APPENDIX D (SAES-422)

Multistate Research Activity Accomplishments Report
Multi-State Project NC1173, "Sustainable Solutions to Problems Affecting Bee Health"
Business Meeting
William Barker, Project Director
Judy Wu-Smart, Project Chair
Thursday, 11 January 2019, 4:30pm – 5:30pm,
Coronado Room- DoubleTree by Hilton Hotel Phoenix Tempe, Arizona

Project/Activity Number: NC1173
Project/Activity Title: Sustainable Solutions to Problems Affecting Bee Health
Period Covered: 1 January to 31 December 2018
Date of This Report: 8 March 2019
Annual Meeting Date(s): 11 January 2019
Participants:

NC_temp1173 participants	Email	Affiliation	Head ?
Averill, Anne	averill@eco.umass.edu	Massachusetts - University of Massachusetts	
Burand, John	jburand@microbio.umass.edu	Massachusetts - University of Massachusetts	
Cowles, Richard	richard.cowles@ct.gov	Connecticut -New Haven	
Danforth, Bryan	bnd1@cornell.edu	New York -Ithaca : Cornell University	
Delaplane, Keith	ksd@uga.edu	Georgia - University of Georgia	Yes
Eitzer, Brian	brian.eitzer@ct.gov	Connecticut -New Haven	Yes
Ellis, James	jdellis@ufl.edu	Florida - University of Florida	Yes
Flenniken, Michelle	michelle.flenniken@montana.edu	Montana - Montana State University	Yes
Groves, Russell	groves@entomology.wisc.edu	Wisconsin - University of Wisconsin	
Harpur, Brock	bharpur@purdue.edu	Indiana - Purdue University	Yes
Hines, Heather	hmh19@psu.edu	Pennsylvania - Pennsylvania State	
Huang, Zachary	bees@msu.edu	Michigan - Michigan State University	Yes
Klingbeil, Michele	klingbeil@microbio.umass.edu	Massachusetts - University of Massachusetts	
Li-Byarlay, Hongmei	hli-byarlay@centralstate.edu	Central State University	
Lopez-Uribe, Margarita	mml64@psu.edu	Pennsylvania - Pennsylvania State	
Rajotte, Ed	uvu@psu.edu	Pennsylvania - Pennsylvania State	
Sagili, Ramesh R	sagilir@hort.oregonstate.edu	Oregon - Oregon State University	Yes
Schroeder, Declan	dcschroe@umn.edu	Minnesota - University of Minnesota	
Spivak, Marla	spiva001@umn.edu	Minnesota - University of Minnesota	Yes
Stoner, Kimberly	kimberly.stoner@po.state.ct.us	Connecticut -New Haven	
Tarpy, David R	david_tarpy@ncsu.edu	North Carolina - North Carolina State University	
Winfree, Rachael	rwinfree@rci.rutgers.edu	New Jersey - Rutgers University	
Wu-Smart, Judy	jwu-smart@unl.edu	University of Nebraska-Lincoln	Yes

Brief summary of minutes of annual meeting:

1. Call to order: The meeting was called to order by Dr. Judy Wu-Smart at 4:30 pm on January 11, 2019.

2. Roll call: The table below provides a list of participants that attended the meeting.

2019 TempNC1173 participants	Email	Affiliation
Flenniken, Michelle	michelle.flenniken@montana.edu	Montana - Montana State University
Huang, Zachary	bees@msu.edu	Michigan - Michigan State University
Li-Byarlay, Hongmei	hli-byarlay@centralstate.edu	Central State University
Schroeder, Declan	dcschroe@umn.edu	Minnesota - University of Minnesota
Spivak, Marla	spiva001@umn.edu	Minnesota - University of Minnesota
Wu-Smart, Judy	jwu-smart@unl.edu	University of Nebraska-Lincoln
Non-NC1173 members		**Affiliation**
Bill Barker		NC1173 project director
Ling-Hsiu Lian		visiting scientist
Chia-Hua Lin (on behalf of Reed Johnson)		Ohio State University
Xinjian Xu		visiting scientist
Tom Webster		Kentucky State University
E.N. Escobar		University of Maryland
Selina Bruckner (on behalf of Geoff Williams)		Auburn University
Priya Charabarti (on behalf of Ramesh Sagili)		Oregon State University
Bret Adee		Adee Honey Farms

3. Chair's report on current membership: The committee chair, Dr. Judy Wu-Smart, discussed membership of the group (https://www.nimss.org/projects/view/appendix_e_direct/18589) and asked those present in the meeting whether they belonged to the NC1173 working group or not. Several students and colleagues were present on behalf of active members (noted in roll call list). Dr. Wu-Smart reported that 29 members across 20 states have rejoined the NC_temp1173 project on the NIMMS website. Anyone present at the meeting that were not an active member was advised to talk with the director of their respective Agricultural Experiment Station in order to be officially added to the Project. Dr. Wu-Smart reminded everyone that NC1173 is undergoing the renewal process and that the group had agreed to reduce the number of objectives to simplify the reporting process. Dr. Wu-Smart reviewed those new objectives and asked if there were any concerns or questions regarding those but received no questions. Members provided positive feedback both in person (at the meeting) and via email (for those who could not attend) for the simplification of the new proposed objectives.

4. Project Director's report: Dr. Wu-Smart introduced Dr. William Barker as the new Project Director. Dr. Barker provided general information about himself and discussed the NC1173 renewal process, timeline, and status. The project description (NC_temp1173) for renewal was submitted to NIMSS in December and is currently awaiting approval. Dr. Barker reminded members that the annual report for the 2019 meeting will be due 60 days after the meeting (March 11th, 2019). Previously, members were supplied the with a template from NIFA to be

filled out individually and returned to the Project Chair to assemble but Dr. Wu-Smart commented that this is a highly inefficient and tedious process which does not highlight collaborative projects well. Therefore, Dr. Wu-Smart suggested setting-up a shared document (google docs) with the template so everyone could input their data on the same document and add to existing projects to reduce redundancy and double reporting by each individual institution. Members agreed that this may be a better way to showcase areas of collaboration among members of NC1173 and to tie accomplishments across states. This will also simplify reporting. Dr. Barker noted that "impact nuggets" written in non-technical language are most useful for NIFA as they communicate our work to policymakers and the public.

5. USDA Advisor for the Project report: In previous meetings, Dr. Mary Purcell-Miramontes, USDA Advisor for the Project, provided information about the USDA budget and relevant competitive grant programs within AFRI. However, the meeting took place during the government shut down so Dr. Purcell-Miramontes was not able to attend the meeting and we were unable to obtain NIFA granting information this year.

6. Location of 2020 NC1173 meeting – The group voted to hold the next meeting together with the American Bee Research Conference and the American Bee Federation meeting in Schaumburg, Illinois in the second week of January, 2020.

7. Adjourned meeting- We adjourned the meeting at 5:20 pm

NC_temp1173 Project Station Report Content:

Objectives:

Objective 1 (stressors): To evaluate the role, causative mechanisms, and interaction effects of biotic stressors (i.e. parasitic mites, pests, and pathogens) and abiotic stressors (i.e. exposure to pesticides, poor habitat and nutrition, management practices) on the survival, health and productivity of honey bee colonies as well as within pollinator communities.

Objective 2 (breeding): To facilitate the development of honey bee stock selection, maintenance and production programs that promote genetic diversity and incorporate traits conferring resistance to parasites and pathogens.

Objective 3 (management): To develop and recommend "best management practices" for beekeepers, growers, land managers and homeowners to promote health of honey bees and pollinator communities.

1. **Impact Nuggets reported by state and multistate research groups.**

Summary: *Multistate project NC1173 members address honey bee colony losses by examining the role of abiotic and biotic stressors play either alone or in combination with others and by mitigating colony health issues through selective breeding programs and integrated management approaches for beekeepers, home owners, and land managers.*

AL: Studied effects of pesticides and parasites, alone and in combination, on honey bees *Apis mellifera*; performed a national colony loss survey; and investigated effects of an organic acid to control the honey bee parasite *Varroa destructor*.
CA, CT, MI, PA, SC: Identified annual and perennial ornamental cultivars that have higher levels of attractiveness to pollinators
CA, IL, IN, MN, PA: Developed citizen-scientist beekeeper network to monitor honey bee health across landscapes
CT: Colonies of bees from five sources of queens were evaluated for their general health, including varroa, populations, strength of colonies, and defensiveness. Of these sources, two sources of bees were found to have acceptable traits for Connecticut beekeepers.
FL: Within the NC1173 project time period, FL participants have focused principally on developing/refining methods one can use to determine the impacts of pesticides on immature and adult honey bees in tier 1-type tests. They, then, use the protocols to determine the impacts of pesticides on honey bees, both immature and adult, in a variety of studies.
IN, MT: Quantified virus abundance in honey bees and mites obtained from the same colonies (n=36) and determined that there was no difference in virus abundance between two bee lines (or genotypes), and that DWV was best correlated in bees and mites, while BQCV levels were much lower in mites than in bees.
MN: Evaluated 5 years of data collected by Tech Transfer Teams about health and survivorship of 23 migratory beekeeping operations based in Upper Midwest, and identified risk factors that lead to increasing odds of colony mortality, that will be shared with beekeepers to help them modify BMP's; Initiated stock selection program for honey bee colonies that are hygienic, high propolis collection and have low mite population growth over the season. Based on findings of benefits of propolis envelope to colony immune system and disease load, we are investigating ways to modify standard Langstroth box interiors (e.g., rough wood and textures) to stimulate bees to create a natural propolis envelope. Tech Transfer Teams (for commercial beekeepers) and Bee Squad (urban beekeepers) work with migratory and small scale beekeepers, respectively, to recommend best management practices.
MT: Continued to monitor and assess the correlations between honey bee colony health (i.e., frame count) and pathogen abundance. Results, which vary, were presented to several stakeholder groups including the MT Beekeepers Association.
NE: We have continued to examine the use of treelines as pesticide (neonicotinoids and Bt-toxins) drift barriers to reduce potential contamination of pollinator habitats near crop fields. We a have also developed integrated pesticide management strategies for beekeepers to better monitor for pesticide incidences and respond with timely management of affected colonies.
OH: Identified an insecticide and an insecticide-fungicide combination applied to almond orchards during bloom capable of harming adult and developing honey bees. Findings have

shaped Best Management Practices for almond pesticide application and resulted in a 50% reduction in insecticide use during bloom.
PA: Demonstrated that 1) landscape context and particularly access to high quality forage is critical for supporting both honey bee and bumble bee colony growth and performance; 2) high densities of honey bees can selected for low nectar production in flowering plant species; 3) the use of metagenomic approach to identify several new viruses infecting honey bees and other bee species around the world.
PA, TX: Characterized use of social pheromones to regulate foraging and mating behavior in honey bees

2. New Facilities and Equipment.
New Bee Labs were established in both Alabama (G. Williams-Auburn University) and Florida (J. Ellis Univ. of Florida)

3. Unique Project Related Findings.
AL: Preliminary results suggest that neonicotinoid exposure under a model exposure scenario negatively affects drone sperm production, but not worker hypopharyngeal glands. Further preliminary work suggest that the oxalic acid shop towel method of application has a low to moderate effectiveness against the mite *Varroa destructor*. Beekeeper survey revealed that 40% of US colonies died between April 1, 2017 and March 31, 2018.
CA, CT, MI, PA, SC: There is considerable variation in attractiveness of different ornamental varieties and cultivars to pollinators which can be considered when designing urban and suburban gardens.
FL: Many pesticides tested in various studies impact multiple parameters measured for developing honey bees. Despite this, risk quotients calculated using the data and the EPA BeeREX file suggest that the tested compounds pose little risk to developing bees in the field.
MN: For commercial beekeepers based in Upper Midwest, that transport their colonies to CA or to South for winter, main risk factors that impact colony health and survivorship are: mite levels > 1/ 100 bees in spring, and >3 mites/ 100 bees in late summer; queen event (no queen in colony) at any point in the summer; and high Nosema loads in fall. Use of fumagillan had no impact on nosema loads or colony survival. Colonies that collect high quantities of propolis have reduced disease loads and better immune system function.
MT: Investigation of honey bee virus infection and associated immune responses at the individual bee and cellular levels. Several genes identified by Brutscher et al Sci Reports, are also regulated in hemocytes.
NE: Treelines reduce the deposition of Bt-laden pollen from GMO corn on milkweed plants and pollinator habitats established near crop fields.

OH: Soybeans represent a significant foraging resource for honey bees in Ohio as soybean pollen was found in 50% of honey samples provided by beekeepers from across the state.
PA: Honey bee winter survival is related to colony size and landscape context, not genetic background. Bee populations host a wide variety of viruses from different families. Long term exposure to high bee foraging densities can lead to reduce floral reward production in plant species

4. Accomplishments by state or multistate groups and NC_temp1173 objective:
Please note states are ordered alphabetically and does not reflect the leading institution in collaborative research groups.
Summary: Accomplishments made by NC1173 members during 2018 covered all three project objectives to improve bee health through a better understanding of the role abiotic and biotic stressors play, improved genetics and breeding, and effective integrated management strategies for land managers and beekeepers. Several objectives were addressed through collaborative research and their work presented here highlight the extensive linkages both among NC1173 members as well as to external peer groups and stakeholders. NC1173 members will continue to obtain feedback from stakeholders through our extension and outreach activities so that we may better prioritize future research and address emerging issues through holistic and collaborative approaches.
AL, GA (Objective 1 stressors): We evaluated the effects of neonicotinoids and *Varroa destructor* on worker hypopharyngeal glands. Workers were exposed to neonicotinoids during development using a model in-hive pollen feeding exposure scenario. Half of experimental workers were further exposed to the mite *Varroa destructor* by artificial inoculation; the other half were not exposed to *V. destructor*. Preliminary data analysis suggest that *V. destructor* negatively affected worker hypopharyngeal glands, but not pesticides.
AL (Objective 3 management): We administered the Bee Informed Partnership's National Colony Loss and Management Survey via online and paper formats. This estimated that US beekeepers lost approximately 40% of their colonies from the period April 1, 2017 and March 31, 2018. Furthermore, our oxalic acid study, which employed 10 control colonies and 10 colonies that received a shop towel containing oxalic acid and glycerin, revealed a moderate level of control against the *Varroa destructor* mite. These data have been submitted to the USDA for their assessment of possible label changes to oxalic acid.
CA, IL, IN, MN, PA, (Objective 1 stressors, 3 management): We demonstrated the surrounding landscape context is critical in determining the growth rates and ultimately survival and fitness of honey bee and bumble bee colonies. We are developing an online portal which will allow beekeepers and others to obtain relative scores of landscape forage, nesting, and pesticide quality for their sites. This portal will also allow us to obtain information from beekeepers on

the health and performance of their colonies, which we will use to develop a health score metric to inform management practices.

CA, CT, MI, PA, SC (Objective 3 management): With funding from the USDA NIFA SCRI, we are evaluating the quality of different ornamental plant varieties and stocks for attracting and nutritionally supporting honey bees and wild pollinators. Our data is demonstrating significant variation among plant stocks, and is being compiled into a list of top-scoring plant stocks to support urban and suburban planting.

CT (Objective 1 stressors): We have previously shown that by using visual sorting by color of the pollen pellets collected at beehives located in a nursery, followed by pesticide analysis of the sorted pollen and palynology to identify the plant sources of the pollen with the greatest acute toxicity of pesticide residues, we were able to associate pollen from the plant genus Spiraea with extraordinarily high concentrations of thiamethoxam and clothianidin, and also with high concentrations of acephate and its metabolite methamidophos. In a study funded by the EPA we have continued this work. Pollen samples were collected at beehives located at two Connecticut nurseries throughout the growing season. These samples are being characterized as to both pesticide content and palynology in an effort to further elucidate plant-pollen pollinator interactions that create the greatest risk

FL (Objective 1 stressors) A: Rearing environment (in vitro or in the hive) did not impact bee survival to adult emergence. Furthermore, our data suggest colonies with brood survival percentages of ≥80% are suitable colonies from which to source larvae for in vitro-rearing risk assessments.

B*: We calculated risk quotients (RQs) for both chlorothalonil and diflubenzuron using the data we generated in our experiments. Collectively, the RQs suggest that neither compound is likely to affect larval mortality directly at field relevant doses given that pollen (the matrix with the residue) composes only a fraction of the total larval diet.

C*: Honey bee larvae exposed to acaricides at concentrations similar to maximum residues found in pollen and honey/nectar had no detectable change in survival or developmental rate. Collectively, our data suggest that residues of amitraz, fluvalinate, and coumaphos at the levels we tested are unlikely to impact immature worker bee survival in the field.

*For studies in “B” and “C”, our data do not preclude any sublethal effects that may result from bee exposure to these compounds or possible synergisms of the compounds when they co-occur in bee colonies.

MN (Objective 1 stressors): The quality of a queen is not reliably predicted on her brood pattern (published article, Lee et al, 2018, Insects)**.** Risk factors that affect colony health and survivorship identified for migratory beekeepers based in Upper Midwest.

MN (Objective 3 management): The Bee Squad (urban beekeeper extension team), taught over 50 hands-on classes for backyard beekeepers, offered free hands-on beekeeping classes for war veterans, continued Bee Network program to collect health data on colonies maintained at

businesses and some homeowner properties, and sold Mite Check kits to monitor Varroa levels and enter mite numbers on a national map, to help backyard beekeepers manage mite populations as needed regionally.

NE (Objective 1 stressors): We are working on methods to analyze the pesticide residues collected from sticky traps placed in and near pollinator habitats with and without treelines to assess their effectiveness as pesticide drift barrier. Other landscape enhancements, such as irrigation of pollinator habitats and legume-rich cover crops, as also being assessed for forage quality, pesticide contamination, and insect/plant abundance and diversity.

NY, PA (Objective 2 breeding): We are working with Jason Rasgon (PSU) to develop methods for genetic transformation of bees, which will facilitate the identification and validation of genetic markers for bee health and behavior.

PA: (Objective 1 stressors). We identified several new viruses infecting bee populations across the world, and identified several of these in US bee populations.

PA (Objective 3 management): We worked together with a team of 36 individual representing 28 state- and national-organizations and stakeholder groups to develop the Pennsylvania Pollinator Protection Plan (P4): http://ento.psu.edu/pollinators/research/the-pennsylvania-pollinator-protection-plan-p4 It summarizes the current state of pollinators in Pennsylvania, and provides recommendations for best practices and resources to support and expand pollinator populations. The P4 focuses on best practices for forage and habitat, pesticide use, and beekeeping in urban, agricultural, natural and roadside habitats.

5. Impact Statements (short outcomes) by state or multistate groups and NC_temp1173 objective. *Please note states are ordered alphabetically and does not reflect the leading institution in collaborative research groups.*

AL (objective 1 stressors): We found that the parasitic mite Varroa destructor, but not neonicotinoids, negatively affected worker food glands in honey bees. Conversely, drones appeared more sensitive to neonicotinoids, as those exposed to the insecticides exhibited reduced sperm quality.

AL (objective 3 management): We estimated that America's beekeepers lost approximately 40% of their colonies between the period April 1, 2017 and March 31, 2018.

CA, IL, IN, MN, PA (objective 1 stressors, 3 management): We have more than 50 beekeepers enrolled in our citizen-beekeeper program, which not only allows us to gather data on bee survival under different management regimes but also supports beekeeper awareness and education.

CT (objective 3 management): Strategies for small-scale queen rearing from high-quality hives were explored: the most satisfactory approach for the CT Queen Breeders Association members will likely be to use the natural swarming tendency to signal the time to split colonies. The excess queen cells produced in the queenless half of the split can then be used for requeening

that colony and several other colonies, too. This strategy minimizes the requirement for having dedicated cell builder/finisher colonies, which would take away resources from other hives.
FL (objective 1 stressors): The FL team focuses principally on developing/refining methods one can use to determine the impacts of pesticides on immature and adult honey bees in tier 1-type tests. They improved a protocol that can be used to rear honey bee workers in vitro (in the lab). This permits one to look at how honey bee exposure to pesticides as immatures impacts their survival to adulthood, developmental time, etc. Furthermore, they have spent considerable time developing a method that can be used to assess how adult honey bee exposure to pesticides via wax, pollen, or sugar water affects bee survival in cage studies. They have used both protocols (the in vitro rearing and adult cage protocols) in several proof-of-concept toxicology studies, leading to the generation of important data related to the impacts of key fungicides, herbicides and insecticides on honey bees.
IN, MT (objective 2 breeding): Quantified virus abundance in honey bees and mites obtained from the same colonies (n=36) and determined that there was no difference in virus abundance between two bee lines (or genotypes), and that DWV was best correlated in bees and mites, while BQCV levels were much lower in mites than in bees.
MN (objective 1 stressors, 2 breeding, 3 management): The main goals of this project are to improve the health and management practices of honey bee colonies, and to ensure the research results are effectively translated to beekeepers, growers of bee-pollinated crops, and the public. It is critical to restore honey bee health and economic vitality to the beekeeping industry. Using novel approaches, we are exploring honey bees' natural defenses against parasites and diseases, breed bees to enhance these traits, and develop ways to improve the overall management practices of honey bee colonies.
MT (objective 1 stressors, 3 management): Research in the Flenniken Lab at Montana State University is focused on understanding the impact of pathogens on honey bee colony losses and the mechanisms of antiviral immunity. In 2018, Flenniken and colleagues wrote two review articles. In 2018, graduate students in the Flenniken laboratory gave presentations at the American Society for Virology Annual Meeting and at the American Bee Research Conference. In 2018, Flenniken gave presentations to stakeholder groups and members of the public including: the Montana State Beekeepers Association, the Pollinator Symposium, and MSU's Science Roadshow 10x10 Talks. In June 2018, Flenniken participated in the Gallatin Valley Farm Fair (~ 1,000, 4th grade students). Flenniken spoke with community members about the importance of honey bee pollinators and research at MSU's Horticulture Farm Field Day, the Gallatin Valley Citizen's Science group, and during volunteer days at the Honey Bee Research Site and Pollinator Garden.
NE (objective 1 stressors, 3 management): Research at University of Nebraska-Lincoln is focused on better understanding to environmental fate of insecticides (neonicotinoids and Bt-toxin) and their potential to contaminate nearby pollinator habitats in order to document

environmentally or field relevant exposure levels on bees and other beneficial insects. We have also started the development of integrated pesticide management strategies to improve beekeepers' ability to proactively monitor for pesticide incidences, reduce pesticide accumulation in hive products (bees, wax, food stores), and mitigate impacts of pesticides through timely management of exposed hives.

PA (objective 3 management): The development of the Pennsylvania Pollinator Protection Plan (P4) has created new networks among researchers, growers, beekeepers and state government agencies, which have been used to form large-scale survey and habitat restoration projects across PA, and bi-annual meetings of the group for discussions.

PA, MD (objective 1 stressors, 3 management): We identified several additional viruses infecting honey bees and other managed bees in our global survey. Using the National Honey Bee Health Survey collections, we have confirmed that two of these viruses are widespread in US bee populations, while others are at low levels or not detectable. This has identified viruses that must be evaluated in more detail to understand if they pose a risk for bees, and flagged other viruses for subsequent monitoring during the annual survey.

OH (objective 1 stressors, 3 management): Almond bloom is the largest managed pollination event in the world and uses 2 million honey bee colonies trucked in from all over the U.S. Beekeepers providing pollination services for almonds have reported seeing problems in as many as 80,000 colonies during almond bloom in 2014 that were attributed to pesticide exposure. To identify the pesticides and tank-mix combinations bees are exposed to during almond bloom Johnson mined the California Pesticide Use Database to identify the top fungicides and insecticides applied to almonds during bloom. These pesticides were applied alone and in field-relevant combinations to honey bee adults and larvae in the lab. An insecticide and a tank-mix combination of an insecticide and fungicide were identified as toxic to bee larvae. These findings have informed the Almond Board of California's recommendation that insecticides not be applied during bloom and has resulted in a 50% reduction in insecticide use during this period when bees may be exposed.

6. Outputs (2018 peer-reviewed publications by active/retired NC1173 members bolded):

Amsalem, E. and **C.M. Grozinger**. "The importance of holistically evaluating data: a comment on Holman". Behavioral Ecology 29(6), 1210–1215 (2018).

Bengtsson-Palme, J., R. T. Richardson, M. Meola, C. Wurzbacher, É. D. Tremblay, K. Thorell, K. Kanger, K. M. Eriksson, G. J. Bilodeau, **R. M. Johnson**, M. Hartmann, and R. H. Nilsson. 2018. Metaxa2 Database Builder: enabling taxonomic identification from metagenomic or metabarcoding data using any genetic marker. Bioinformatics. 34: 4027–4033.

Dai, P., Jack, C.J., Mortensen, A.N., Bustamante, T., **Ellis, J.D**. 2018. Chronic toxicity of amitraz, coumaphos and fluvalinate to *Apis mellifera* L. larvae reared *in vitro*. Scientific Reports, 8:5635. https://doi.org/10.1038/s41598-018-24045-3.

Dai, P., Jack, C.J., Mortensen, A.N., Bloomquist, J.R. **Ellis, J.D.** 2018. The impacts of chlorothalonil and diflubenzuron on *Apis mellifera* L. larvae reared *in vitro*. Ecotoxicology and Environmental Safety 164: 283-288. https://doi.org/10.1016/j.ecoenv.2018.08.039.

Doke, M.A., McGrady, C.M., Otieno, **M., Grozinger, C.M., and M. Frazier**. "Colony size, rather than geographic origin of stocks, predicts overwintering success in honey bees (Hymenoptera: Apidae) in the northeastern United States" Journal of Economic Entomology (2018) https://doi.org/10.1093/jee/toy377

Drummond, F., Elissa S. Ballman, **Brian D. Eitzer**, Brianne Du Clos, and James Dill. 2018. Exposure of honey bee (Apis mellifera L.) colonies to pesticides in pollen, a statewide assessment in Maine. Environmental Entomology 47(2):378-387

Evans E, Smart M, Cariveau D, **Spivak M**. 2018. Wild, native bees and managed honey bees benefit from similar agricultural land uses. *Agriculture, Ecosystems and Environment.* 268: 162-170.

Evans E, Smart M, Cariveau D, **Spivak M.** 2018. Wild, native bees and managed honey bees benefit from similar agricultural land uses. *Agriculture, Ecosystems and Environment.* 268: 162-170.

Galbraith, D. A., Z. L. Fuller, A. Brockman, **M. Frazier,** M. W. Gikungu, K. M. Kapheim, J. T. Kerby, S. D. Kocher, O. Losyev, E. Muli, H. M. Patch, J. M. Sakamoto, S. Stanley, A. D. Vaudo and **C. M. Grozinger.** "Investigating the viral ecology of global bee communities with high-throughput metagenomics " Scientific Reports 8 (1): 8879 (2018).

Holt, H.L., Villar, G. and **C.M. Grozinger**. "Molecular, physiological and behavioral responses of honey bee (Apis mellifera) drones to infection with microsporidian parasites" Journal of Invertebrate Pathology 155, 14-24 (2018).

Lee, KV, Goblirsch M, McDermott E, Tarpy DR, **Spivak M.** 2019. Is the brood patterns within a honey bee colony a reliable indicator of queen quality? *Insects* 10, 12; doi:10.3390/insects10010012

Johnson, R. M., B. A. Harpur, K. A. Dogantzis, A. Zayed, and M. R. Berenbaum. 2018. Genomic footprint of evolution of eusociality in bees: floral food use and CYPome "blooms." Insectes Soc. 65: 445–454.

Ma, R., Villar, G., **Grozinger, C.M**., and **J. Rangel**. "Larval pheromones act as colony-wide regulators of collective foraging behavior in honey bees" Behavioral Ecology 29(5): 1132–1141(2018).

Mortensen, A., **Ellis, J.D**. 2018. A honey bee (*Apis mellifera*) colony's brood survival rate predicts its *in vitro*-reared brood survival rate. Apidologie 49(5): 573-580. https://doi.org/10.1007/s13592-018-0584-0.

Mu, J., Wu, Q., Yang, Y., Huang, M. and **C. M. Grozinger**. "Plant reproductive strategies vary under low and high pollinator densities" Oikos 127: 1081-1094, 10.1111/oik.04711 (2018).

Ostiguy N, Drummond FA, Aronstein K, Eitzer B, **Ellis JD**, **Spivak M**, **Sheppard WS**. 2019. Pesticide exposure to honey bees in a four-year nationwide study. *Insects,* 10, 13, doi:10.3390/insects10010013.

Spivak M, Goblirsch, M, Simone-Finstrom M. Social-medication in bees: The line between individual and social regulation. Submitted Nov 2018 to *Curr. Opinion Insect Science.*

Richardson, R. T., H. R. Curtis, E. G. Matcham, C. Hua Lin, S. Suresh, D. B. Sponsler, L. E. Hearon, and **R. M. Johnson**. 2018. Quantitative multi-locus metabarcoding and waggle dance interpretation reveal honey bee spring foraging patterns in Midwest agroecosystems. Mol. Ecol. 418590.

Richardson, R. T., M. N. Ballinger, F. Qian, J. W. Christman, and **R. M. Johnson**. 2018. Morphological and functional characterization of honey bee, Apis mellifera, hemocyte cell communities. Apidologie. 49: 397–410.

Richardson, R. T., J. Bengtsson-Palme, M. M. Gardiner, and **R. M. Johnson**. 2018. A reference cytochrome c oxidase subunit I database curated for hierarchical classification of arthropod metabarcoding data. PeerJ. 6: e5126.

Vaudo, A.D., Farrell, L.M., **Patch, H.M., Grozinger, C.M.** and J.F. Tooker. "Consistent pollen nutritional intake drives bumble bee (Bombus impatiens) colony growth and reproduction across different habitats" Ecology and Evolution 8 (11), 5765-5776 (2018).

Wagoner K, **Spivak M**, Rueppell O. 2018. Brood affects hygienic behavior in the honey bee (Hymenoptera: Apidae). *J. Econ. Entomol.* toy266, https://doi.org/10.1093/jee/toy266

Villar, G., Wolfson, M.D., Hefetz, A.H. and **C.M. Grozinger**. "Evaluating the role of drone-produced chemical signals in mediating social interactions in honey bees (Apis mellifera)" J Chemical Ecology 44(1): 1-8 (2018).

Zarrillo, T.A. and K.A. Stoner. 2018. The bee fauna of an Atlantic coastal plain tidal marsh community in Southern New England. Journal of Mellittology.

7. Scientific and Outreach Oral Presentations by state.

Alabama:

Williams, G.R., Honey bee toxicology, 2018 South Carolina Beekeepers' Association, Columbia, USA, 3 March 2018.

Williams, G.R., Honey bee toxicology, 2018 University of Florida Panhandle Bee College, Marianna, USA, 23-24 March 2018.

Williams, G.R., Honey Bee Toxicology, 2018 UGA Young Harris Beekeeping Institute, Young Harris, USA, 9-11 May 2018.

Williams, G.R., When parasites & pesticides collide, 2018 UGA Young Harris Beekeeping Institute, Young Harris, USA, 9-11 May 2018.

Williams, G.R., When parasites & pesticides collide, 2018 Georgia Beekeepers' Association Meeting, Cumming, USA, 27-29 September 2018.

Straub, L., Kolari, E., Villamar-Bouza, L., Bruckner, S., Vidondo, B., Chantawannakul, P., Maitip, J., Williams, G., Neumann, P. Field effects of two neonicotinoid pesticides on honey bee drones, *Apis mellifera*. 2018 Eurbee, Ghent, Belgium, 18-20 September 2018.

Bruckner, S., Straub, L., Villamar-Bouza, L., Neumann, P., Williams, G. Effects of neonicotinoids on honey bee food glands. 2018 Eurbee, Ghent, Belgium, 18-20 September 2018.

Bruckner, S., Baker, C., Salem, A., Williams, G. Neglected stressor interactions: How do parasitic mites and neonicotinoid insecticides affect honey bee food glands? 2018 Entomological Society of America Meeting, Vancouver, Canada, 11-14 November 2018.

Connecticut: The information was disseminated during 34 presentations including local, state, national, and international meetings reaching over 1500 individuals

Florida (J. Ellis):

The information was disseminated during 20 presentations (local, state, national, and international) to over 4,575 individuals.

Montana (M. Flenniken) -
Wyoming State Beekeepers' Association Annual Meeting, Invited Speaker, "The impact of viruses on honey bees at the colony, individual, and cellular levels", Casper, Wyoming (December 6, 2018) ~ 30 attendees.

Washington State Beekeepers' Association Annual Meeting, Invited Speaker, "The impact of viruses on honey bees at the colony, individual, and cellular levels", Spokane Washington (November 16, 2018), ~ 150 attendees.

Oregon State / Regional Beekeepers' Association Annual Meeting, Invited Speaker, "Honey Bee Colony Health", Salem, Oregon, (October 27, 2018); ~ 250 attendees.

Montana State Beekeepers' Association Annual Meeting, Invited Speaker, "Honey Bee Colony Health", Bozeman, MT (October 18, 2018); ~ 70 attendees.

MUS Science Roadshow Hi-Line Tour, seven presentations, **Oct. 3-6, 2018.**

Pollinator Symposium, Flenniken Lab Graduate Students (i.e., Fenali Parekh, Alex McMenamin, and Sandra Barroso Arevelo) gave short presentations to the public on their research efforts aimed at understanding the role of pathogens on honey bee health at both the colony and individual bee levels, Bozeman, MT (Aug. 9, 2018); ~ 50 community members.

Big Sky Gallatin Country Women's Club (WGWC), Invited Speaker, "Honey Bee Research at MSU", Big Sky, MT (June 13, 2018); ~ 60 community members.

Expanding Your Horizons, Flenniken lab students (i.e., Vanessa Orcutt and Marie Pizzorno) interacted with 6^{th}-8^{th} grade girls interested in STEM, Bozeman, MT (April 21, 2018); ~ 60 students.

Science Inquiry Lecture Series sponsored by Gallatin Valley Friends of the Sciences**,** Speaker, "Honey Bee Health and Your Health", Bozeman, MT (March 21, 2018), approximately 180 community members

Honey Bee Pathogens sponsored by Gallatin Valley Beekeeping Club**,** Speaker, "Honey Bee Pathogens", Bozeman, MT (March 10, 2018), 75 attendees.

Beekeeping Master Course University of British Columbia, Invited Speaker, "Bee Pathogens 501", and, "Honey Bee Pathogen and Pathway Discovery", Vancouver, BC, Canada, (February 2018).

Montana State University Ag Connects, Speaker, "Honey Bee Health and Your Health", Bozeman, MT (January 15, 2018).

Nebraska (J. Wu-Smart- * invited apeaker):

*Nebraska One Health in a Changing Climate Conference (keynote speaker) Dec 6, 2018

*Missouri State Beekeepers Association, Kirksville, MO Oct 21, 2018

UNL Science Literacy 101: Pollinators & Pesticides (5 classes @ 80-100 students each) Aug 2018

*Americorps Common Grounds Lecture Series, Lincoln NE July 19, 2018

*South Dakota Beekeepers Association July 14, 2018

*Australian Bee Congress Conference (2 presentations) Jun 26-30, 2018

*Nebraska Beekeepers Association Fun Day, UNL Bee Lab research June 24, 2018

*Joselyn Castle Lecture Series, Omaha NE Jun 13, 2018

*NE Kansas Beekeeper's Association Fun Day (2-40 min sessions) Troubleshooting failures, field inspection training Jun 2, 2018

*Americorp Common Grounds Lecture Series: Pollinators, Fremont NE May 10, 2018

*Omaha Beekeepers Association Mar 18, 2018

*Wesleyan University Dept. of Biology seminar Mar 12, 2018

*OLLI:Oshers Lifelong Learning Institute, Lincoln NE Mar 2, 2018

NE extension Mid-Winter Conference (Pesticide Certification Training-Honey Bee Health Coalition Protecting Pollinators Module) Feb 15, 2018

Ohio (R. Johnson):

Lin, C.-H., & Johnson, R.M.Effect of Insecticides, Fungicides and Combinations Applied to Almonds During Bloom on Honey Bee Queens. Poster presentation at The Almond Board of California Annual Conference, Sacramento, CA. December 4, 2018

Johnson, R.M. Effect of pesticides and pesticide mixtures applied to almonds during bloom on honey bees. Presented at the Entomological Society of America Annual Meeting, Vancouver, BC. November 14, 2018.

Johnson, R.M. Honey bee ecotox testing for pesticide registration. Presented at Materials Innovations for Sustainable Agriculture Conference, University of Central Florida, Orlando, FL. November 1, 2018.

Johnson, R.M. Risks and benefits for honey bees in agricultural and urban environments. Presented in Biology Department Seminar Series, Wabash College, Crawfordsville, IN. October 25, 2018.

Johnson, R.M. Where are honey bees going in agricultural and urban landscapes? Presented in Land Grant seminar series, Central State University, Wilburforce, OH. September 25, 2018.

Johnson, R.M. Where are honey bees going in agricultural and urban landscapes? Presented in Department of Entomology seminar series, University of Kentucky, Lexington, KY. August 30, 2018.

Johnson, R.M. Effect of pesticide combinations on honey bee larvae. Pollinator Community of Practice Webinar Series, United States Environmental Protection Agency. May 5, 2018
Johnson, RM. Effect of insecticide and fungicide combinations applied to almonds during bloom on survival of honey bees. Presented at the International IPM Symposium, Baltimore, MD. March 21, 2018.

Lin, C.-H., Wade, A., Kurkul, C. & Johnson, R.M. Effect of insecticides, fungicides and combinations applied to almonds during bloom on survival of honey bee larvae. Poster presentation at the Ohio Valley Chapter of the Society for Environmental Toxicology and Chemistry, Columbus, OH. April 20, 2018

Gross, B. and Johnson, RM. Drone brood removal: A bee-utiful form of Varroa control and source of edible insect protein. Presented at the American Bee Research Conference, Reno, NV. January 8, 2018.

Johnson, R.M., Wade, A., Kurkul C. and Lin, C.-H. Effects of insecticide-fungicide combinations commonly applied to almonds during bloom on honey bee larval development. Presented at the American Bee Research Conference, Reno, NV. January 9, 2018.

Richardson, R., Curtis, H., Lin, C.-H., Johnson. R.M. Investigating honey bee pollen foraging patterns using multi-locus metabarcoding. Presented at the American Bee Research Conference, Reno, NV. January 8, 2018.

Lin, C.-H. Sponsler, D., Richardson, R., Glinski, D., Henderson, M., Minucci, J., Purucker T., Johnson, RM. Honey bees and neonicotinoid-treated corn seed: Pollen contamination, exposure, and effects. Presented at the American Bee Research Conference, Reno, NV. January 9, 2018.

Minnesota (M. Spivak):
Spivak M, Koch R, Cira T. 2018. Let's see it from both sides: Perspectives of farmers and commercial beekeeper on protection of honey bees. University of Minnesota Extension. www.beelab.umn.edu/sites/beelab.umn.edu/files/both_sides_web_final.pdf

Spivak M, Koch R, Cira T. 2018. Getting to know commercial beekeepers. University of Minnesota
Extension.
www.beelab.umn.edu/sites/beelab.umn.edu/files/web_commercial_beekeepers.pdf

Pennsylvania:

Grozinger, C.M. 2018. "Honey bee health: from genes to ecosystems". European Congress of Entomology. Naples, Italy.

Grozinger, C.M. 2018. "Honey bee health: from genes to ecosystems", Entomological Society of America, Entomological Society of Canada, Entomological Society of British Columbia International Meeting. Vancouver, BC, Canada

Grozinger, C.M. 2018. "Honey bee health: from genes to ecosystems", Biology and Genomics of Social Insects, Cold Spring Harbor Laboratory

Grozinger, C.M. 2018. "Cooperation and conflict in insect societies" University of Muenster, Muenster Graduate School for Evolution, Germany

Grozinger, C.M. 2018. "Cooperation and conflict in insect societies" University of Ulm, Institute of Evolutionary Ecology and Conservation Genomics, Germany

Grozinger, C.M. 2018. "Cooperation and conflict in insect societies" Max Plank Institute for Chemical Ecology, Jena, Germany

Grozinger, C.M. 2018. "Bees in the Anthropocene" R.W. Moriarty Science Seminar Series, Carnegie Museum of Natural History, Pittsburgh, PA

Grozinger C.M. 2018. "Context is key: tools for adapting beekeeping to diverse landscapes in PA and beyond" Pennsylvania State Beekeepers Association Annual Meeting, State College, PA, 2 presentations,

Grozinger C.M. 2018, "Pennsylvania Pollinators: Our Legacy and Our Future" Marcellus Shale Coalition, State College, PA.

Grozinger C.M. 2018. "Pennsylvania Pollinators: Our Legacy and Our Future"PA Forest Products Association. University Park, PA.

Grozinger, C.M. 2018 “Nutritional Ecology of Bees” and “Landscape effects on bee health”. Maryland State Beekeepers Association Annual Meeting, 2 presentations, Annadale, MD.

Grozinger C.M. 2018 “Tools for adapting beekeeping to diverse landscapes” American Honey Producers Association Annual Meeting, San Diego, CA.