analysis of prey DNA is not new to science, however it is expensive. One technique developed during this grant has streamlined and reduced the cost of sample processing that will allow future studies to analyze significantly more specimens. As agricultural entomologists, we generally know which groups of predators were likely to be important but the activity by earwigs was both a surprise and a minor concern for some members of the industry. In some apple varieties, earwigs can sporadically cause minor fruit damage. Earwigs are well known to be important predators of woolly apple aphid, an increasingly important pest in newer apple plantings. Future studies to evaluate how earwigs may affect fruit damage compared to their contribution to overall biological control will be important knowledge for the design of sustainable IPM programs in tree fruits.

Percentage of the total number of predator gut content samples that tested positive for codling moth from seven orchards over a three year period.





What is the Cost of Enhanced Biocontrol?

5. Economic Analysis

Gallardo, Brunner, Castagnoli, Grant

Benefits to the Agricultural Industries

The economic analysis showed that both apple and pear growers were willing to pay extra for insecticides that would preserve natural enemies. Surveys showed that apple growers were willing to pay $26.60/acre to decrease toxicity to natural enemies, $61.83/acre to be less toxic to wildlife and $43.10 to decrease toxicity to aquatic organisms. Pear growers showed different trends with a willingness to pay $33.37/acre to decrease toxicity for natural enemies, $25.28/acre for decreased toxicity to wildlife and $19.68/acre for reduced toxicity to aquatic organisms.

A second analysis focused on how the use of pesticides disruptive to natural enemies affected costs of controlling secondary pests. Examination of spray records for seven apple orchard operations in Washington found that for every $1 spent on insecticides that were toxic to natural enemies, an additional $0.52 was spent on secondary pests. Similarly, analysis of the spray records for 10 pear orchards in the Hood River of Oregon showed that for every $1 spent on disruptive materials that $0.47 was required to control secondary pests.

Both of these studies show that economic incentives exist to conserve natural enemies and that growers and IPM practitioners recognize and are willing to pay to enhance biological control.

Getting the Results to the Users

6. Outreach

Brunner, Goldberger, All participants

Benefits to the Agricultural Industries

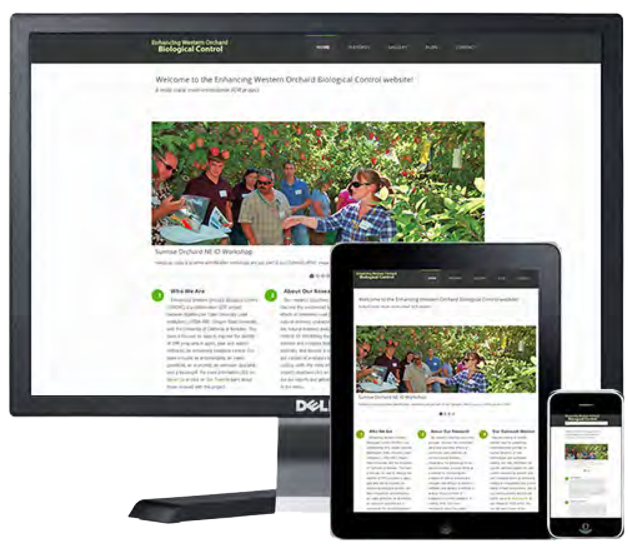
A large amount of this project's resources were dedicated to outreach activities, highlighting the importance the project participants put on this aspect of the project. Without effective outreach activities the results generated by projects such as this one generate new scientific information, but do little to change perceptions and practices of stakeholders. The goal of the outreach objective was not just to develop knowledge and technology for the apple, pear and walnut industries, but to integrate this information with older information and deliver it in a way that would impact their decision-making and management practices.

In the final year of our project we focused our activities in two major areas, hands-on mini-workshops and further development of web resources. We knew from research that students retain new information better when they are actively involved in the learning process. Therefore, the hands-on mini-workshops involved meeting with small groups from key industry organizations, especially those shown to be early adopters of new knowledge and technology, were conducted in an engaging and interactive way. We held 10 mini-workshops over the winter of 2012/13 that included a total of 175 participants. We anticipate more rapid adoption of basic and new biocontrol information and practices through these hands-on educational activities. For the workshops, we developed hand-out materials including natural enemy fact sheets as well as a 19 x 13-inch natural enemy wall poster, which has been very popular with workshop participants and at grower meetings. These hand-out materials can also be downloaded from our project website.

Web Resources – a Legacy for the Future

Preserving our project results and providing useful resources for our stakeholders has been a top priority of this project from the start. We've tried to stay ahead of the changes in digital technology by frequently updating our web platform and it is currently available on nearly any platform/device combination. The website (enhancedbiocontrol.org) is a repository of all of the research results from the project's different objectives in many forms. For Washington growers, the information generated by the project is also being incorporated into the WSU-Decision Aid System (das.wsu.edu) which is used to make IPM decisions on >80% of Washington tree fruit acreage.

In addition to comprehensive reports, the project website contains a listing of all related publications with links for reading, printable identification guides, workshop handouts, viewable presentations, natural enemy image galleries, videos of techniques and collaborator insights, and an interactive pesticide effects table developed from the results obtained in Objective 1, as well as a compiled database of pesticide effects on natural enemies that will be placed both on our project web site and the WSU-DAS website. The website will remain accessible well beyond the end of this project and thanks to new leveraged funding, we will continue to update and add features making it an enduring legacy.



It's More Than Just What we Started to do. Just a few Examples:

Leveraged Funding Projects

Promoting biological control through hands-on and web-based training course, mobile apps, and assisted technology transfer. JF Brunner, U Chambers, A Gadino. WSDA-USDA Specialty Crop Block Grant. $155,743 (2013-2015).

This project will provide for more hands-on workshops as well as an online course that will focus on the basics of biocontrol, key natural enemies in orchards, newly developed tools to monitor and predict natural enemy presence, and pesticide effects on natural enemies; all knowledge gained from this SCRI project. We will also create an innovative and user-friendly pest and natural enemy identification guide available online and as a mobile app to complement the on-line course. In addition, the funding will allow us to extend work performed over the past 2 years with IPM practitioners to evaluate new natural enemy monitoring tools in their orchards and provide feedback. The new project's outcomes have the potential to benefit the entire tree fruit industry through increased awareness and utilization of biocontrol resulting in reduced pesticide applications/costs and increased worker, food, and environmental safety.

Conservation biological control of pear psylla in PNW pears. PW Shearer, KG Amarasekare. Washington Tree Fruit Research Commission. $ 71,571 (2013-2014).

This project is focused on evaluating if the use of mating disruption for CM in pears allows improved biological control of pear psylla during the summer. It will use a combination of the technologies developed in objectives 1-3 from our SCRI project to help tease apart which natural enemies are more common and the best ways to conserve the natural enemies important in pear psylla population suppression.

Enhancing BC in apples: how do conventional and organic systems differ? Jones VP, U Chambers. Washington Tree Fruit Research Commission. $303,858 (2011-2013).

This project used the attractant lures developed in objective 2 of the SCRI grant. We focused on the differences in the natural enemy complexes in paired organic and conventional orchards. The data from this project were taken in the same manner as used in our studies done in the SCRI grant in objective 2, which expands the data available to make natural enemy models. The work done under this project also showed that we could use conventional pesticides at low rates (10% field rate) with timing and treatment intervals similar to organic treatments and still achieve commercially acceptable damage levels similar to either organic or conventional programs. The low rate treatments had similar natural enemy abundance and diversity as the organic treatments at a very low cost and with an 80% reduction in pesticides applied.

Enhancing tree fruit IPM decision-making through advances on WSU-DAS and training of growers and pest management advisors. Jones VP, U Chambers, JF Brunner. Wash. State Dept. Agric. SCRI block grant. $214,215 (2011-2014).

Developing new natural enemy and pest models for WSU-DAS. Jones VP, U Chambers. Washington Tree Fruit Research Commission $151,497 (2013).

These two grants are aimed at improving the WSU-Decision Aid System (DAS), by incorporating models developed using data from the the SCRI project and by collecting more data to generate new models of not only natural enemies, but also pests. These grants also provided funds to enhance our outreach efforts to users throughout the state of Washington, develop orchard management systems to help minimize pesticide use in orchard systems, and to develop push notifications so that growers are alerted immediately when critical IPM events occur or are predicted to occur.

Models to assess pesticide impacts on codling moth, obliquebanded leafroller, and Chrysopa nigricornis. Jones VP, A Gadino, JF Brunner. Washington Tree Fruit Research Commission $226,690 (2012-2015).

This grant is a spinoff from Objective 1 of the SCRI grant. Both the large scale field trials and the lab trials were difficult, very expensive, and prone to problems associated with year-to-year variation in pest and natural enemy population levels. This leveraged project uses field-aged residues to monitor how pesticides degrade over time and combines those data with state-of-the-art demographic models that mimic the phenology found in the field. These models then allow us to evaluate the effects of different treatment regimes for pests to evaluate the best ways to reduce pest populations while preserving natural enemy populations.

Project Output

Presentations:

2013

Amarasekare KG, PW Shearer. Comparing effects of newer insecticides on two green lacewings species, *Chrysoperla johnsoni* and *Chrysoperla carnea* (Neuroptera: Chrysopidae). Orchard Pest and Disease Management Conference, Portland, OR.

Astorino J, R. Torcasso, J Goldberger. The influence of social networks, environmental consciousness, and farm structure on the adoption of a sustainable agriculture practice. Joint Meeting of the Agriculture, Food and Human Values Society and Association for the study of Food and Society. East Lansing, MI.

Beers EH. IPM Grab Bag: Current Insect Pest Management Issues in Tree Fruits. 67th Lake Chelan Horticultural Day, 21 Jan., Chelan, WA.

Beers EH. Current Insect Pest Management Issues in Apples – New and Old. Apple Day, 22 Jan., Wenatchee, WA.

Beers EH. Woolly Apple Aphid: All you wanted to know, and more…. Northwest Wholesale Recertification Day, 15 Jan., Wenatchee, WA. (invited speaker).

Chambers U, L Garcia, F. Sarmiento. Enhancing biological control in western orchards (Mejorando el control biologico en huertos del oeste). Wash. State Hortic. Assoc. Ann. Meeting, Wenatchee, WA. 2-4 Dec. 2013. (invited speaker)

Jones VP. Alternative methods of codling moth control. Columbia Fruit IPM meeting. 13 Feb. (invited speaker)

Jones VP, J Brunner, EH Beers, K Gallardo, NJ Mills, PW Shearer, S Castagnoli, DR Horton, TR Unruh, J Goldberger, U Chambers, A Gadino, A Bixby-Brosi, K. Amarasekare. Enhancing biological control in western orchards: A summary of new information and directions for future research. Wash. Tree Fruit Research Commission Crop Protection Meeting. 30 Jan. (invited speaker)

Jones VP, U Chambers, A Bixby-Brosi. Enhancing BC in apples: how do conventional and organic systems differ? Wash. Tree Fruit Research Commission Crop Protection Meeting. 30 Jan.

Jones VP, A Gadino, J Brunner. Models to assess pesticide impact on CM, OBLR, and *Chrysopa nigricornis*. Wash. Tree Fruit Research Commission Crop Protection Meeting. 30 Jan.

Jones VP. Biocontrol research in the last five years and the next five. Wash. State Hortic. Assoc. Ann. Meeting, Wenatchee, WA. 2-4 Dec. 2013. (invited speaker)

Mills, N.J. Selective pesticides and biological control in walnut pest management. California Walnut Board Annual research conference, Bodega Bay, CA. Jan. 25.

Shearer PW. Enhancing biological control in western USA pear orchards. Department of Horticulture. Oregon State University, Corvallis, OR. Mar. 4. (invited seminar)

Unruh TR. Major predators of codling moth: Earwigs can be your friend. Wilbur Ellis, Organic pest consultants and growers meeting, Prosser, WA. Dec.

2012

Beers EH, L Gontijo, B Greenfield, P Smytheman. Nontarget effects of pesticides on natural enemies: Woolly apple aphid as a case study. Western Orchard Pest and Disease Management Conference, Portland, OR. 11-13 Jan.

Beers EH. Management of secondary and invasive pests. WSU Government Relations Committee, Wenatchee, WA.

Beers EH. Secondary pests of commercial fruit orchards. Blue Mountain Horticultural Society, 1 Feb., Milton-Freewater, OR

Beers EH. Update on invasive pests and their management. Washington State Horticultural Association Annual Meeting, Yakima, WA. 3-5 Dec. (invited speaker).

Brunner JF. Key pests and their management. Washington State Horticultural Association Annual Meeting, Yakima, WA. 3-5 Dec. (invited speaker).

Chambers U, VP Jones, GG Grove. Evaluation of environmental data used for IPM models. Washington Tree Fruit Research Commission Technology meeting. Ellensburg, WA. 10 May.

Chambers U, VP Jones, GG Grove. Evaluation of environmental data used for IPM models. Pacific Branch Entomological Society of America, Portland, OR. 26-28 Mar.

Gadino AN, VP Jones, JF Brunner, EH Beers, K Gallardo, J Goldberger, NJ Mills, PW Shearer, S Castagnoli, DR Horton, TR Unruh. Enhancing biological control to stabilize western orchard IPM programs. Western Orchard Pest and Disease Management Conference, Portland, OR. 11-13 Jan.

Gadino AN, JF Brunner. Stinkbugs: A formidable enemy and a clicker survey of BC practices in orchards. Chelan Fruit meeting. Okanagan, WA. 1 Mar. (invited speaker)

Gadino AN, VP Jones, JF Brunner, EH Beers, K Gallardo, J Goldberger, N Mills, PW Shearer, S. Castagnoli, DR Horton, TR Unruh. Enhancing BC to stabilize western orchard IPM and a clicker survey of BC practices in orchards. Lake Chelan fruit education meeting. Lake Chelan, WA. 16 Jan. (invited speaker)

Gadino AN, VP Jones, JF Brunner, EH Beers, K Gallardo, J Goldberger, N Mills, PW Shearer, S. Castagnoli, DR Horton, TR Unruh. Enhancing BC to stabilize western orchard IPM and a clicker survey of BC practices in orchards. WSU Winter Apple meetings. Wenatchee, WA. 18 Jan. (invited speaker)

Gadino AN, VP Jones, JF Brunner, EH Beers, K Gallardo, J Goldberger, N Mills, PW Shearer, S. Castagnoli, DR Horton, TR Unruh. Enhancing BC to stabilize western orchard IPM. North Central Washington Fieldman's Association. 1 April. Wenatchee, WA. (invited speaker)

Gallardo K. Cost of production of apple, cherry, and pear. Washington State Horticultural Association Annual Meeting, Yakima, WA. 3-5 Dec. (invited speaker)

Jones VP, NJ Mills, AJ Bixby-Brosi, DR Horton, TR Unruh, PW Shearer. Using HIPVs to sample natural enemies in Western apple, pear, and walnut orchards. Western Orchard Pest and Disease Management Conference, Portland, OR. 11-13 Jan.

Jones VP, AN Gadino, JF Brunner. Models to assess pesticide impacts on CM, OBLR and the lacewing *C. nigricornis*. Washington Tree Fruit Research Commission Pest Management Meeting, Pasco, WA. 25-26 Jan.

Jones VP, U Chambers, AJ Bixby-Brosi. Enhancing BC in apples: how do conventional and organic systems differ? Washington Tree Fruit Research Commission Pest Management Meeting, Pasco, WA. 25-26 Jan.

Jones VP. Peering into the future: The directions for apple IPM and the role of Biocontrol. Washington Tree Fruit Research Commission Pest Management Meeting, Pasco, WA. 25-26 Jan. (invited speaker)

Jones VP. How a perfect storm of technology, legislation, and applied ecology can potentially lead to IPM in Western Orchards. Purdue University, Dept. Entomology seminar, West Lafayette, IN. 11-13 Apr. (invited speaker)

Jones VP. How a perfect storm of technology, legislation, and applied ecology can potentially lead to IPM in Western Orchards. UC Davis, Dept. Entomology seminar, Davis, CA. 24-25 Apr. (invited speaker)

Jones VP. Information transfer using low and high technology. Afghan Executive Management training course. Wenatchee, WA. 13 Sept. (45 min presentation)

Jones VP. Using the WSU-Decision Aid System to manage tree fruit pests in nursery situations. Northwest Nursery Improvement Institute. Wenatchee, WA. 11 Oct. (invited speaker).

Jones VP, U Chambers, GG Grove. Evaluation of environmental data used for IPM models. Washington Tree Fruit Research Commission Technology meeting. Ellensburg, WA. 25 Oct.

Jones VP, U Chambers. Long-range forecasts, virtual weather stations, and new models for WSU-DAS. Washington Tree Fruit Research Commission Technology meeting. Ellensburg, WA. 25 Oct.

Lehrer N, J Goldberger. Following the money: impacts and implications of new federal funding for fruit and vegetable research. Agriculture, Food, and Human Values Society Ann. Meeting, NY, NY. 20-24 Jun.

Mills NJ. Selective pesticides and biological control in walnut pest management. Annual Research Conference, Bodega Bay, CA, Jan. 27.

Mills NJ. The role of biological control in walnut production. Quad-county Walnut Institute, Stockton, CA, Feb. 16.

Mills NJ. Selective pesticides and biological control in walnut pest management. Tri-county Walnut Day, Yuba City, CA, Feb. 29.

Mills NJ. Patterns in the biodiversity of natural enemies in California walnut orchards. 24th International Congress of Entomology, Daegu, Korea, Aug. 24. (invited speaker)

Shearer PW, KG Amarasekare and PH Brown. Developing new information and tools to enhance biological control in pear and sweet cherry orchards. Winter Horticulture Meeting, Oregon State University Extension Service, Hood River, OR.

Unruh TR. Evolution toward softer IPM for tree fruits may enhance biological control of codling moth. Western Orchard Pest and Disease Management Conference, Portland, OR. 11-13 Jan.

Unruh TR. The current state of knowledge about beneficial insect releases and what we hope to learn. Wilbur Ellis, Organic pest consultants and growers meeting. Prosser, WA, Jan.

2011

Amarasekare KG, PW Shearer, A Borel. Lethal and sublethal effects of fungicides on the natural enemy *Deraeocoris brevis* (Hemiptera: Miridae). Western Orchard Pest and Disease Management Conference, Portland, OR. 8-10 Jan.

Amarasekare KG, PW Shearer, S Castagnoli. Lab and field studies to improve biological control in pear orchards. Winter Horticulture Meeting, Oregon State University Extension Service, Hood River, OR.

Amarasekare KG, PW Shearer, N Allum, A Borel. Laboratory bioassays to estimate lethal and sublethal effects of newer insecticides on the green lacewing *Chrysoperla carnea*. National Entomological Society of America (ESA) meeting, Reno, NV. 13 Nov.

Amarasekare KG, PW Shearer. Effects of pesticides on lacewings and *Deraeocoris brevis*: conserving important pear natural enemies. OSU Mid-Columbia Research and Extension Center Field Day, Hood River, OR. 20 July.

Bixby-Brosi A, VP Jones. Monitoring tools for biological control agents. WA Hort. Assoc. 6 Dec.

Chambers U, VP Jones. Biological control and the WSU Decision Aid System. WA Hort. Assoc. 6 Dec.

Gadino A, JF Brunner. Outreach education on biological control in orchards. WA Hort. Assoc. 6 Dec.

Gallardo RK, Q Wang, and JF Brunner. Great apples at low pests: growers' valuation of insecticide features. Selected paper presented at the Western Agricultural Economics Association Annual Meetings. Banff, CA. June 29-July 1.

Gallardo RK. Economics of biological control in orchards. OSU Mid-Columbia Research and Extension Center Field Day, Hood River, OR. 20 July.

Gallardo RK, Q Wang. Growers' willingness to pay for pesticides' environmental features: direct vs. indirect valuation. WSU College of Agriculture, Human, and Natural Resources Extension Conference. Pullman, WA. Oct 4.

Gallardo RK. Economics of biological control. WA Hort. Assoc. 6 Dec.

Goldberger J, N Lehrer. Using grower surveys to measure adoption of information-intensive agricultural innovations: the case of biological control in orchard systems. Joint Meeting of the Agriculture, Food, and Human Values Society and Association for the Study of Food and Society, Missoula, MT. 9-12 Jun.

Goldberger, J. Pear survey results and the implications for information transfer. OSU Mid-Columbia Research and Extension Center Field Day, Hood River, OR. 20 July.

Gontijo L, EH Beers, WE Snyder. Impact of flowering plants on syrphid attraction and woolly apple aphid suppression. Western Orchard Pest and Disease Management Conference, Portland, OR. 8-10 Jan.

Gontijo L, EH Beers, WE Snyder. Impact of natural enemies on woolly apple aphid suppression. Pacific Branch Entomological Society of America (ESA), Kona, HI. 27-30 Mar.

Jones VP, DR Horton, TR Unruh. Defining NE biology and phenology to improve IPM. WTFRC Crop Protection Meeting. Yakima, WA. 27 Jan.

Jones VP, U Chambers. Enhancing BC in apples: how do conventional and organic IPM systems differ? WTFRC Crop Protection Meeting. 28 Jan. Yakima, WA.

Jones VP, U Chambers, JF Brunner, EH Beers, J Goldberger, K Gallardo, NJ Mills, DR Horton, TR Unruh, PW Shearer, S Castagnoli, K Amarasekare, SA Steffan, N Lehrer, WE Jones. Enhancing BC to stabilize western orchard IPM systems. WTFRC Crop Protection Meeting. Yakima, WA. 28 Jan. (invited speaker)

Jones VP, U Chambers, JF Brunner, NJ Mills. Web-based IPM and biological control educational programs. Wash. Tree Fruit Res. Commission Technology Review. 14 April.

Jones VP. How IPM can help reduce chemical offsite movement. Soil Cons. Service Meeting. Portland, OR. 18 April.

Jones VP. Natural enemy lures and phenology models. OSU Mid-Columbia Research and Extension Center Field Day, Hood River, OR. 20 July.

Jones VP. Biological control in Washington apple orchards: advances in year 3. WSU Sunrise Field Day, Wenatchee, WA. 16 Aug.

Jones VP. Delivery of science-based information. WA Hort. Assoc. 5 Dec.

Jones VP. Predicting when natural enemies are present. WA Hort. Assoc. 6 Dec.

Lehrer N, J Goldberger, N Mills, J Brunner. Biological control in California's walnut orchards. Annual Meeting of the Association of Applied Insect Ecologists, Monterey, CA. 30 Jan - 1 Feb.

Lehrer N, J Goldberger. Knowledge pathways and agricultural pesticides: redirecting extension to encourage biological control of walnut pests. Ann. Meeting Rural Sociological Society, Boise, ID. 28-31 July.

Mills NJ. Selective pesticides and biological control of walnut pests. California Walnut Board Ann. Res. Conference, Bodega Bay, CA. Jan. 2011.

Mills NJ. Enhancing western orchard biological control. Assoc. Applied IPM Ecologists, Monterey, CA. 30 Jan - 1 Feb.

Mills NJ. Pesticide effects on natural enemies. OSU Mid-Columbia Research and Extension Center Field Day, Hood River, OR. 20 July.

Mills NJ. Overview: role of biological control in IPM. WA Hort. Assoc. 6 Dec.

Mills NJ. Effects of pesticides on natural enemies. WA Hort. Assoc. 6 Dec.

Shearer PW. Current and pending orchard insect management research. Winter Horticulture Meeting, Oregon State University Extension Service, Hood River, OR. 9 Feb.

Shearer PW. Field studies of pesticide effects on natural enemies. OSU Mid-Columbia Research and Extension Center Field Day, Hood River, OR. 20 July.

Shearer PW, K Amarasekare, VP Jones, SA Steffan. Improving biological control of insect pests of cherry. OR/WA Cherry Research Review. Hood River, OR. 7 Nov.

Unruh TR, DR Horton, EH Beers. Efficacy and best practices for predator releases: lacewings, beetles, and mites. WTFRC Crop Protection Meeting. Yakima, WA. 28 Jan.

2010

Amarasekare KG, PW Shearer and AA Borel. Lethal and sublethal effects of newer insecticides on the natural enemy *Deraeocoris brevis* (Hemiptera: Miridae). 84th Annual Western Orchard Pest and Disease Management Conference. Portland, OR. 13-15 January.

Amarasekare K, PW Shearer and AA Borel. Effects of newer insecticides on the natural enemy *Deraeocoris brevis* (Uhler) (Hemiptera: Miridae). Poster. International Organization for Biological Control. Workshop on "Sustainable protection of fruit crops in the Mediterranean area". Vico del Gargano, Italy. Sept. 12-17.

Jones VP. Enhancing biocontrol in Western orchards: an overview. Wash. State Horticultural Assoc. 7 Dec. Yakima, WA. (invited speaker)

Jones VP, SA Steffan. New monitoring systems for natural enemies. Wash. State Horticultural Assoc. 7 Dec. Yakima, WA. (invited speaker)

Jones VP. Conservation BC in Western Orchard Crops: A comprehensive approach. WRCC 2185 Annual Meeting, Coeur d' Alene, ID. Oct. 25 (invited speaker).

Jones VP and SA Steffan. Update on the USDA Specialty Crops Research Initiative project on "Enhancing Biological Control in Western Orchards". WSU-Sunrise Research Orchard Field Day. 29 July.

Mills, NJ. Selective pesticides and the biological control of walnut pests. Walnut Research Conference, Bodega Bay, Jan 28, 2010.

Jones VP, U Chambers, B Petit. WSU-DAS and virtual weather stations. SAGES Climate Change Meetings, Vancouver, BC. 24 March 24. (invited speaker)

Jones VP, SA Steffan, CC Baker, TD Melton. Enhancing biological control in orchard systems: using HIPV's as monitoring tools. 84th Annual Western Orchard Pest and Disease Management Conference. Portland, OR. 13-15 January.

2009

Steffan SA. Biocontrol Innovation at the WSU Tree Fruit Research and Extension Center. WSU Tree Fruit Field Day. 22 July.

Unruh TR. Enhancing western orchard biological control. WSU Tree Fruit Field Day. 15 July.

Steffan SA. Biocontrol in Pacific NW Orchards. Pest Management Transition Project outreach meetings in north central WA. 28 May, 3 June, 10 June.

Symposia presentations:

2014

We organized symposium entitled "*Progress towards integration of conservation biological control in Western apple, pear, and walnut orchards"* on our project for the Pacific Branch of the Entomological Society of America that will be presented at the Tuscon meetings in 7-10 April with the following titles and speakers:

Jones VP. Enhancing biological control in Western apple, pear, and walnut orchards.

Jones VP, NJ Mills, DR Horton, TR Unruh E. Milickzy, PW Shearer. Evaluating floral lures and herbivore-induced plant volatiles for monitoring natural enemies and improving biological control in western orchards.

Mills NJ. Comparative analysis of pesticide effects on natural enemies in Western orchards: a synthesis of laboratory bioassay data.

Beers EH. Natural enemies and non-target effects: Do lab results predict field results?

Unruh TR. A broader approach to gut content analysis for better understanding of predator diets.

Shearer PW, K Amarasekare, S Castagnoli. Assessing conservation biological control in Mid-Columbia pear orchards.

Brunner JF, K Gallardo. Assessing the economic value of biocontrol in western orchard systems

Goldberger J. Who uses biological control and why? Evidence from surveys of walnut and pear growers in the western US.

Gadino A. Developing an outreach program for a regional, multi-year grant: lessons learned and future directions.

Chambers U. Making new information accessible to the stakeholders through websites, decision support systems and smartphone apps.

2013

Jones VP, N Mills, J Brunner, E Beers, U Chambers, A Gadino, D Horton, P Shearer, S Castagnoli, K. Amarasekare, T Unruh. Enhancing biological control in Western orchards: an overview of a five year effort. Pacific Branch Entomol. Soc. American. Lake Tahoe, NV. 7-10 Apr.

Jones VP. C.W. Woodworth Award Presentation. Pacific Branch Entomol. Soc. American. Lake Tahoe, NV. 7-10 Apr.

2012

Beers EH. Biocontrol and IPM: the key component or the missing link? Pacific Branch Entomological Society of America, Portland, OR. 26-28 March

Gadino AN. Using clicker technology as an innovative tool for capturing information in research and extension. Pacific Branch Entomological Society of America, Portland, OR. 26-28 Mar.

Jones VP, U Chambers, B Petit. Decision support systems to aid in the adoption of IPM programs in tree fruits. Symposium presentation, Pacific Branch Entomological Society of America, Portland, OR. 26-28 Mar.

Jones VP, NJ Mills, DR Horton, TR Unruh, PW Shearer. Monitoring and modeling natural enemies to enhance biological control in Western USA tree crops. 2nd International Organic Fruit Research Symposium. International Association of Horticultural Science, Leavenworth, WA. 18-20 Jun.

Jones VP. Update on WSU-Decision Aid System and the USDA-SCRI Biological Control project. Ann. Wash. State Hort. Assoc. Meeting 3-4 Dec.

Mills NJ. Biological pest control in organic tree crops in the western U.S.: An overview. 2nd International Organic Fruit Symposium, Leavenworth, WA, Jun. 19.

Smith TJ, VP Jones. Effects of sublethal pesticide residues on the dispersal capabilities of codling moth (*Cydia pomonella*) and obliquebanded leafroller (*Choristoneura rosaceana*). Pacific Branch Entomological Society of America, Portland, OR. 26-28 Mar.

2011

Jones VP, NJ Mills, DR Horton, SA Steffan, TR Unruh, PW Shearer, A Bixby-Brosi. Using herbivore-induced plant volatiles to enhance biological control in Western Apple, Pear, and Walnut orchards. National ESA Symposium, Reno - *Host Plant Volatiles: Identifying New*

Approaches for Insect Pest Management. 13 Nov.

Steffan SA, VP Jones, CC Baker, E Miliczky, DR Horton. Host plant volatiles as tools for monitoring and manipulating natural enemies. National ESA Symposium, Reno - *Host Plant Volatiles: Identifying New Approaches for Insect Pest Management. 13 Nov.*

2010

Brunner JF, MD Doerr. Control of direct pests of organic apples: Successes and challenges. Symposium presentation, Pacific Branch of the Entomological Society of America's 94th annual meeting, Boise, ID. 11-14 April.

Jones VP, SA Steffan, DR Horton, NJ Mills, PW Shearer. Enhancing BC in organic orchards using HIPV lures to characterize, monitor and manipulate natural enemies. Symposium presentation, Pacific Branch of the Entomological Society of America's 94th annual meeting, Boise, ID. 11-14 April.

Mills NJ. Predation of syrphids in organic prunes: How many predators are enough? Symposium presentation, Pacific Branch of the Entomological Society of America's 94th annual meeting, Boise, ID. 11-14 April.

Shearer PW. Peach Orchard ground cover management mitigates bug damage. Symposium presentation, Pacific Branch of the Entomological Society of America's 94th annual meeting, Boise, ID. 11-14 April.

Steffan SA, VP Jones, CC Baker, and TD Melton. Chumming for predators: HIPV lures as monitoring tools for natural enemies. Pacific Branch of the Entomological Society of America's 94th annual meeting, Boise, ID. 11-14 April.

Unruh TR. Who's eating whom? Evaluating predators and parasitoids and the influence of the farmscape using protein-marking and gut content analysis. Pacific Branch of the Entomological Society of America's 94th annual meeting, Boise, ID. 11-14 April.

National Symposium (2010)

We presented a 3 hour symposium on our project at the Entomological Society of America Annual Meeting in San Diego, CA (15 Dec 2010) entitled "Building the Framework to Enhance Biological Control in Orchard System: Progress and Problems in the Western U.S." - 10 presentations:

Jones VP. Overview and information needed to integrate conservation BC into orchard systems.

Horton DR, E Miliczky, VP Jones. Diversity and phenology of the predator complex in orchards.

Steffan SA, VP Jones, CC Baker, TD Melton. Use of HIPV lures to evaluate natural enemy abundance, diversity and phenology.

Mills, NJ. How do we estimate direct and indirect effects of pesticides on BC? An overview of problems and solutions.

Amarasekare KG, PW Shearer. Use of laboratory assays to estimate pesticide effects on BC agents.

Beers EH, L Gontijo. Connecting the dots: do laboratory bioassays predict disruption of BC in the field?

Gallardo K, JF Brunner, Z Wang. The importance of economics in the adoption of BC programs: use of budgets and case studies.

Goldberger J, N Lehrer. Use of grower surveys to evaluate BC adoption and knowledge transfer.

Chambers U, VP Jones, JF Brunner, B Petit. Decision support systems as a method to enhance adoption of BC.

Brunner JF, C Pickel, S Castagnoli, K Lewis, P van Buskirk, WE Jones, TJ Smith. Synthesis and outreach programs: leaving a legacy useful to growers and consultants.

2009

Beers EH. Cover Crops: Inviting Natural Enemies into Your Orchard. Int. IPM Symposium. Portland, OR. 24-26 March. (invited speaker)

Beers EH. Disruption of Secondary Pests of Apple in the Northwest by Reduced-Risk Pesticides. Int. IPM Symposium. Portland, OR. 24-26 March. (invited speaker)

Jones VP. Using pest and natural enemy phenology to enhance biological control in orchards. Int. IPM Symposium. Portland, OR 24-26 March Publications. (invited speaker)

Jones VP, JF Brunner, GG Grove, B Petit, GV Tangren, WE Jones. Evolution and implementation of decision support systems in perennial crops. Pacific Branch Ent. Soc. of Am., San Diego, CA. 31 April. (invited speaker)

Posters

2013

Amarasekare KG, PW Shearer. Effects of newer insecticides on the green lacewing Chrysoperla carnea. Centennial Celebration and Annual Open House - Research Highlights. Mid-Columbia Agricultural Research and Extension Center, Oregon State University, Hood River, OR.

Unruh TR. Measuring predation on codling moth. Western Orchard Pest and Disease Conference, 11-13 Jan. Portland, OR

2012

Amarasekare KG, PW Shearer, N Allum, AA Borel. Effects of newer insecticides on the green lacewing *Chrysoperla carnea*. Annual Meeting of Orchard Pest and Disease Management Conference, Portland, OR. 11-13 Jan.

Amarasekare KG, PW Shearer, N Allum, AA Borel. Lethal and sublethal effects of insecticides on *Chrysoperla carnea* (Neuroptera: Chrysopidae). 7th International IPM Symposium, Memphis, TN. 27-29 Mar.

Amarasekare KG, PW Shearer, N Allum, AA Borel. Effects of newer insecticides on the green lacewing *Chrysoperla carnea*. Annual Meeting of the Pacific Branch Entomological Society of America (ESA), Portland, OR. 11-13 Jan.

Bixby-Brosi AJ, VP Jones, Evaluating the attractive radius of HIPV lures in western orchards (Poster). Washington State Horticulture Association. Yakima, WA. 3-4 Dec.

Bixby-Brosi AJ, U Chambers, V Jones, Enhancing biological control in apples: How do conventional and organic systems differ? (Poster). Washington Tree Fruit Research Commission. 25-26 Jan. Pasco, WA.

Gadino AN, WE Jones, U Chambers. Natural enemies and enhancing BC in your orchard. Washington State Horticultural Association Annual Meeting, Yakima, WA. 3-4 Dec.

Jones, WE, AN Gadino, U Chambers, JF Brunner, VP Jones. Digital Outreach: Educating Stakeholders about Enhanced Orchard Biological Control. Washington State Horticultural Association Annual Meeting, Yakima, WA. 3-5 Dec.

Smith TJ, VP Jones. The effects of sublethal pesticide residues and flight on codling moth, *Cydia pomonella* (Linnaeus), obliquebanded leafroller, *Choristoneura rosaceana* (Harris) and convergent ladybird beetle, *Hippodamia convergens* (Guérin–Méneville). Pacific Branch Entomological Society of America, Portland, OR. 26-28 Mar.

Unruh TR. Key predators of codling moth. WA Horticultural Association, Yakima WA. 3-5 Dec.

2011

Amarasekare KG, PW Shearer, A Borel. Effects of two key orchard fungicide treatments on the natural enemy *Deraeocoris brevis* (Uhler) (Hemiptera: Miridae). Annual Pacific Branch Entomological Society of America (ESA), Kona, HI. 27-30 Mar.

Jones VP, U Chambers, JF Brunner, EH Beers, J Goldberger, K Gallardo, NJ Mills, DR Horton, TR Unruh, PW Shearer, S Castagnoli, K Amarasekare, SA Steffan, N Lehrer, WE Jones. Enhancing BC to stabilize western orchard IPM systems. WTFRC Crop Protection Meeting. Yakima, WA. 28 Jan.

Jones VP, JF Brunner, EH Beers, J Goldberger, K Gallardo, NJ Mills, DR Horton, TR Unruh, PW Shearer, S. Castagnoli, K Amarasekare, U Chambers, A Gadino, A Bixby-Brosi, N Lehrer, WE Jones. Enhancing biological control to stabilize Western orchard IPM systems. WSU Sunrise Field Day, Wenatchee, WA. 16 Aug.

Gallardo RK, Q.Wang. Growers' willingness to pay for pesticides' environmental features: direct vs. indirect valuation. WSU Sunrise Field Day. Wenatchee, WA. 16 Aug.

Unruh TR, DR Horton, EH Beers. Efficacy and best practices for predator releases: lacewings, beetles, and mites. WTFRC Crop Protection Meeting. Yakima, WA. 28 Jan.

2010

Amarasekare KG, PW Shearer and AA Borel. Effects of newer insecticides on the natural enemy *Deraeocoris brevis* (Uhler) (Hemiptera: Miridae). Poster. Pacific Branch Entomological Society of America's 94th annual meeting. Boise, ID. 11-14 April. (PDF 580KB)

Jones VP, S Steffan, JF Brunner, EH Beers, J Goldberger, K Gallardo, U Chambers, NJ Mills, DR Horton, T Unruh, PW Shearer and S Castagnolli. Enhancing Biological Control to Stabilize Western Orchard IPM Systems. Poster. WSU Academic Showcase. (PDF 8.4MB)

Popular Articles:

2013

Chambers U, V Jones, A Gadino, W Jones, N Mills, J Brunner. Part 1. Enhancing Biocontrol: Overview. Good Fruit Grower. Feb. 1, 2013.

Bixby-Brosi A, V Jones, D Horton, T Unruh, N Mills, P Shearer, J Brunner. Part 2. Enhancing Biocontrol: Natural Enemy Inventory. Good Fruit Grower. Feb. 15, 2013.

Gadino A, V Jones, N Mills, P Shearer, T Unruh, J Brunner. Part 3. A New Tool for IPM: Natural enemy models. Good Fruit Grower. March 1, 2013.

Gadino A, T Unruh, J Brunner. Part 4: Codling moth: It's what's for dinner. Good Fruit Grower. March 15, 2013.

Gallardo K, and J Brunner. Part 5: Calculating the value of biological control. Good Fruit Grower. April 1, 2013.

Chambers U, N Mills, E Beers, T Unruh, P Shearer, J Brunner, K Amarasekare and V Jones. Part 6: Your management program matters. Good Fruit Grower. April 15, 2013.

Goldberger J, W Jones and N Lehrer. Part 7: Pear growers surveyed on biological control. Good Fruit Grower. May 1, 2013.

Jones W, A Gadino, U Chambers, J Brunner. Part 8: Outreach: the final goal. Good Fruit Grower. May 15, 2013.

2012

Warner, G. Watch out, codling moth! Spiders will eat anything they can physically tackle, including codling moth larvae and pupae. Good Fruit Grower. May 1.

Hansen, M. Easier access to MRLs. Visit the DAS web site. Good Fruit Grower. March 15.

Warner, G. Let natural enemies play a role. IPM means managing pests, not eliminating them. Good Fruit Grower. February 1.

2011

Wheat D. Entomologist makes research relevant. Capitol Press. 22 April. (Jones interview)

Clark B. Entomologists open new frontiers to aid sustainable future for for fruit growers. WSU *On Solid Ground*. 25 May. (Jones, Brunner, Beers interview).

Warner G. $4.5M project. Good Fruit Grower. 15 March. (Jones interview)

Warner G. Watch out for the good guys: Biological control is more important than people realize. Good Fruit Grower. 15 March. (Jones interview)

Warner G. Scientists study pesticide effects: The choice and timing of pesticide sprays can influence biological control. Good Fruit Grower. 1 April. (Mills interview)

Warner G. Who's eating codling moth. Good Fruit Grower. 15 April. (Unruh interview)

Warner G. Counting the benefits of biocontrol. Good Fruit Grower. 1 May. (Gallardo, Brunner interview)

Warner G. Who's making the decisions. Good Fruit Grower. 15 May. (Goldberger interview)

Clark B. The model makers. WSU CAHNRS and Extension Alumni and Friends Connections Magazine. Fall 2011. (Jones interview)

2010

Steury T. 2010. Cultivated landscapes: The kinder, gentler orchard. Washington State Magazine 9(4):38-43.

Refereed Publications

2014

We have contacted the journal *Biological Control* and arranged for the publication of a special issue with 14 different articles (*below*) all by our team members. These articles will go through the normal peer review process and be published together in a single issue devoted to our project. This method of publication brings our work together in a single location available in the best libraries in the world as well as available on the internet.

Jones VP, NJ Mills, JF Brunner, DR Horton, EH Beers, TR Unruh, PW Shearer, J Goldberger, K Gallardo, S Castagnoli, N Lehrer, SA Steffan, KG Amarasekare, U Chambers, AN Gadino. 2014. From planning to execution to the future: An overview of a concerted effort to enhance biological control in Western apple, pear, and walnut Orchards.

Amarasekare KG, PW Shearer, NJ Mills. 2014. Testing the selectivity of pesticide effects on natural enemies in laboratory bioassays.

Mills NJ, EH Beers, PW Shearer, TR Unruh, KG Amarasekare. Comparative analysis of pesticide effects on natural enemies in Western orchards: a synthesis of laboratory bioassay data.

Shearer PW, KG Amarasekare, EH Beers, NJ Mills, VP Jones. 2014. Large-plot field studies to assess impacts of newer insecticides on non-target arthropods in Oregon pear orchards.

Beers EH, NJ Mills, PW Shearer, DR Horton, E Milickzy, KG Amarasekare. 2014. Non-target effects of orchard pesticides on natural enemies: lessons from the field and laboratory.

Jones VP, CC Baker, AJ Bixby-Brosi. 2014. Evaluating release rates and longevity of natural enemy attractant lures.

Jones VP, DR Horton, NJ Mills, TR Unruh, CC Baker, TD Melton, E Milickzy SA Steffan, PW Shearer, KG Amarasekare. 2014. Evaluating herbivore-induced plant volatiles and floral volatiles for monitoring natural enemies in apple, pear and walnut orchards.

NJ Mills, Jones VP, DR Horton, TR Unruh, CC Baker, SA Steffan, TD Melton, PW Shearer, KG Amarasekare, E Milickzy. Using herbivore-induced plant volatiles and floral volatiles to attract natural enemies for studies of ecosystem structure and function.

Jones VP, NJ Mills, PW Shearer, TR Unruh, DR Horton, E Milickzy, TD Melton, CC Baker. 2014. Using natural enemy lures to develop phenology models for IPM purposes: an example using *Chrysopa nigricronis* Burmeister (Neuroptea: Chrysopidae).

Unruh TR, E Milickzy, DR Horton . 2014. The spider fauna using codling moth, *Cydia pomonell*a, in apple orchards as determined by molecular gut content analysis.

Gallardo K, JF Brunner, S Castagnoli, NJ Mills, J Grant. 2014. Capturing the economic value of biological control.

Goldberger J, N Lehrer, JF Brunner, NJ Mills. 2014. Biological control adoption in western orchard systems: Results from grower surveys

Jones WE, U Chambers, AN Gadino, JF Brunner, VP Jones. 2014. Web-based outreach for orchard management decision-makers.

Gadino AN, JF Brunner, U Chambers, S Castagnoli, WE Jones . 2014. A perspective on the extension of research-based information to orchard management decision-makers: Successes and failures and potential future directions.

2013

Amarasekare KG, PW Shearer. 2013. Life history comparison of two green lacewings species, *Chrysoperla johnsoni* and *Chrysop-*

erla carnea (Neuroptera: Chrysopidae). Environmental Entomology. (*in press*)

Amarasekare KG, PW Shearer. 2013. Comparing effects of insecticides on two green lacewing species, *Chrysoperla johnsoni* and*Chrysoperla carnea* (Neuroptera: Chrysopidae). J. Economic Entomology 106:1126-1133).

Amarasekare KG, PW Shearer. 2013. Laboratory bioassays to estimate the lethal and sublethal effects of various insecticides and fungicides on *Deraeocoris brevis* (Hemiptera: Miridae). J. Economic Entomology. 106: 776-785.

Beers EH. 2012. Effect of trap color and orientation on the capture of *Aphelinus mali* (Haldeman) (Hymenoptera: Aphelinidae), a parasitoid of woolly apple aphid (Hemiptera: Aphididae). J. Econ. Entomol. 105: 1342-1349.

Gallardo RK, Q Wang. 2013. "Willingness to Pay for Pesticides' Environmental Features and Social Desirability Bias: The Case of Apple and Pear Growers." *Journal of Agricultural and Resource Economics* 38:124-139.

Gallardo RK, D Toro-Gonzalez, JR Goldberger, N Lehrer, JF Brunner. "Factors Affecting the Adoption of Integrated Pest Control, An Application to the Pacific Northwest Pear Industry." *Journal of Agricultural and Resource Economics. (submitted)*

Gontijo L, EH Beers, WE Snyder. 2013. Flowers promote aphid suppression in apple orchards. Biol. Contr.: (*in press*).

Gontijo L, SD Cockfield, EH Beers. 2012. Natural enemies of woolly apple aphid (Hemiptera: Aphididae) in Washington state. Environ. Entomol. 41: 1364-1371.

Jones VP, R Hilton, JF Brunner, WJ Bentley, DG Alston, B Barrett, RA Van Steenwyk, LA Hull, JF Walagenbach, WW Coates, TJ Smith. 2013. Predicting emergence of codling moth, *Cydia pomonella* (Lepidoptera: Tortricidae) on a degree-day scale in North America. Pest. Management Sci. *(in press*). DOI 10.1002/ps.3519

Jones VP, NG Wiman. Age-based mating success in codling moth and obliquebanded leafroller. *J. Insect Sci. (in press).*

Pfannestiel RS, BE Mackey, TR Unruh. 2012. Leafroller parasisism across an orchard landscape in central Washington and effect of neighboring rose habitats on parasitism. Biological Control. 62:162-172.

Schmidt RA, EH Beers, TR Unruh, DR Horton. 2013. Releases of insectary-reared *Galendromus occidentalis* (Acari: Phytoseiidae) in commercial apple orchards. J. Econ. Entomol. 106. *(in press*)

Steffan SA, Y Chikaraishi, DR Horton, N Ohkouchi, ME Singleton, EJ Bosak, E Milicyky, DB Hogg,VP Jones**.** 2013. Trophic hierarchies unmasked via amino acid isotopic analysis. PLOS ONE 8: 1-10.

Wiman NG. VP Jones. 2013. Attack biology and egg maturation strategy of two tachinid parasitoids of leafroller (Lepidoptera: Tortricidae) pests in tree fruit. Ann. Entomol. Soc. Amer. 106: 485-490.

Wiman NG, VP Jones. 2013. Influence of oviposition strategy of *Nemorilla pyste* and *Nilea erecta* (Diptera: Tachinidae) on parasitoid fertility and host mortality. Biol. Control 64:195-202. link: http://dx.doi.org/10.1016/j.biocontrol.2012.12.008

Wiman NG, VP Jones. Sublethal effects of pyriproxyfen and methoxyfenozide on *Nemorilla pyste* and *Nilea erecta* (Diptera: Tachinidae), parasitoids of leafrollers (Lepidoptera: Tortricidae) in tree fruits. *J. Pest Management Sci. (in press)*

2012

Horton DR, E Miliczky, VP Jones, CC Baker, TR Unruh. 2012. Diversity and phenology of the generalist predator community in apple orchards of Central Washington State (Insecta, Araneae) *Can. Entomol. 144: 691-710.*

Jones VP, NG Wiman 2012. Modeling the interaction of physiological time, seasonal weather patterns, and delayed mating on population dynamics of codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae). *Popul. Ecology* 54: 421-429.

Smith TJ. 2012. Effects of flight and sublethal pesticide residues on codling moth (*Cydia pomonella* (L.), obliquebanded leafroller, *Choristoneura rosaceana* (Harris), and convergent ladybird beetle, *Hippodamia convergens* (Guérin−Méneville). MS Thesis, Washington State University, Department of Entomology, Pullman, WA.

Unruh TR, LA Lacey, HL Headrick, RS Pfannenstiel. 2012. The effect of the granulosis virus (PapyGV) on larval mortality and feeding behavior of the *Pandemis* leafroller, *Pandemis pyrusana* (Kearfott) (Lepidoptera: Tortricidae) Biocontrol Sci. Techn. 22:981-990.

Unruh TR. RS Pfannenstiel, C Peters, J Brunner, VP Jones. 2012. Parasitism of leafrollers in Washington fruit orchards is enhanced by perimeter plantings of rose and strawberry. Biological Control 62:162-172.

2011

Jones VP, SA Steffan, NG Wiman, DR Horton, E Miliczky, QH Zhang, CC Baker. 2011. Evaluation of herbivore-induced plant volatiles for monitoring green lacewings in Washington apple orchards. Biol. Control. 56: 98-105 doi:10.1016/j.biocontrol.2010.10.001

2010

Jones VP, SA Steffan, LA Hull, JF Brunner, DJ Biddinger. 2010. Effects of the loss of organophosphate pesticides in the US: Opportunities and needs to improve IPM programs. Outlooks in Pest Management (invited paper) 21: 161-166.

Jones VP, JF Brunner, GG Grove, B Petit, GV Tangren, WE Jones. 2010. A web-based decision support system to enhance IPM programs in Washington tree fruit. Pest Management Sci. 66:587-595. (311KB)

2009

Horton DR, VP Jones, TR Unruh. 2009. Use of a new immunomarking method to assess movement by generalist predators between a cover crop and tree canopy in a pear orchard. Am. Entomol. 55:49-56. (3.4MB)

Jones VP, TR Unruh, DR Horton, NJ Mills, JF Brunner, EH Beers and PW Shearer. 2009. Tree Fruit IPM Programs in the Western United States: The challenge of enhancing biological control through intensive management. Pest Management Sci. 65: 1305-1310. (PDF 168KB)

Misc. Outreach

Amarasekare KG. KIHR- (Local Radio Station, Hood River, OR) - Radio Talk on enhancing biological control in tree fruit orchards. 5 Jan.

Shearer PW. KIHR - (Local Radio Station, Hood River, OR). Radio Talk Biological control: using good bugs to take care of bad bugs.

Jones VP. The future of IPM in orchard crops. 15 min. video, part of the series by the University of California program on Extending Orchard IPM knowledge in California. 11 April 2013. http://ucanr.edu/sites/OrchardIPM/Video_Library_875/

Meetings Attended/Hosted

2013

Identification of natural enemies in tree fruit orchards. Annual Sunrise Research Orchard Field Day, Wenatchee, WA. 7 August 2013.

Mobile Predator Lab. Training workshop, Qualls Bayer Acre Day, Ephrata, WA. 17 July 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Wenatchee, WA. 7 March 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Wenatchee, WA. 5 March 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Wenatchee, WA. 27 February 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Cashmere, WA. 14 February 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Wenatchee, WA. 13 February 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Yakima, WA. 5 February 2013.

Biological Control Basics & Natural Enemy ID. Training workshop, Wenatchee, WA. 24 January 2013.

Biological Control Basics & Natural Enemy ID.. Training workshop, Chelan, WA. 16 January 2013.

2012

Enhanced Biocontrol in Western Orchards Research and Advisory Committee meeting, Portland, OR. 9-10 Jan.

Western Orchard Pest and Disease Management Conference, Portland, OR. 11-13 Jan.

Washington Tree Fruit Research Commission Pest Management Meeting, Pasco, WA. 25-26 Jan.

Enhanced Biocontrol in Western Orchards Short course, 8-9 Feb. Wenatchee and Tricities, WA; Hood River, OR (teleconference to all locations and speakers at all locations).

Pacific Branch Entomological Society of America, Portland, OR. 26-28 March.

Washington Tree Fruit Research Commission Technology meeting. Ellensburg, WA. 10 May.

2nd International Organic Fruit Research Symposium. International Association of Horticultural Science, Leavenworth, WA. 18-20 Jun.

Enhanced Biocontrol in Western Orchards Research Committee meeting, Wenatchee, WA. 21-22 June.

Enhanced Biocontrol in Western Orchards natural enemy identification and sampling workshop. Hood River, OR. Aug 3.

Enhanced Biocontrol in Western Orchards natural enemy identification and sampling workshop. Wenatchee, WA. Aug 23.

Northwest Nursery Improvement Institute. Wenatchee, WA. 11 Oct.

Washington Tree Fruit Research Commission Technology meeting. Ellensburg, WA. 25 Oct.

Washington State Horticultural Association Annual Meeting, Yakima, WA. 3-5 Dec.

Agriculture, Food, and Human Values Society Ann. Meeting, NY, NY. 20-24 June.

Leveraged Funding

Beers EH. Biocontrol of woolly apple aphid. Washington Tree Fruit Research Commission. $108,635. (2009-2011).

Beers EH. Biocontrol of woolly apple aphid. Washington State Commission on Pesticide Registration. $42,078. (2009-2011).

Beers EH. Insectary plantings for natural enemies of woolly apple aphid. WSU BioAg Program. $24,473. (2010-2011).

Brunner JF, U Chambers, A Gadino. Promoting biological control through hands-on and web-based training course, mobile apps, and assisted technology transfer. USDA-WSDA Specialty Crops Block Grant Program. $155,743. (2013-2015).

Jones VP, U Chambers. Enhancing BC in apples: how do conventional and organic systems differ? Washington Tree Fruit Research Commission. $303,858. (2011-2014).

Jones VP, U Chambers, JF Brunner. Enhancing tree fruit IPM decision-making through advances on WSU-DAS and training of growers and pest management advisors. Wash. State Dept. Agric. SCRI block grant. $214,215. (2011-2014).

Jones VP, A Gadino, JF Brunner. Models to assess pesticide impacts on CM, OBLR, and *C. nigricornis.* Washington Tree Fruit Research Commission $226,690. (2012-2015).

Jones VP, U Chambers. Developing new natural enemy and pest models for WSU-DAS. Washington Tree Fruit Research Commission $151,497. (2013).

Jones VP, A Gadino. Evaluating low dose insecticide residues on codling moth flight and behavior. Washington State Commission on Pesticide Registration. $21,438 (2013).

Jones VP, SA Steffan. Enhancing biological control in cherries. Washington State Commission on Pesticide Registration $23,189. (2010) .

Mills NJ, C Pickel, J Grant, SC Welter. Selective pesticides and biological control in walnut pest management $21,726. (2011-2012).

Mills NJ. Spider mite management in Walnuts. California Walnut Board. $178.383. (2013-2015).

Shearer PW. Conservation biological control of pear psylla in PNW pears. Washington Tree Fruit Res. Commission. $75,571. (2013-2014).

Shearer PW, K Amarasekare, VP Jones, SA Steffan. Improving biological control of insect pests of cherry. Washington Tree Fruit Research Commission $79,485. (2010-2011).

Unruh TR, DR Horton, EH Beers. Efficacy and best practices for predator releases: lacewing, beetles, and mites. Washington Tree Fruit Research Commission. $237,997. (2010-2012).

Acknowledgements

Matching Funds Sources

- Wash. Tree Fruit Research Commission
- Wash. State Commission on Pesticide Registration
- California Walnut Board
- Hood River Pear Growers
- Washington State University
- Oregon State University
- University of California at Berkeley
- USDA-ARS Yakima Ag. Res. Lab

Grower Cooperators:

- California Walnut growers of Suisun Valley, Davis and Chico.
- Oregon Pear Growers in Hood River
- Washington apple growers in Quincy, Bridgeport, Frenchman Hills, Yakima, and Wapato.

Participating Personnel

Beers Lab (Obj. 1)
Bruce Greenfield

Brunner Lab (Obj. 6)
Wendy Jones

Gallardo Program (Obj. 5)
Qianqian Wang (*Grad. Student*)

Goldberger Program (Obj. 6)
Dr. Nadine Lehrer (*Post-Doc. Scientist*)
Joseph Astorino (*Grad. Student*)
Rebekah Torcasso (*Grad. Student*)
Emily Green-Tracewicz (*Grad. Student*)

Horton and Unruh Labs (Obj. 1-4)
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Merilee Bayer
Deb Broers
Franscico De La Rosa

Jones Lab - Obj. 2, 3, 6
Dr. Ute Chambers (*Post-Doc. Scientist*)
Dr. Andrea Bixby-Brosi (*Post-Doc. Scientist*)
Dr. Angela Gadino (*Post-Doc. Scientist*)
Dr. Shawn Steffan (*Post-Doc. Scientist*)
Callie C. Baker
Tawnee D. Melton
Teah Smith (*Grad. Student*)
Brad Petit
Stacey McDonald
Nik Wiman (*Grad. Student*)

Mills Lab - Obj. 1-3
Kevi Mace-Hill
Laura Jones
Lisa Fernandez (*Grad. Student*)

Shearer Lab - Obj. 1-3
Dr. Kaushalya Amarasekare (*Post-Doc. Scientist*)