SAES-422 Multistate Research Activity Accomplishments Report

submitted by Roy Van Driesche, April 15, 2014

Project No. NE1332

Project Title: Biological Control of Arthropod Pests and Weeds
Report Information:
Period the Report Covers: 03/2013-03/2014
Annual Meeting Date: January 9, 2014
NE1332 met in conjunction with USDA FS Invasive Species meeting, Annapolis, MD, January 9, 2014. The group sponsored a symposium (1:00-3:30) and business meeting (12:00-1:00)

Participants

1. Ken Bloem	USDA APHIS Raleigh, NC
2. Hannah Broadley	University of Massachusetts
3. Richard Casagrande	University of Rhode Island
4. Joe Elkinton	University of Massachusetts
5. Fritzi Grevstad	Oregon State University
6. Ann Hajek	Cornell University
7. Judy Hough-Goldstein	University of Delaware
8. Bob Nowierski	USDA NIFA
9. Scott Salom	Virginia Tech
10. Jil Swearingen	Cheverly, MD
11. Lisa Tewksbury	University of Rhode Island
12. John Peter Thompson	NISC ISAC
13. Bob Tichenor	USDA APHIS PPQ
15. John Vandenberg	USDA ARS Ithaca
16. Roy Van Driesche	University of Massachusetts
17. Aaron Weed	Dartmouth College
18. Mark Whitmore	Cornell University

Brief Summary of Minutes of Annual Meeting
The business meeting was moderated by the newly elected president, Roy Van Driesche. The first order of business was to decide on what to do about next year's officers. It was decided to stick to the original plan for new officers to serve for two years and then move up, such that Roy Van Driesche will remain president until the group's 2015 meeting, at which time Scott Salom would become president, Judy Hough-Goldstein would become president-elect, and a new secretary would have to be elected. The second item of business was to decide on the venue for the group's next meeting. It was decided to hold the meeting with the ESA Eastern Branch meeting in March of 2015. (However, later it was learned that the meeting site was not favorable and the venue for the 2015 meeting was changed to be Annapolis, MD, as part of the USDA FS invasive species meeting, as in 2014.) Finally, there were general discussions of current biological control projects and Bob Nowierski presented information on new federal funding opportunities for biological control.

Symposium Program
Held in conjunction with USDA FS Invasive Species meeting, Annapolis, MD, January 9th (1:00-3:30), Roy Van Driesche moderator

1. Update on biological control of winter moth -Joe Elkinton and Hannah Broadley

2. Classical biological control of emerald ash borer: recent progress and potential for success-Jian Duan, Leah Bauer, Kris Abell, Juli Gould, Roy Van Driesche

3. Massachusetts state-listed butterfly *Pieris oleracea* prospers using the invasive form of cuckoo flower *Cardamine pratensis*--Megan Herlihy and Roy Van Driesche

4. Overview of weed biocontrol progress in region-Dick Casagrande

5. Mile-a-minute weed and weevil response to varying moisture and temperature regimes-Scott Berg and Judy Hough-Goldstein

6. Update on prospects for biological control of Japanese knotweed. Frizi Grevstad

Accomplishments

Goal 1 (Conservation of existing natural enemies)

Objective 1. To conserve natural enemies in blueberry production (F. Drummond, U. Maine)

- **Outputs (events, publications)** A summary of research on the ecosystem services that natural enemies provide in *Vaccinium* crops globally is forthcoming (Jones et al., in press) and a second publication was published illustrating how pesticides used in lowbush blueberry structure the ant community (Choate et al., 2013).
- **Outcomes (change in status of system)** Transition to newer types of pesticides, especially the shift away from organophosphate insecticides, has enhanced the diversity and abundance of *Formica* ants in lowbush blueberry.
- **Impacts (benefits)** Greater awareness by growers in the choices for selection of pesticides that have reduced impact on natural enemies, as well as, availability of a new educational bulletin (D'Appollonio-Cote et al., 2013) has resulted in less use of older, more toxic pesticides.

Objective 2. To determine distribution and impact of *Cotesia rubecula* (R. Van Driesche, UMASS)

- **Outputs (events, publications)** The research of a masters student on this system was published (see two Herlihy papers listed), as was one paper for the general public (see Chew article)
- **Outcomes (change in status of system)** Competition from *Cotesia rubecula* has reduced levels of *Cotesia glomerata*.
- **Impacts (benefits)** The introduction of *C. rubecula* has had a positive effect on the conservation of a state-listed native butterfly (*Pieris oleracea* Harris) that was formerly suppressed by *C. glomerata*.

Objective 3. To examine the effects of exotic plants on ecosystem function (P. Shrewsbury and M. Raupp, University of Maryland)

- **Outputs (events, publications).** Results of studies were presented at two invitational seminars: 1) The International Symposium on Biological Control of Arthropods in Pucon, Chile, and 2) Clemson University, Department Colloquium Series.
- **Outcomes (change in status of system).** The general trend is for increasing use of exotic plants with increasing urbanization. Data are mixed as to the impact of alien plants on arthropod communities and ecosystem services they provide. Results suggest the response of arthropods to native woody landscapes compared to exotic was somewhat taxon specific. Specifically, Lepidoptera appear to be responding to host plant origin (more diverse and abundant in native landscapes) more so than other taxa. Parasitoids were also more abundant and diverse in native landscapes than alien. However, predator diversity and abundance, and levels of predation on herbivores did not differ between native and alien landscapes. There was no difference in overall levels of feeding damage in native compared to exotic woody landscapes, suggesting minimal impacts of increased use of alien plants in landscapes on the ecosystem service of predation.
- **Impacts (benefits).** Discussions with gardening enthusiasts and Master Gardeners suggest there is increasing awareness of the importance of plant function rather than just plant origin.

Goal 2 (Augmentation programs)

Objective 4. To release and evaluate augmentative biological control agents and educate the public about their role in pest management. (M. Mayer, New Jersry; M. Hoffmann, Cornell University)

- **Outputs** *Trichogramma ostriniae* were introduced into five vineyards to further evaluate their effect on number of grape clusters infested with grape berry moth larvae. Trials were conducted with a Y-tube olfactometer to determine whether *T. ostriniae* displayed a preference for high vs. low relative humidity. Egg cleaning aerodynamic sorting of parasitized and unparasitized host eggs was tested using a commercial seed sorter. Also, a retrospective on 20 years' research on *Trichogramma ostriniae* was presented at the 2013 Eastern Branch meeting of the Entomological Society of America. An undergraduate student was mentored in scientific methods.

- **Outcomes and impacts**

  1. **Cornell University.** When *T. ostriniae* was introduced to vineyards, there was a slight but significant reduction in the number of grape clusters infested by grape berry moth. This suggests the value of integrating biological control with insecticidal control or application to organic vineyards. Further research will confirm whether the effect can be amplified by optimizing the quantity, timing, and location of releases. *Trichogramma ostriniae* had a preference for high humidity over low humidity, but no preference when humidity levels were within 30% of each other. This suggests that humidity may play a role in field efficacy and that releases under dry conditions may be contraindicated.

  2. **New Jersey.** In 2013, the Mexican bean beetle (MBB) *Epilachna varivestis* (Coleoptera: Coccinellidae) biological control program involved 31 growers and 40 survey locations with a history of Mexican bean beetle pressure. A total of 336,000 adult, were released at the survey locations with additional soybean field releases totaling 270,500 parasites to keep pressure on the Mexican bean beetle population. During the 2013 season a total of 606,500 *P. foveolatus* were released statewide. There were no reported insecticide treatments for Mexican bean beetle in soybeans in 2013 and there have been no treatments since 1987.

Goal 3 (Classical Biological Control)

Objective 5. To develop a biological control program for exotic *Phragmites australis* (R. Casagrande, URI; B. Blossey, Cornell Univ.)

- **Outputs**: Host range testing was completed in quarantine at URI for two potential biological control agents for *P. australis: Archanara geminipuncta* and *A. neurica*. Funding and research coordination was provided for experiments on these agents in outdoor behavioral trials by CABI in Switzerland.
- **Outcomes**: *A. geminipuncta* and *A. neurica* were found to be host-specific to *P. australis*. Preliminary data indicate that both agents oviposit on exotic *P. australis* in preference to native North American phragmites.

Objective 6. To develop a biological control program for swallowworts in North America (R. Casagrande, URI)

- **Outputs**: We revised and resubmitted a release petition for *Hypena opulenta* against swallowworts to USDA-APHIS. This request was recommended for USDA approval by TAG in August, 2013.
- **Outcome**: Canada granted immediate release approval and we made two shipments of *H. opulenta* to Canadian colleagues, who released these agents near Ottawa in September, 2013.

Objective 7. To establish and evaluate herbivores released against mile-a-minute weed (J. Hough-Goldstein, University of Delaware).

- **Outputs (events, publications).** A Biological Control of Northeastern Weeds Cooperators Meeting was co-hosted by J. Hough-Goldstein and the Phillip Alampi Beneficial Insect Laboratory at the New Jersey Public Health, Environmental and Agricultural Laboratory (PHEAL), on Feb. 19, 2013. The meeting was attended by 112 people from 11 states, and included talks by J. Hough-Goldstein and S. Berg as well as others; PowerPoints from the presentations have been posted on the web site at http://ag.udel.edu/enwc/research/biocontrol/mileaminute.htm. New publications include reports assessing use of restoration planting along with the mile-a-minute weevil, *Rhinoncomimus latipes*, to enhance biological control of mile-a-minute weed (Cutting and Hough-Goldstein 2013, Lake et al. 2013), and a paper describing the role of phototaxis in host-finding behavior of the weevil (Smith and Hough-Goldstein 2013).
- **Outcomes (change in status of system).** During 2013, graduate student Scott Berg conducted the second year of a 2-year study on *P. persicaria* response to weevils and drought conditions. In addition, undergraduate Marisa DelCorso completed a third year of an experiment testing weevils and a restoration seed mix, separately and together, for their effects on mile-a-minute weed and the resulting plant community, on State Game Land property in PA, and undergraduate Jennifer Schoenstein conducted a second year of tests comparing *R. latipes* that had been mass-reared since 2004 with weevils collected from the field in Delaware. Scott Berg's results support previous field observations that *R. latipes* is the most effective in controlling mile-a-minute weed in warm, low-moisture conditions. The results of the State Game Land study suggest, as in previous studies, that an integrated program that includes restoration planting along with the weevil can help restore a mostly native ecosystem and avoid the "invasive species treadmill," where suppression of mile-a-minute weed leads to invasion by another aggressive invasive plant like Japanese stiltgrass. In the comparison of mass-reared and field weevils, the laboratory insects laid more eggs but had reduced survival in several cases, and had reduced responsiveness to diapause-inducing cues, but these differences were probably not all genetically based. Exposure to older plants had the greatest effect on induction of reproductive diapause in both laboratory and field weevils, with effects of day length and temperature less pronounced. At least a portion of the laboratory weevil population overwintered successfully. Results suggest that it is not necessary to add wild-type genetic material to the rearing colony at this time.
- **Impacts (benefits).** The weevil *Rhinoncomimus latipes*, first released in 2004 for control of mile-a-minute weed, *Persicaria perfoliata*, is now well-established in the mid-Atlantic region and parts of surrounding states. In 2013, 86,060 weevils were reared and shipped from the NJ Department of Agriculture Phillip Alampi Beneficial Insect Laboratory and released in 10 states in the Northeast, from MA to VA, and west to WV. Also, since 2004, the Phillip Alampi Beneficial Insect Laboratory has released 170,618 *R. latipes* adults into 13 New Jersey counties. Weevils have been recovered at all of the release sites (100%) as well as at 219 dispersal/non-release sites, 51 of which were found in 2013. All new 2013 release sites already had *R. latipes* present.

- **Impacts (benefits).** Overall conclusions reached so far are that the biocontrol weevil *R. latipes* will be extremely successful in controlling *P. perfoliata* on its own in certain circumstances, and will contribute to an integrated management program under other conditions.

Objective 8. To develop an effective biological control program for the emerald ash borer
(R. Van Driesche, UMASS, with K. Abell and federal cooperators J. Duan, L. Bauer, J. Gould)

- **Outputs (events, publications)** A key paper on the establishment and impact of the larval parasitoid *Tetrastichus planipennisi* was published (Duan et al., 2013) summarizing data for first five years following this species' release in MI (2008-2012). A similar paper summarizing establishment and impacts of the egg parasitoid *Oobius agrili* for the MI study plots for the same time period is in preparation.
- **Outcomes (change in status of system)** *Tetrastichus planipennisi* is now widespread and abundant in study areas in MI and is causing significant (ca 20%) levels of larval mortality
- **Impacts (benefits)** Emerald ash borer population growth rates in our study plots has now fallen to below the level of replacement, showing that the population is now collapsing in that area. This is due to both reduction in the ash resource due to EAB-caused tree mortality and to increased mortality from natural enemies suffered by remaining EAB attacking remaining ash trees in plots.

Objective 9. To establish and evaluate natural enemies of the hemlock woolly adelgid
(J. Elkinton, UMASS; M. Mayer, New Jerswy)

- **Outputs (events, publications).** Leah Flaherty join the Elkinton lab at the University of Massachusetts as a postdoc and conducted a predator exclusion study on hemlock woolly adelgid in Banner Elk, North Carolina starting in February 2014. Banner Elk is where *Laricobius nigrinus* has been established in substantial numbers. Indeed we collected 2500 of these beetles at that location in three days in November 2014. Richard McDonald and his collaborators believe that *Laricobius nigrinus* has turned the corner of adelgid infestations in that region. We chose two sites in Banner Elk where beetles have been established and a third site about 50 km away where no beetles have been released. We put fine-mesh bags on understory trees and removed any beetles that we found on branches before placing the bags. We were disappointed to find no measurable difference in the disturbance rate of adelgid ovisacs by predators and no differences in adelgid population growth or survival inside versus outside the bags. We note the beetles tend to aggregate toward sunlit branches either the top of the canopy in the forest or on the forest edge so perhaps this explains our negative results. We note further that Bud Mayfield reported more positive results when he worked on upper-level branches at a *Laricobius* release site in Georgia. We plan to continue these studies in the fall 2014.
- **Outcomes and Impacts.** A total of 10,915 *L. nigrinus* have been released in New Jersey since 2005. In 2013, 848 *L. nigrinus* larvae and 285 adults were recovered which was the largest number of hemlock woolly adelgid predators ever recovered in New Jersey in a single year and the total is greater than all previous years combined for all species. There were two first time recoveries from release sites as well as over 100 dispersal site recoveries. We have confirmed dispersal of *L. nigrinus* over 17 miles from the Delaware Water Gap north to past Buttermilk Falls.

Objective 10. To establish and evaluate natural enemies of the winter moth (J. Elkinton, UMASS)

- **Outputs (events, publications).** Nothing to report.
- **Outcomes (change in status of system).** The winter moth (*Operophtera brumata*: Geometridae: Lepidoptera), has continued to spread west and south across Massachusetts and Rhode Island. Outbreak populations occurred in 2013 for the first time in SE Connecticut and other populations have been found in SW Connecticut. Also in 2013, defoliation by winter moth occurred for the first time in coastal Maine. Both of these areas will receive our attention for parasitoid releases in 2014. We have introduced several thousand *Cyzenis albicans* (Diptera: Tachinidae) at 22 sites in eastern Massachusetts, Rhode Island, and Maine. We have expanded our yearly effort to collect *C. albicans* in Victoria, British Columbia. In 2013, we released 1600 flies at each of seven sites: Jamestown, RI, Bristol RI, Cape Elizabeth, ME; Harpswell Neck, ME; Lexington, MA; Mattapoisett, MA and Halibut Point MA. All the flies were mated and fed before we released them. At each of our *Cyzenis* release sites from previous years, and at other permanent non-release sites we continued to monitor year-to-year changes in winter moth density. We collected approximately 12,000 winter moth pupae from these collections and reared them to the adult stage. We recovered flies for the first time at one of our 2011 releases sites in Newton MA.

- **Impacts (benefits)** In 2013, we recovered *C. albicans* at all six of the pre-2011 release sites. At most sites, parasitism was low (<5%) but substantial parasitism occurred at four sites: 30% parasitism at Wellesley, 10 % at Hingham, and 8% at two other sites. Winter moth densities have declined by 95% at our site in Wellesley where parasitism rates have been higher than 30 % for two years in a row.

Objective 11. To distribute and evaluate *Peristenus relictus*, a parasitoid of the tarnished plant bug.

Nothing to report for 2013.

Objective 12. To establish and evaluate biological control agents for garlic mustard (*Alliaria petiolata*) (B. Blossey, Cornell University)

Nothing to report for 2013

Objective 13. To investigate potential new biological control projects for the northeast.

- **Outputs (events, publications).** Nothing to report
- **Outcomes (change in status of system)**

1. **Knotweed Biological Control**. We anticipate an APHIS permit for release of a biological control agent, knotweed psyllid (TAG approval obtained) from research underway by cooperators Fritzi Grevstad (Oregon) and Dick Shaw (CABI Great Britain).
2. **Plum Curculio**: During 2012-13, four commercial organic apple orchards and three research apple orchards were inoculated with persistent NY strains of entomopathogenic nematodes (EPN) as biological control agents of plum curculio. Follow-up soil samples show the gradual establishment of EPN populations, which is reflected in plum curculio larval bioassays and reductions in fruit damage over the 2-year period. Results have been shared with grower and researcher audiences at grower meetings, professional meetings, and in trade publications. (A. Agnello, NYS Agric. Expt. Sta., Geneva, New York)
3. **Japanese Beetle.** Surveys were done to determine the distribution and timing of occurrence of the Japanese beetle parasitoids *Tiphia vernalis* and *T. popilliavora* in other New England states such as Massachusetts and New Hampshire. *Tiphia vernalis* was found in these Massachusetts counties: Worcester, Middlesex, Hampden, Hampshire, and Franklin. Wasps were collected from Rockingham and Hillsborough counties in New Hampshire. Wasps were not collected from Cheshire County, but only one location was visited in this county. Nevertheless, *T. vernalis* was found in the neighboring Hillsborough County, New Hampshire to the east and Worcester County, Massachusetts in the south. *Tiphia popilliavora* wasps were found in the following three of the seven Massachusetts counties visited: Worcester, Hampshire and Essex. *Tiphia popilliavora* is present in Rockingham, Hillsborough and Cheshire counties in New Hampshire. (A. Legrand, Univ. of CT).

- **Impacts (benefits).** Nothing to report

Goal 4 (Evaluation and Education)

Objective 14. To distribute information on the successful biological control of the birch leafminer throughout the northeastern states (R. Casagrande, URI)

- **Outputs (events, publications).** The success of this project was discussed by Dick Casagrande (URI) in presentations to Massachusetts Horticultural Society – May 2013, Rhode Island Wild Plant Society – July 2013, New England Grows! - January 2014, Ecological Landscaping Association – February 2013. A chapter on this program was included in a Forest Service publication edited by Roy Van Driesche.

- **Outcomes (change in status of system).** Over 2,000 stakeholders were made aware that birch leafminer is under complete biological control from Maine through New Jersey and west through Minnesota.
- **Impacts (benefits).** Informed stakeholders will discontinue insecticide applications against this pest.

Objective 15. To provide web-based information for growers, landscape managers, educators, and students on biological control programs (P. Shrewsbury, University of Maryland; Tony Shelton, Cornell University)

- **Outputs (events, publications).**
  1) **University of Maryland**. The University of Maryland continued to produce a weekly electronic newsletter "Landscape and Nursery IPM Pest Alert" throughout the 2013 growing season to provide timely information on pest identification and management tactics particularly emphasizing biological controls. In addition to overall newsletter contributions I write the "*Beneficial of the Week*" segment for the newsletter. This collaborative project involves several Extension personnel (led by Stanton Gill) and Master Gardeners, landscapers, nursery producers, and government agency staff. The newsletter is emailed weekly to over 2,200 stakeholders in over 20 states weekly.
  2) **Cornell University.** The highly popular web site, Natural Enemies: a Guide to Biological Control Agents in North America, http://www.nysaes.cornell.edu/ent/biocontrol, is the most widely accessed web site on biological control according to Google. It is accessed by students from grade school to graduate school, and by the general public and the scientific community. Through this site, field workers attempting to initiate programs are able to find researchers who can guide them. Contributors are enthusiastic about this project and the public response to it, and often answer questions from site visitors.
- **Outcomes (change in status of system).**
  1) **University of Maryland.** UMD research has determined degree day (DD) information on target life stages of key scale insects. This information is incorporated into the newsletters. The web site has been updated to be more user-friendly and provide an archive of past reports with a search engine.
  2) **Cornell University.** This last year we added two new natural enemies to the website. We are currently looking to put it on another platform besides html, which causes the website to look differently on different devices.
- **Impacts (benefits).**
  1) **University of Maryland.** Surveys of the newsletter consistently provide excellent ratings (13 years). Moreover, these surveys document that the Pest IPM Alert has increased knowledge, changed practices, reduced pesticide inputs, reduced costs, and increased the adoption of IPM practices – all standard measures of the impacts of an extension program. For example, from the 2013 survey when recipients were asked: Are the Pest Alerts useful to you and your business 91% ranked the Alert at the highest ranking; Do the Pest Alerts help you to effectively identify pest insects, diseases, and/or weeds, 90% ranked the Alert the highest; Are you making fewer or more accurate pesticide applications – 82% ranked the Alert the highest. Related specifically to the *Beneficial of the Week* segment questions on improving recognition of beneficials and altering pest management strategies ranked 80% and 60% respectively.
  2) **Cornell University.** We continue to get about 50,000 hits per month on the site. This attests to the sites popularity. A report on the site was presented at the W-3185

meeting on Oct. 2, 2013: Spreading the word on biological control: the 15th anniversary of the website on natural enemies in North America.

Objective 16. To publish the results of biological control research in refereed journals, books, and proceedings. (See list of new publications below)

Ballard, M., **J. Hough-Goldstein**, and D. Tallamy. 2013. Arthropod communities on native and non-native early successional plants. *Environmental Entomology* 42:851-859.

Chew, F. S., R. G. **Van Driesche**, and R. A. Casagrande. 2012. Native butterfly confronts exotic plants and parasitoids Massachusetts Butterflies No. 39, Fall, pp. 1-6.

Choate, B. and F. **Drummond**. 2013. The role of insecticides in structuring *Formica* mound ant communities (Hymenoptera: Formicidae) in Maine lowbush blueberry. J. Econ. Entomol. 106(2): 716 – 726.

Cutting, K., and **J. Hough-Goldstein**. 2013. Integration of biological control and native seeding to restore invaded plant communities. *Restoration Ecology* 21: 648-655.

D'Appollonio-Cote, J., D. E. Yarborough, and F. **Drummond**. 2013 Maine Wild blueberry pesticide chart – 1 of 3. http://umaine.edu/blueberries/files/2010/05/2013-ME-Wild-BB-Pesticide-Chart-Insecticides.pdf

Duan, J.J., L. S. Bauer, K.J. Abell, J. P. Lelito, R. **Van Driesche**. 2013 Establishment and abundance of *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in Michigan: Potential for success in classical biocontrol of the invasive emerald ash borer (Coleoptera: Buprestidae). *Journal of Economic Entomology* 106:1145-1154.

Frye, M.J. and **J. Hough-Goldstein**. 2013. Plant architecture and growth response of kudzu (Fabales: Fabaceae) to simulated insect herbivory. *Environmental Entomology* 42: 936-941.

Herlihy, M. V. and R. G. **Van Driesche**. 2013. Effects of *Cotesia rubecula* (Hymenoptera: Braconidae) on survival of larval cohorts of *Pieris rapae* (Lepidoptera: Pieridae) on collards: impact evaluation of the impact of an introduced biological control agent. *Florida Entomologist* 96: 360-369.

Herlihy, M. V., D. L. Wagner, and R. G. **Van Driesche**. 2014. Persistence in Massachusetts of the veined white due to use invasive form of *Cardamine pratensis*. *Biological Invasions in press*.

Jones, M.S. H. Vanhanen, R. Peltola, and F.A. **Drummond.** 2014. A Global Review of Arthropod-Mediated Ecosystem-Services in *Vaccinium* Berry Agroecosystems. *Terrestrial Arthopod Reviews* 5(x): *in press*

Lake, E., K. Cutting, and **J. Hough-Goldstein**. 2013. Integrating biological control and native plantings to restore sites invaded by mile-a-minute weed, *Persicaria perfoliata*, in the mid-Atlantic US. pp. 254-261 In Y. Wu, T. Johnson, S. Sing, R. Rhagu, G. Wheeler, P. Pratt, K. Warner, T. Center, J. Goolsby, and R. Reardon (eds.) Proceedings of the XIII International Symposium on Biological Control of Weeds. USDA Forest Service, FHTET-2012-07. 530 pp.

Obeysekara, P. T., and **A. Legrand.** 2014. Analysis of *Tiphia* parasitoids preovipositional behaviors and of their scarab host defensive responses. *Biological Control* 69: 97-106.

Obeysekara, P.T., **A. Legrand** and G. Lavigne. 2014. Use of herbivore-induced plant volatiles as search cues by *Tiphia vernalis* and *Tiphia popilliavora* to locate their below-ground scarabaeid hosts. *Entomologia Experimentalis et Applicata* 150: 74–85.

Smith, J.R. and **J. Hough-Goldstein**. 2013. Phototaxis, host cues, and host-finding in a monophagous weevil, *Rhinoncomimus latipes*. *Journal of Insect Behavior* 26:109–119.