Multistate Research Activity Accomplishments Report
Multi-State Project NC1173, "Sustainable Solutions to Problems Affecting Bee Health" Business Meeting
Marc Linit, Project Director
Judy Wu-Smart, Project Chair
Thursday, 11 January 2018, 5:00pm – 6:00pm,
Tahoe Room, Grand Ballroom- Grand Sierra Resort, Reno, NV

Project/Activity Number: NC1173
Project/Activity Title: Sustainable Solutions to Problems Affecting Bee Health
Period Covered: 1 January to 31 December 2017
Date of This Report: 7 March 2018
Annual Meeting Date(s): 11 January 2018
Current NC1173 Participants:

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Brief summary of minutes of annual meeting:

1. Call to order
   a. The meeting was called to order by Juliana Rangel at 5:12 pm.

2. Roll call
   a. The following people attended the meeting:

- Marc Linit, linit@missouri.edu
- Judy Wu-Smart, jwu-smart@unl.edu
- Zachary Huang, bees@msu.edu
- Marla Spivak, spiva00@umn.edu
- Brian Eitzer, brian.eitzer@ct.gov
- Hongmei Li-Byarlay, hlibyar@ncsu.edu
- Juliana Rangel, jrangel@tamu.edu
- Tom Webster, Thomas.webster@kysu.edu
- Reed Johnson, Johnson.5005@osu.edu
- Jamie Ellis, jdellis@ufl.edu

- Geoff Williams, williams@auburn.edu
- Keith Delaplane, ksd@uga.edu
- Margarita Lopez-Uribe, mml64@psu.edu
- Priyadarshini Chakrabarti, (on behalf of Ramesh Sagili, ramesh.sagili@oregonstate.edu)

3. Chair's report on current membership

The committee chair, Juliana Rangel, discussed the membership of the group (http://www.nimss.org/projects/view/participant_list/16199) and asked those present in the meeting whether they belonged to the NC1173 working group or not. Dr. Rangel and Dr. Marc Linit, Administrative Advisor, noted that there are currently 37 members listed for NC1173 on the NIMMS website. Anyone present at the meeting was advised to talk with the director of their respective Agricultural Experiment Station in order to be officially added to the Project.

4. Project Director's report
   a. Project Director Dr. Marc Linit discussed how to access the National Information Management & Support System (NIMSS) website, where information about the NC1173 project is located. You can go to the website http://www.nimss.org/ then search for NC1173, view, all info on project on the left panel, and participant directory appears.
   b. The group will need to submit a renewal for NC1173 in Fall 2018 and there was discussion about whether the group would like to maintain its status as a "funded" NC project or would like to switch to a "Extension Research Activity" group or ERA. The advantage of an ERA is that the paperwork requirements associated with the application and annual reports is much reduced, but some members may lose access to Hatch-related funds if the group loses "funded" status. Everyone agreed that we would like to continute as a funded "NC" project and incoming Chair Dr. Judy Wu-Smart committed to working with members to get the renewal submitted. Dr. Linit outlined the timeline for renewal, which is available on the NIMMS site, and includes submission of Issues and Justifications by September 15, 2018 and Objectives and Appendix E documents by October 15, with the full proposal due in by December 15.
   c. Dr. Linit was pleased to report that the midterm review for NC1173 had been completed by the North Central Regional Committee and went very smoothly. The next item that the group will need to address is the annual report for the 2018 meeting, which is due 60 days after the meeting. Members were supplied the with a template from NIFA to be filled out and returned to Dr. Wu-Smart (new Project Chair) by mid-February. Everyone was asked to highlight areas of collaboration among members of NC1173 and to tie accomplishments to the 6 Objectives in the current project. Dr. Linit noted that "impact nuggets" written in non-technical language are most useful for NIFA as they communicate our work to policymakers and the public.
   d. The Administrative Advisor Report was presented by Dr. Linit. He noted that the federal government is currently funded under a 3rd continuing resolution until late January and the budget situation beyond that point will depend on Congress. The

budget that is passed will affect funding to USDA's NIFA and the Hatch appropriation under which multistate projects are funded.

5. Report given by Dr. Rangel for Mary Purcell
   Dr. Mary Purcell-Miramontes, USDA Advisor for the Project, was not able to attend the meeting, but sent slides summarizing the budget situation and relevant competitive grant programs within AFRI. Dr Purcell-Miramontes report indicated that the current proposed budget imposes a 21% cut on USDA as a whole and a 5.4% cut for NIFA. The competetive grants programs at AFRI would be level at $349 million and the SCRI program would be increased by $4 million. The 7 research/extension awards funded with $6.8 million from the New Frontiers in Pollinator HealthProgram were presented. Below is some of the information Mary sent to Dr. Rangel:

   NIFA – AFRI Pollinator Health update 2018/ Mary Purcell-Miramontes
   2016 AFRI New Frontiers in Pollinator Health: $6.8 Million for the following 7 research and extension awards (see next page for list of projects)
   2016 Pests and Beneficial Species awarded 4 research grants (approx. $500K each) Projects will be sent in a follow-up email
   2017 AFRI Pollinator Health Program: Research and Application: $10 Million available and 12 standard awards are pending (27% success rate). Awards will be announced in February –March 2018)
   Funding for this program will decrease in 2018 to $3.3M to fund other new initiatives (below). Maximum award sizes will be $500,000
   *Starting In FY 2017, Pests and Beneficial Species does not solicit pollinator proposals now that there is a stand-alone Pollinator health program;
   New AFRI Initiatives in FY **2018** (these topics would be appropriate for pollinators). Further program details and points of contact will be announced in the Foundational RFA which is expected in March 2018)

   A slide with funding opportunities through AFRI from Dr. Purcell was displayed and is available as a part of the meeting minutes. It was noted by Dr. Linit that NIFA is looking for a proposal out of NC1173 members that addresses an objective of the current or future NC1173 projects

6. Location of 2019 NC1173 meeting – The group voted to hold the next meeting together with the American Bee Research Conference and the American Honey Producers Association meeting in Phoenix, AZ in the second week of January, 2019.

7. Adjourned meeting at 6:00 pm

NC1173 Project Station Report Content:

NC1173 Objectives:

1. To evaluate the role and causative mechanisms of parasitic mites, viruses, and microbes in pollinator abundance and honey bee colony success
2. 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
3. To determine how land management practices affect pollinator nutrition and how nutrition affects honey bee colony productivity and success
4. To assess the effects of exposure to pesticides and other xenobiotics on the survival, health and productivity of honey bee colonies and pollinator abundance and diversity
5. To determine the effects of interactions among various factors affecting pollinator and honey bee colony health
6. To develop and recommend "best practices" for beekeepers, growers, land managers and homeowners to promote honey bee and pollinator health

1. Impact Nugget: A concise statement of advancements, accomplishments and impacts. (Limit to 1-2 sentences)

CT: Efforts were made to identify insecticides which could be used safely in the hive to target small hive beetles. Chlorantraniliprole was found to not have activity against small hive beetle adults. Bacillus thuringiensis var. galleriae was found to be active against Aethina tumida larvae.

FL: Investigations into the effects of pesticides on honey bees have highlighted a number of impacts these products have on adult and immature bees. To that end, we developed protocols that can be used to determine the impacts of pesticides on adult and immature honey bees.

ME: After two years of testing with farmers, we Deployed “BeeMapper” a web-based tool for maine farmers and beekeepers to determine floral resources and wild bee abundance in landscapes surrounding wild blueberry fields. The URL is: https://umaine.edu/beemapper/

MI: We determined that Varroa destructor can affect adult worker bees’ flight ability adversely, even when the mites were only on bees for a short period (within 24 hours).

MN: Increased public awareness and legislative actions about the importance of floral nutrition, uncontaminated by pesticides, to honey bee health and native bee abundance and diversity.

MT: 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 2017, this research was reported in four scientific papers. In 2017, graduate students in the Flenniken laboratory gave

presentations at the American Society for Virology Annual Meeting and at the American Bee Research Conference. Flenniken presented our research at the Entomological Society of America meeting and the Society for Invertebrate Pathology. In 2017, Flenniken gave presentations to stakeholder groups and members of the public including: the Montana State Beekeepers Association, Lewis and Clark County Extension, the Pollinator Symposium, and MSU's Science Roadshow 10x10 Talks. In June 2017, Flenniken participated in the Gallatin Valley Farm Fair (~ 900, 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 Gardener's Club, and during volunteer days at the Honey Bee Research Site and Pollinator Garden.

NE: Began research to examine the use of existing tree lines as pesticide drift barriers to mitigate contamination of pollinator habitats near corn fields. The goal of this project is to develop sustainable landscape enhancement designs to improve floral availability for bees in in agricultural landscapes and mitigate pesticide contamination in pollinator habitats established near crop fields.

OH: Identified insecticides and insecticide-fungicide combinations applied to California almonds while in bloom that have the capability of killing adult honey bees and harming development of immature worker bees and queens.

OH: Developed new methods for semi-quantitatively identifying pollen collected by honey bees and solitary bees using DNA sequencing and multiple DNA barcoding loci.

PA: Identified core genetic pathways involved in bee responses to pathogens and parasites, demonstrated the importance of high quality nutrition in improving bee resilience to pathogens and parasites, and identified the key factors determining pollen nutritional quality. Initiated studies using stakeholder supplied data and information from public databases to evaluate the role of landscape quality in bee health.

2. New Facilities and Equipment. Include production areas, sensors, instruments, and control systems purchased/installed.

ME: Finished third year of field-testing a portable Doppler radar sensor for evaluating honey bee colony activity. A patent has been filed and a small business grant has been submitted for funding to begin producing commercial units.

MN: A new Bee and Pollinator Research Center was constructed on the St Paul campus of the University of MInnesota. It is 10,700 sq ft to support honey bee and native bee research, outreach and education

OH: A new PCR thermocycler was purchased in 2017 for the Ohio State University Bee Lab.

3. Unique Project Related Findings. List anything noteworthy and unique learned this year.

CT: Samples of honey bee pollen collected at commercial nurseries that had been previously analyzed and had a high risk quotient were sorted by color with the separate colors being re-analyzed and submitted for palynology. These further analyses indicated that pollen from Spiraea was the main source of the elevated risk.

ME: Engaged volunteer beekeepers to conduct a statewide survey of pesticide exposure. We found that maine honey bees have relatively low exposure to pesticides. Honey bee colonies that forage in wild blueberry fields and other agricultural fields have the highest exposure, but despite this risk quotients were low. Colonies located in urban areas and coniferous forest had the lowest exposures among all landscapes.

ME: We repeated our experiments conducted in 2015 and 2016 on honey bee and bumble bee exposure to mixtures of the insecticide acetamiprid and the fungicide propiconazole in the field and did not find evidence of lethal synergy.

MN: A *Varroa* mite testing kit was developed to assist backyard beekeepers assess the levels of this parasitic mite in their bee colonies The Mite Kit is being sold by major beekeeping suppliers nationally. A commentary co-authored by current and former students of the UMN Bee Lab was published by the Agricultural Science and Technology (CAST) Commentary, QTA2017, and was presented by M. Spivak to legislative aides in Washington, DC in June 2017.

MT: Determined that samples longitudinally collected for honey bee colony health monitoring studies, should obtain samples on precise sampling dates, as pathogen prevalence and abundance in honey bee colonies is dynamic throughout the season and changes every week.

MT: Determined that not all virus infection levels are tightly associated with *Varroa destructor* mite infestation (i.e., Deformed wing virus (DWV) abundance is associated with mite infestation, whereas Lake Sinai virus 2 abundance does not correlate with mite infestation level).

MT: Determined that dsRNA (regardless of sequence specificity) activates honey bee antiviral immune responses; verified the involvement of Dicer, which is a key protein in the RNA interference (RNAi) pathway that may also play additional roles in honey bee immune defense; and identified a new putative cyclin dependent kinase that is important to honey bee antiviral defense.

OH: When given a choice between urban and agricultural environments in Ohio honey bees were found to spend a majority of their foraging effort in agricultural areas where they collected pollen from clovers and goldenrod.

PA: Determine that lipid content of pollen is a critical determinant of bee foraging preferences and resilience to pathogens and parasites (Objective 3, 5)

4. Accomplishment Summaries. Draft one to three short paragraphs (2 to 5 sentences each) that summarize research or outreach accomplishments that relate to the project objectives.

Objective 1: To evaluate the role and causative mechanisms of parasitic mites, viruses, and microbes in pollinator abundance and honey bee colony success

MI: We tested whether inoculating honey bees at larval or adult stages with autoclave-inactivated nosema spores can induce tolerance of honey bees to *Nosema ceranae* later in life. We determined that inoculating at newly eclosed stage provided better protection against *Nosema ceranae*. We also assessed changes in gene expression in honey bees after exposure to inactivated *Nosema* spores. We found a significant upregulation of some immune genes in a laboratory assay. In field assay, using marked bees introduced into colonies, we also found profound impact of vaccination in protecting honey bees. We first vaccinated bees with 40,000 autoclaved spores when bees were 1 day old, then recovered them from colonies and inoculated them with 40,000 live spores. Twenty-day old bees showed a 50% reduction in infection rate when they were vaccinated, compared to unvaccinated controls. In addition, spore levels were 3.25 times higher in controls compared to vaccinated bees. Thus this method of vaccination might be useful for beekeepers.

MI: While the effect of *Varroa* mite on honey bee behavior and physiology are well studied, we do not know if mites feeding on phoretic hosts (adult honey bees) pose any significant damage to their short term hosts. We therefore tested the effect of mites on the flight ability of tethered honey bees. Bees were tethered on the arm of a standard flight-mill and allowed to fly overnight. We found a significant negative impact of mites on adult bee's flight ability. This study was conducted in Henan, China because I did not have any flight mills. I am trying to make 6 flight mills (mostly DIY) at UIUC here, which I will bring back to MSU in May.

MT: To further investigate the relationship of multiple factors, including pathogen prevalence and abundance, and colony health we monitored commercially managed migratory honey bee colonies involved in California almond pollination in 2014. Results indicate that the abundance of each pathogen was influenced by different factors, though in general pathogen abundance was most consistently associated with the date of sampling. We determined that Deformed wing virus (DWV) abundance was positively associated with the percentage of Varroa destructor mite infestation, whereas Lake Sinai virus 2 (LSV2) was negatively associated with the percentage of mite infestation. Interestingly, colonies that exceeded the 3% threshold for mite infestation were more likely to die by the end of the study in one beekeeping operation, but not the other; indicating that additional factors impacted colony longevity. Data from this and other longitudinal observational cohort studies that precisely account for sampling date will lead to a better understanding of the influence of pathogens on honey bee colony mortality and the effects of abiotic factors (e.g., season/date, weather events, and agrochemical exposure) on these associations.

MT: Recent high annual losses of honey bee colonies are associated with many factors, including RNA virus infections. Honey bee antiviral responses include RNA interference and immune pathway activation, but their relative roles in antiviral

defense are not well understood. To better characterize the mechanism(s) of honey bee antiviral defense, bees were infected with a model virus in the presence or absence of dsRNA, a virus associated molecular pattern. Regardless of sequence specificity, dsRNA reduced virus abundance. We utilized next generation sequencing to examine transcriptional responses triggered by virus and dsRNA at three time-points post-infection. Hundreds of genes exhibited differential expression in response to co-treatment of dsRNA and virus. Virus-infected bees had greater expression of genes involved in RNAi, Toll, Imd, and JAK-STAT pathways, but the majority of differentially expressed genes are not well characterized. To confirm the virus limiting role of two genes, including the well-characterized gene, dicer, and a probable uncharacterized cyclin dependent kinase in honey bees, we utilized RNAi to reduce their expression in vivo and determined that virus abundance increased, supporting their involvement in antiviral defense. Together, these results further our understanding of honey bee antiviral defense, particularly the role of a non-sequence specific dsRNA-mediated antiviral pathway.

PA: Together with an international consortium of researchers, published a meta-analysis of transcriptomic data to find conserved pathways responding to pathogens and parasites in honey bees. We led an international consortium of researchers in a meta-analysis of 19 transcriptome data sets to identify genes that were consistently regulated by viral pathogens, Nosema parasites, and Varroa parasites on honey bees. These represent the primary pathogens and parasites undermining bee health. These studies identified suites of genes whose expression varies in response to all pathogenes/parasites, and others that are uniquely response to one. This information can be used to develop biomarkers of immunocompromised colonies and develop management strategies to improve bee resilience to parasites and pathogens. Also, in lightly-managed colonies of bees in Kenya, demonstrate that colony size was more important than colony type in determining colony health (McMenamin et al 2017).

Objective 2: 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

CT: We have initiated a bee breeding program to promote genetic diversity and incorporate traits conferring resistance to parasites and pathogens. This program includes captured feral swarms as local survivors.

MN: A new grant was funded to M. Spivak from USDA-NIFA, which will include a new honey bee breeding project; a collaborative project between the University of Minnesota and the USDA-ARS Bee Breeding Lab in Baton Rouge, LA, to select honey bee colonies for disease and *Varroa* mite resistance through breeding for hygienic behavior, propolis collection, and slow *Varroa* population growth over the season.

Objective 3: To determine how land management practices affect pollinator nutrition and how nutrition affects honey bee colony productivity and success

IA: We received funding from USDA-NIFA challenge grant, began a 3 year project to determine the value of prairie as a source of late summer forage for honey bees that is missing in central Iowa, and likely the greater Midwest. Preliminary evidence suggests that honey bees experience a dearth of forage beginning in August which corresponds to a loss of hive weight and reduced worker lipid stores. When given access to prairie, this weight loss is prevented. We have also conducted experiments to examine the effects of diet quality (during both larval and adult stages) on aspects of honey bee health. Results to date suggest both high quantity and quality pollen provide protection from viral infection, as well as affect worker bees' responsiveness to queen pheromone. We also received a small grant from the Eastern Apicultural Society to examine the effect of landscape-derived nutritional resources (prairie vs. intense ag) on the health and fecundity of queens.

OH: In collaboration with Ohio beekeepers, we collected honey produced in a variety of landscapes in Ohio and found that areas with more soybeans being grown had more soybean pollen in honey. Documenting the link between soybean agriculture and honey production stands to both improve soybean management in regards to bees, through more judicious use of insecticides, and enhance soybean yield through bee pollination.

PA: Using data from PA State Beekeepers Association, demonstrate the interactions of Varroa treatment, landscape forage quality, landscape pesticide use, and honey bee colony density as a determinant of honey bee colony overwintering survival. Also, demonstrated that the lipid content of pollen is critical for bee feeding preferences. We published two studies identifying bumble bees' dietary preferences for protein:lipid ratios and demonstrating that bees preferentially forage on flowering plant species to obtain pollen with these preferred ratios from their pollen. This information can be used to develop improved artificial diets for bumble bees (current diets do not have the preferred protein:lipid ratios) and optimize planting for habitat restoration for bumble bees. These studies also lay the groundwork for similar studies to evaluate the nutritional needs and foraging preferences of other bee species.

Objective 4: To assess the effects of exposure to pesticides and other xenobiotics on the survival, health and productivity of honey bee colonies and pollinator abundance and diversity

CT: Pesticide analysis and palynology was conducted on sorted high risk pollen samples collected at ornamental nurseries to determine which plant species were being treated with pesticides that would lead to high risk to honey bees.

IA: We received funding from Bayer CropScience and Syngenta to determine the exposure of honey bees to neonicotinoids when perennial, attractive bee forage in habitats made available within crop fields. This study was conducted during 2017 and includes estimating neonicotinoids in soil, leaf tissue and bees foraging on flowers within these habitats.

ME: We showed that neonicotinoid insecticide exposure to honey bees in Maine is exceedingly low and that Varroa mite is a much higher threat to honey bee health in Maine than exposure to insecticides.

ME: We also showed that previous reported synergistic effects in the laboratory of the insecticide acetamiprid and the fungicide propiconazole do not appear to result in the field for either honey bees or bumble bees when exposed simultaneously to these pesticides.

NE: Pesticide analysis is being conducted to determine the concentration of neonicotinoid residues expressed in floral resources in pollinator habitats near corn fields with and without drift barriers. The abundance and diversity of bees in these pollinator habitats are also being assessed.

OH: We continued examining the potential for insecticides and insecticide-fungicide combinations applied to California almonds during bloom to affect honey bees and identified pesticides that may be responsible for the poor performance of bee colonies sometimes associated with almond pollination.

Objective 5: To determine the effects of interactions among various factors affecting pollinator and honey bee colony health

IA: We have conducted both field and experimental studies to assess interacting stressor effects on honey bee and wild bee health. First, we completed experiments (both cage and RNA-sequencing) demonstrating a significant interaction between poor diet and viral infection in mortality and on gene expression. Second, we examined how honey bee colonies and bees in those colonies responded to living in soybean fields with varying levels of insecticide exposure, and then moved half of these colonies to prairies, which we suspect provides higher nutritional availability at the end of the season. These experiments will allow us to address whether good nutrition at the end of the season can overcome negative effects (if any, yet to be seen) of early season insecticide exposure. We also published a review in *Current Opinion in Insect Science* investigating the interacting effects of disease and nutrition on honey bee health.

MI: We assessed honey bee worker survival and gene expression levels in bees that there exposed to *Nosema* alone, pesticide alone, both together, or neither (control). We have evidence that the two adverse factors interact to affect both survival and gene expression patterns. Data are still being analyzed for this project.

PA: Demonstrated that the lipid content of pollen is critical for improving bee resilience to parasites and pathogens. Together with collaborators from the

University of Udine, Italy, we demonstrated that, when parasitized by Varroa mites, bees provided with pollen - and specifically, the lipid fraction of pollen - live longer than parasitized bees who are not fed pollen or are fed pollen without the lipid fraction. Varroa is the major factor underlying honey bee colony losses in temperate environments, and this information can be used to improve supplementary diets for bees (currently, these diets focus on protein, not lipids).

Objective 6: To develop and recommend "best practices" for beekeepers, growers, land managers and homeowners to promote honey bee and pollinator health

IA: We hired an extension specialist (Randall Cass) to focus solely on honey beekeepers, farmers and land owners interested in the conservation of honey bees and native bees. In late 2017, he began surveying these three populations to determine willingness to make land set aside for conservation available to beekeepers. Initial work with Pheasants Forever suggests a sub-population of landowners interested in enhancing land for pollinators and making this available to honey beekeepers.

NE: We are monitoring hives on several specialty crop farms to evaluate floral availability, colony health, and honey production and using hive scales to make landscape recommendations to address seasonal floral dearth.

5. Impact Statements. Please draft 2 or 3 impact statement summaries related to the project objectives. Statements should be quantitative when possible and be oriented towards the general public. This is perhaps the most difficult yet most important part of the report.

CT: We found that Bacillus thuringiensis var. galleriae was found to be active against small hive beetle larvae.

FL: We participated in the NC1173 objective aimed at investigating pesticide impacts on bees. Within the NC1173 project time period, my team and I 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. We improved a protocol that can be used to rear honey bee workers *in vitro* (in the lab). This permits us to look at how honey bee exposure to pesticides as immatures impacts their survival to adulthood, developmental time, etc. Two reporting periods ago (2015 report), we held a meeting that was attended by over 20 individuals working in the field of honey bee toxicology. The result of this meeting was that 15 laboratories from multiple countries took part in an international ring test of the protocol during the previous reporting period (2016 report). Data analysis was completed during the current reporting period (2017). Ultimately, 13 laboratories satisfied the validity criteria and the test design's performance was determined adequate for regulatory testing. The ring test demonstrated that the OECD GD 239 methodology (with the UF amendments) for evaluating the repeat (cumulative)

exposure of a compound on developing bees can be successfully conducted. Furthermore, we 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. We have used both protocols (the *in vitro* rearing and adult cage protocols) in a number of proof-of-concept toxicology studies, leading us to generate important data related to the impacts of key fungicides, herbicides and insecticides on honey bees.

ME: Wild blueberry in Maine has experienced an economic collapse. The prices that growers receive now are below standard production costs. We have been able to provide guidance to growers on reducing inputs in production. Pollination is their largest input but is also one of the most important. Our research on honey bee and wild native bee pollination requirements for this crop allowed growers to make informed decisions on pollination. This led to a shift in the reliance on honey bees more towards native wild bees. In 2017, approximately 28,000 colonies were rented by Maine wild blueberry growers compared to 85,000 in 2016. The resulting yields were lower in 2017, but many growers were allowed to stay in business.

MN: A new Bee and Pollinator Research Center was constructed on the St Paul campus of the University of MInnesota to expand and support honey bee and native bee research, outreach and education in the Upper Midwest

MT: We determined that Deformed wing virus (DWV) abundance was positively associated with the percentage of *Varroa destructor* mite infestation, whereas Lake Sinai virus 2 (LSV2) was negatively associated with the percentage of mite infestation. Colonies that exceeded the 3% threshold for mite infestation were more likely to die by the end of the study in one beekeeping operation, but not the other; indicating that additional factors impacted colony longevity.

MT: We determined that virus-infected bees had greater expression of genes involved in RNAi, Toll, Imd, and JAK-STAT pathways, but the majority of differentially expressed genes are not well characterized. We confirmed the virus limiting role of two genes, including the well-characterized gene, *dicer*, and a probable uncharacterized *cyclin dependent kinase* in honey bees.

OH: The insecticides and the insecticide-fungicides were applied to a majority of California almonds during bloom in 2015. We found that some insecticides and insecticide-fungicide combinations can affect development in immature honey bee workers and queens and also have the potential to kill adult honey bees. In 2015 these pesticides were applied to 90,000 acres of almonds during bloom and may have harmed 180,000 bee colonies providing pollination services to orchards on which these pesticides were applied.

PA: Formed working group through SESYNC to develop predictive models for pesticide use, toxicity and exposure across the US

PA: 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.

PA: Received funding from the USDA-PD-STEP program to develop a new program targeting middle- and high-school students from underserved rural and urban communities. We hosted a one-week workshop in July 2017 that trained 17 teachers.

PA: Engage Pennsylvanians in two citizen science programs: Tracking Feral Bees and Landscape for Bees.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced.

Amsalem, E. and C. M. Grozinger. "Evaluating the molecular, physiological and behavioral impacts of CO_2 narcosis in bumble bees (*Bombus impatiens*)". *Journal of Insect Physiology* 101:57-65 (2017).

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Asare, E., A.K. Hoshide, F.A. Drummond, X. Chen, and G.K. Criner. 2017. Economic riskof bee pollination in Maine wild blueberry, *Vaccinium angustifolium* Aiton. J. Econ. Entomol. Doi: 10.1093/jee/tox191: 1-13.

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Drummond, F.A., A.C. Dibble, C. Stubbs, S. Bushmann, J. Ascher, and J. Ryan. 2017. A Natural History of Change in Native Bees Associated with Lowbush Blueberry in Maine. Northeastern Naturalist. 24 (15): 49-68.

Drummond, F.A., E. S. Ballman, B. D. Eitzer, B. Du Clos, and J. Dill. Exposure of honeybee colonies to pesticides in pollen, a statewide survey in Maine. Environ. Entomol. doi: 10.1093/ee/nvy023

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O'Neal, S., Anderson, T. and Wu-Smart, J. 2018. Interactions between pesticides and pathogen susceptibility in honey bees. *Curr. Opin. Insect Sci.* 26: 57-62

Piccolomini, A. M., Flenniken, M., O'Neill, K., Peterson, R. The effects of an ultra-low-volume application of etofenprox for mosquito management on Megachile rotundata (Hymenoptera: Megachilidae) larvae and adults in an agricultural setting, (2017) 1-6. *Journal of Economic Entomology*, doi.org/10.1093/jee/tox343.

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Richardson, R T, J Bengtsson-Palme, and R M Johnson. 2017. Evaluating and optimizing the performance of software commonly used for the taxonomic classification of DNA metabarcoding sequence data. Molecular ecology resources 17:760–769.

Simone-Finstrom M, Borba RS, Wilson M, Spivak M. 2017 Propolis counteracts some threats to honey bee health. Review. Insects 8: 46: DOI:10.3390/insects8020046

Smart MD, Cornman RS, Iwanowicz DD, McDermott-Kubeczko M, Pettis JS, Spivak MS, Otto CRV. 2017 A comparison of honey bee-collected pollen from working agricultural lands using light microscopy and ITS metabarcoding. J. Environ. Entomol. http://dx.doi.org/10.1093/ee/nvw159

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Sponsler, D B, and R M Johnson. 2017. Mechanistic modeling of pesticide exposure: The missing keystone of honey bee toxicology. Environmental toxicology and chemistry / SETAC 36:871–881.

Sponsler, D B, E G Matcham, C-H Lin, J L Lanterman, and R M Johnson. 2017. Spatial and taxonomic patterns of honey bee foraging: A choice test between urban and agricultural landscapes. Journal of Urban Ecology 3.

Spivak, M., Wu-Smart, J., Otto, C., Smart, M., Goblisrch, M., Lee, K., and Browning, Z. 2017. Why Does Bee Health Matter? The Science Surrounding Honey Bee Health Concerns and What We Can Do About It. Council for Agricultural Science and Technology Commentary

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7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized.

Brianne Du Clos, Cyndy Loftin, and F.A. Drummond. 2017. The release of Beemapper, a software mapping tool for wild bee prediction. Annual Summer Wild Blueberry Field Day, Jonesboro, ME.

Cowles, R. 2017.Bees and the Neonicotinoid Controversy. Plant Science Day - The Connecticut Agricultural Experiment Stations Open House in Hamden, CT

Cunha, Souza, A.E., F.A. Drummond, and N. Emanetoglu. 2017. Evaluating a Doppler Radar Based Activity Monitor for Assessing Bee Colony Health. NSF REU Sensors Conference, Univ. Maine, Orono, ME, 8/10/17.

Drummond, F.A. 2018. Pollination of wild blueberry. Bates College, Lewiston, ME. 2/27/18.

Drummond, F.A. Neonicotinoid exposure to honey bees, with special focus on Maine. Maine Agricultural Trade Show, January 11, 2018. Augusta, ME.

Drummond, F.A. Neonicotinoid exposure to honey bees, with special focus on Maine. Maine Potato Conference, January 18, 2018. Caribou, ME.

Drummond, F.A. Pollination of highbush blueberry. 2017. Northeast Vegetable and Fruit Groswers meeting, Manchester, NH.

Eitzer, B. 2017. Collection and Analysis of Plant Nectar and Pollen and Honey Bee Collected Pollen at Ornamental Nurseries. The 54th Annual North American Chemical Residue Workshop in Naples FL

Eitzer, B. 2017. Evaluating the Risk Pesticide Use Pose to Honey Bees" at the American Bee Research Conference, Galveston TX.

Ellis, J. 2017. FL: The information was disseminated during 14 presentations (local, state, national, and international) to over 1,711 individuals.

Flenniken, M. 2017 Gallatin Gardeners Club, Invited Speaker, "Honey Bee Health", Bozeman, MT (May 1, 2017); ~ 100 community members.

Flenniken, M. 2017 Lewis & Clark County Agricultural Extension Presentation for Brent Sarchet's Advanced Beekeepers Course, Invited Speaker, "Honey Bee Pathogens", Helena, MT (June 10, 2017); ~ 35 people.

Flenniken, M. 2017. Entomological Society of America, Pacific Branch Meeting, Speaker, "Honey Bee RNA-mediated antiviral responses", April 4 2017, Portland, Oregon.

Flenniken, M. 2017. INBRE, Café Scientifique Invited Speaker, "What's Killing the Bees? The Impact of Pathogens and Other Factors on Honey Bee Colony Health", Bozeman, MT (March 28, 2017); ~ 100 community members.

Flenniken, M. 2017. Montana State Beekeepers' Association Annual Meeting, Invited Speaker, "Honey Bee Colony Health", Bozeman, MT (October 20, 2017).

Flenniken, M. 2017. National Resource Conservation Service (NRCS) Pollinator Plantings and Monitoring meeting, discussion and tour of MSU's Honey Bee Research Site and Pollinator Garden (July 10, 2017); ~ 15 people.

Flenniken, M. 2017. Pollinator Symposium, Flenniken Lab Graduate Students (i.e., Laura Brutscher, Alex McMenamin, and Will Glenny) 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 (April 19, 2017); ~ 50 community members.

Flenniken, M. 2017. Society for Invertebrate Pathology of America, Invited Speaker, "Bee Viruses and Honey Bee Health", August 2017, San Diego, CA

Flenniken, M. Entomological Society of America, Invited Speaker, "Honey Bee Viruses, Colony Health, and Antiviral Defense", November 7 2017, Denver, CO.

Grozinger, C. Pennsylvania Hardwoods Development Council Meeting. State College, PA, May 10, 2017

Grozinger, C. AdkAction.org and Wild Center Buzz Fest, at Tupper Lake, NY and Old Forge, NY, July 19-20, 2017

Grozinger, C. Ag Progress Days, Pine Grove Mills, PA, August 17, 2017

Grozinger, C. APPL-RED (Authentic Plant Pollinator Landscape for Educators) workshop from July 24-July 28, 2017 at University Park. Instructors: Annmarie Ward, Christina Grozinger, Harland Patch, Kathy Hill, Katy Evans, Emily Erickson, Tyler Jones and Doug Sponsler.

Grozinger, C. Centre County Master Gardeners Conference, University Park, PA, March 20, 2017

Grozinger, C. Cornell University. Patton Lecture in Insect Physiology. Department of Entomology.

Grozinger, C. Future of Bee Health in Africa. International Centre for Insect Physiology and Ecology (September 2018).

Grozinger, C. Georgia Tech University. Department of Biology.

Grozinger, C. Insect Chemical Ecology Short Course. Penn State University, University Park, PA (June 2017).

Grozinger, C. Invited presentation, 2017 Southeast PA Green Industry Conference, Doylestown, PA January 2017

Grozinger, C. Penn State Millennium Cafe, University Park, PA, June 20, 2017

Grozinger, C. Penn State Science Policy Society - Science on Tap Series, University Park, PA, April 18, 2017 (and associated radio interview on WFREQ)

Grozinger, C. Penn State University. Center for Infectious Disease Dynamics.

Grozinger, C. Pennsylvania State Beekeepers Association Annual Meeting, State College, PA, November 2017

Grozinger, C. Plenary Lecture. Association for Chemoreception Sciences (AChemS) annual meeting, Bonita Springs, FL

Grozinger, C. West Virginia University. Davis College of Agriculture, Natural Resources

Grozinger, C. Weston Backyard Beekeepers Association, Weston, CT, May 23, 2017

Johnson, R M and C-H Lin. 2017. Bloom spray effects on bee health. Almond Board of California Annual Meeting. Sacramento, CA.

Johnson, R M. 2017. The European honey bee, Apis mellifera, as a model for pesticide combination testing. Pollinator Community of Practice Webinar Series, United States Environmental Protection Agency.
Johnson, R M. 2017. A view across the landscape of bee cytochrome P450 genes in 10 bee species. Entomological Society of America Annual Meeting, Denver, CO.
Johnson, R M. 2017. Corn, soybeans and honey bees. Department of Entomology Seminar Series. Iowa State University, Ames, Iowa.
Johnson, R M. 2017. European honey bee, Apis mellifera, as a model pollinator for toxicological testing. Honey bee toxicology,detoxification pathways and the relevance for bee colonies and other pollinators.International Bee Conference. Berlin, Germany.
Johnson, R M. 2017. Honey bees and neonicotinoid-treated corn seed: contamination, exposure and effects. Environmental Modeling Public Meeting at the United States Environmental Protection Agency. Arlington, VA.
Johnson, R M. 2017. Measuring and mitigating abrasion of treated corn seed coatings as a route of insecticide exposure for honey bees. American Chemical Society Annual Meeting, Washington, DC.
Nuri W. Emanetoglu, Berkay Payal, Herbert M. Aumann, Jennifer Lund, Francis Drummond. 2017. Honeybee colony ativity monitor using radar principles. NABEC Ann. Meeting, Boston, MA, 8/2/17
Spivak, M. 2017. 93rd Annual meeting of the Kansas Entomological Society and Beneficial Insects Symposium, Univ Nebraska, “Status of Bee Health: Untying a Messy Knot” April 14-15
Spivak, M. 2017. Cork County Beekeepers Association, Cork, Ireland “Benefits of Propolis to Bee Health,” Helping Beekeepers: Tech Transfer Teams and the Bee Squad,” “Honey Bee Hygienic Behavior.” March 24-25.
Spivak, M. 2017. Council for Ag, Science and Technology (CAST), Presentation for Congressional Staffers: House and Senate Aides. “Why Does Bee Health Matter? The Science Surrounding Honey Bee Health Concerns and What We Can Do About It”, Washington, DC June 19.
Spivak, M. 2017. Doanne Lecture: University of Wisconsin, Madison, WI. “Honey Bee Colonies Have Socialized Medicine” Dec 1
Spivak, M. 2017. Ecology, Evolution and Behavior Dept, Univ MN, Graduate Recruitment Seminar. “Honey Bee Social Immunity” Jan 26
Spivak, M. 2017. Invited Extension and Beekeeping presentations: over 50 from UMN Bee Lab
Spivak, M. 2017. TED Global: (over 2.5 Million viewers as of Jan 2018) http://www.ted.com/talks/marla_spivak_why_bees_are_disappearing.html
Spivak, M. 2017. University of Manitoba, Winnipeg, Canada. “Socialized Medicine in Honey Bee Colonies” March 13-14.
Stoner, K. 2017. "Planting for Crop Pollinators. Winter Conference of the Connecticut Northeast Organic Farming Association, Danbury, CT
Stoner, K. 2017. Conservation in Your Own Backyard. White Memorial Conservation Center in Litchfield, CT

Stoner, K. 2017. Planting for the Bees' Needs. NOFA Summer Conference, Hampshire College, Amherst, MA
Stoner, K. 2017. Planting for the Bees' Needs.. The CT Audubon Center. Glastonbury, CT o
Stoner, K. 2017. Pollinator Health and Habitat. At the Fairfield County Regional Conservation Partnership, Wilton CT
Stoner, K. 2017. An Act Concerning Pollinator Health: State Efforts to Protect Pollinators in Connecticut. Eastern Branch Meeting of the Entomological Society of America, Newport, RI.
Stoner, K. 2017. Connecticut Native Plants for Bees. Conference on transportation design for Departments of Transportation nation-wide. Newington, CT
Stoner, K. 2017. Creating and Improving Pollinator Habitat on Your Farm. New Haven, CT
Stoner, K. 2017. Pesticides in Trapped Honey Bee Pollen from Ornamental Plant Nurseries. Protecting Urban Pollinators Conference, Traverse City, MI
Stoner, K. 2017. Planting for the Bees' Needs. The annual meeting of the North Central Conservation District. Vernon ,CT
Stoner, K. 2017. Pollinators in the Garden. Milford Garden Club, Milford CT
Wu-Smart, J. 2017. Effects of neonicotinoids on queen bees- North Carolina State University Department Research Seminar, NC
Wu-Smart, J. 2017. Effects of neonicotinoids on queen bees-Iowa State University Department Research Seminar, IA
Wu-Smart, J. 2017. Effects of neonicotinoids on queen bees-Kansas State University Department Research Seminar, KS
Wu-Smart, J. 2017. Effects of pesticide residues in hives- SE Connecticut Beekeeper's Association Conference, CT
Wu-Smart, J. 2017. Honey bee health- Nebraska Department of Agriculture Inspectors Conference, NE
Wu-Smart, J. 2017. Mitigation neonicotinoid exposure risks to bees-North American Beekeeping Tradeshow and Conference, TX
Wu-Smart, J. 2017. Nebraksa Beneficial Insect Protection Plan-U.S. Fish and Wildlife Conference, NE
Wu-Smart, J. 2017. Neonicotinoids and honey bee health- MN Governor's Pollinator Protection Task Force Conference, MN
Wu-Smart, J. 2017. Pesticide residues in brood comb- NE Kansas Beekeeper's Association Fun Day, KS
Wu-Smart, J. 2017. Protecting bees from neonicotinoids- Oregon Beekeeper's Association Conference, OR.
Wu-Smart, J. 2017. Troublingshooting queen failures- NE Kansas Beekeeper's Association Fun Day, KS
Wu-Smart, J. 2017. Wild bees- NE Kansas Beekeeper's Association Fun Day, KS

8. Fund leveraging, specifically, collaborative grants between stations and members.

Dr. Eitzer, Dr. Stoner and Dr. Cowles are all participants in a large funded SCRI project entitled "Protecting Pollinators with Economically Feasible and Environmentally Sound Ornamental Horticulture" coordinated by Cristi Palmer at Rutgers that includes several other members of NC1173

A collaborative USDA-SCRI planning grant ($33,000) was received to facilitate a meeting between stakeholders and researchers from Ohio State University, Oregon State University, Montana State University, University of Florida and University of California-Davis.

A collaborative USDA-AFRI grant ($469,220) examining the effects of heavy metal contamination in urban landscapes on pollinators and effects on urban agriculture was awarded to NC1173 members Johnson (Ohio State University) and Toth (Iowa State University).

Dr. Drummond was awarded $75,000 from the Maine Department of Transportation to determine the effect of managing roadside habitat for honey bees, native bees, and butterflies.

USDA-AFRI Foundational Program: PI: Spivak "Benefits of Propolis to Honey Bee Health and Beekeeping Sustainability" $999,740, 2018-2022

USDA-AFRI Foundational Program: (PI: Dan Cariveau, UMN, total award $999,803; co-PI Spivak) "Ecology and economics of pollinator habitat: Using a landscape-scale experiment to determine cost-effective restoration strategies for beneficial insects"

State of North Dakota, PI Spivak. "Tech-Transfer Team Program for Commercial Beekeepers" $63,380

Bee Informed Partnership, Inc. Cooperative Work Agreement, PI: Spivak Tech Transfer Team in Upper Midwest, $87,820

USDA-NIFA: (PI: Olav Ruepell, Univ NC Greensboro, total award $999,329) "Identification Of Brood Signals That Induce Hygienic Behavior In Honey Bees To Develop And Implement Novel Strategies For Varroa Control And Sustainable Apiculture"

USDA-NIFA: NC IPM Pollinator Habitat Survey ($20,000), Co-PI: Wu-Smart Survey bee communities in established pollinator habitat near agricultural production fields.

USDA-NIFA NE Extension Implementation Program **($627,447**): Co PI: Wu-Smart "Integrated Pesticide Management Program for Beekeepers"

USDA-Sustainable Agriculture Research & Extension (SARE) grant (**$115,628**): co-PI: Wu-Smart "Co-stacking enterprises by partnering women beekeepers with women farmers"

9. Other relevant accomplishments and activities.

Wu-Smart co-developed a pesticide training module that meets continuing education unit (CEU) requirements: "Protecting Honey Bees in Productive Agriculture: A module for crop

consultants, advisors, and applicators.
https://unl.box.com/s/ql8kiemd8jrbik0j701lxxlcjbakpmew
This was a collaborative effort sponsored and reviewed by the Honey Bee Health Coalition (https://honeybeehealthcoalition.org/about-the-coalition/) which consists of beekeepers, researchers, IPM professionals, non-profit organizations, government agencies and industry partners.