APPENDIX D - SAES-422
Format for Multistate Research Activity
Accomplishments Report

Note: This report is submitted each year of an activity's duration and is due 60 calendar days following the annual meeting. The SAES-422 is submitted electronically by AAs into NIMSS. Annual Reports for MRF projects are available to NIFA through NIMSS.

Project/Activity Number: NC1173
Project/Activity Title: Sustainable Solutions to Problems Affecting Bee Health
Period Covered: 10/01/2024 to 09/30/2029
Date of This Report: 03/03/2025
Annual Meeting Date(s): 01/09/2025 – 01/11/2025

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Brief Summary of Annual NC1173 Multi-State Project Meeting

Minutes taken by Brock Harpur (Purdue University)

In attendance (in person): Priya Chakrabarti Basu, Cameron Jack, Reed Johnson, Zachary Huang, Judy Wu-Smart, Michelle Flenniken, Robyn Underwood, Paula Wolfe (Kelsey Fisher),Selina Brochener, Lewis Bartlett, Declan Schroeder, Geoff Williams, Kate Anton, Juliana Rangel, Esmaeil Amiri, Ramesh Sagili

In attendance (virtual): Jeffrey Harris, Brock Harpur, Hongmei Li-Byarlay, Brian McCornack, Tania Kim, Brian Spiesman, Minglin Ma, Laura Figueroa, Neal Williams, Margarita Lopez-Uribe, Cameron Jack, Joseph Gorres, David Tarpy

Time in: 5:00pm

Time out: 6:05pm

1) Introductions, Roll Call, and Meeting Agenda

Meeting Agenda - Business Meeting

1. Call to order
2. Roll call
3. Chair's report on current membership (Priya Chakrabarti Basu)
4. Project Director's report (Hamilton/McCornack)
5. Next progress report (deadline and challenges)
6. Location of next NC1173 meeting
7. Open discussion
8. Concluding remarks
9. Adjourn

2) Membership changes: we are down one member as of 2025 due to a university-level issue

3) Brian McCornack updates on the Director's report. Ensuring we continue to highlight multistate outputs is key and the plan for the next five years. Loved the idea of a website. We need to continue thinking of multistate grants. Next report due in 60 days but deadline of content is end of month. This is a Final Report we will be submitting (to be clarified with Christina).

4) Next Progress report updates to Priya are due Jan 29th. A template will be sent by Priya on Monday. Overview of goals and milestones was presented. Discussion on how revisions and goals have been set by previous leaders and how we tackle previous goals and milestones. Some discussion on how the milestones link up, etc.
Request for previous edits and revisions:
https://docs.google.com/document/d/1oe_mevoE5Mz2u5cOkFWHJY6Z5IuOcI0mYqDkPCvZw-k/edit?usp=sharing

Discussion on how the funding works here. There is a lot of flexibility in how reporting works and we can discuss this with Brian, especially when discussing multistate. Some additional discussion on how to fund some of the annual goals. We will have to discuss how to reach the milestones. Priya to send out survey/email on which milestones we are already targeting to reach them.

6) Montana for the next meeting.

7) Open discussion we will be electing a vice chair at next meeting.

8) Priya to share NC1173 drive for all of us.

<u>NC1173 Objectives</u>

1. To evaluate the role, causative mechanisms, and interaction effects of (a) biotic stressors (i.e., parasitic mites, pests, and pathogens) and (b) abiotic stressors (i.e., climate change, exposure to pesticides, poor habitat, and nutrition, management practices) on the survival, health, and productivity of wild and managed pollinators.
2. To facilitate the assessments of genetic diversity of wild bees, and the development of honey bee stock selection, maintenance, and production programs that incorporate traits conferring resistance to parasites and pathogens.
3. To develop monitoring programs that assess bee species richness and abundance in agroecosystems, and how these metrics of bee communities are changing over time.
4. To develop and recommend "best management practices" for beekeepers, growers, land managers, and homeowners to promote wild and managed bee health.

<u>NC1173 Accomplishments:</u>

Objective 1a: Biotic Stressors, Pests & Pathogens
The *Varroa destructor* mite is one of the deadliest honey bee ectoparasites currently the U.S. beekeeping industry is facing. *Varroa destructor* feeds on honey bees and decimates colony populations resulting in colony death. *Varroa* mites also transmit viruses within and between colonies. High mite infestation coupled with high levels of viruses, including deformed wing virus (DWV), are often associated with overwinter losses of honey bee colonies. NC1173 members are addressing the *Varroa destructor* mite challenge by developing novel chemical and biological control options for management (Jack, University of Florida [UF]; Huang, Michigan State University [MchSU]; Sagili, Oregon State University [OSU]). Based on research at UF (Jack) of an RNAi product, a company is now preparing the final submission to the EPA for a new treatment registered for the use of controlling *Varroa destructor*. They also tested a relatively new class of chemicals (isoxazolines) on *Varroa destructor* to evaluate the likelihood of development of a new *Varroa* treatment. Further research at MchSU (Huang) is focusing on establishing a method to more accurately measure how often *Varroa destructor* switches hosts in honey bees, with a more natural distribution of available hosts, with mites from newly emerged bees. They obtained more data of how a hormonal analog affected *Varroa* mite reproduction, showing that the chemical when mixed in beeswax, can significantly reduce *Varroa* mite offspring. The Sagili Lab (OSU) is evaluating the effectiveness of oxalic acid vaporization against *Varroa* and safety to honey bee

larvae and also evaluating the efficacy of amitraz in *Varroa* control and potential resistance of *Varroa* against amitraz.

As *Varroa destructor* is also able to transmit viral diseases in honey bee colonies, a number of NC1173 members are examining the impacts of viruses on colony health (Flenniken, Montana State University [MoSU]; Amiri, Mississippi State University [MsSU]). Graduate students in the Flenniken lab (MoSU) analyzed ~ 600 bees from laboratory experiments to determine the efficacy of immune stimulatory compounds in virus-infected honey bees. Flenniken lab also carried out research aimed at determining the efficacy of immune stimulatory compounds to reduce honey bee virus infections, and to better understand the mechanisms of honey bee antiviral defense. The Amiri Lab (MsSU) in collaboration with the Tarpy Lab (NCSU) investigated the trade-off between pathological stress and fitness traits in honey bee drones and found that the well-established trade-offs in life history traits are uncoupled in drones. Increased natural virus infection does not decrease reproductive potential but instead incurs cost to immune function and potentially affects survival. They also described deformed wing (DW) symptoms in *S. richteri*, as an alternative host for DWV. DW alates were found in three of nine (33%) laboratory colonies. The symptoms ranged from severely twisted wings to a single crumpled wing tip. Additionally, numerous symptomatic alates also displayed altered mobility, ranging from an ataxic gait to an inability to walk. Viral replication of DWV was confirmed using a modified strand-specific RT-PCR. Their results suggest that *S. richteri* can be an alternative host for DWV, expanding our understanding of DWV as a generalist pathogen in insects.

In addition to viruses, beekeeping practices and emerging threats to beekeeping have also been examined by NC1173 members (Lopez-Uribe, Pennsylvania State University [PSU]; Bartlett, University of Georgia [UGA]; Williams, Auburn University [AU]). The Lopez-Uribe Lab (Lopez-Uribe and Underwood; PSU) collected data replicating the experimental design of Cambron-Kopco et al. 2024 in several apiaries to better understand the role of local genetics in disease management for beekeepers. The Bartlett Lab (UGA) increased beekeeper knowledge of *Vespa velutina* and launched a larger and official yellow-legged hornet response team. The Williams Lab (AU) has been leading international research efforts and conducting experiments on *Tropilaelaps* mite dispersal. They also performed the 2023-2024 U.S. Beekeeping Survey.

Small hive beetles are an important pest for the U.S. beekeeping industry and several labs (Jack, UF; Bartlett, UGA) have been making research progress in understanding this pest and finding effective control measures. The Jack Lab (UF) has been developing assays for semi-field testing of small hive beetle attractants and repellents. The Bartlett Lab (UGA) is moving forward on EPA evaluation of small hive beetle control. Other studies on honey bee pathogens include screening novel active ingredients for fungicidal effects on *Ascosphaera apis* (chalkbrood) infection in honey bees and screening for pathogens present in honey bee colonies across Florida (Jack, UF), multistate SCRI project on examining European Foulbrood infection in honey bee colonies pollinating blueberries (NC1173 members include Sagili lab as lead [OSU] and Chakrabarti-Basu, Washington State University [WSU]).

The Vanette Lab at University of California, Davis (UC Davis) characterized the composition of nectar chemistry across plant species used by many bee pollinators, assessed effects of symbiotic yeasts on bumble bee and native bee (*Osmia*) communities and their pathogens and also worked to characterize the role of phage in shaping honey bee and bumble bee gut microbiota. They were able to characterize variation in nectar chemistry across plant species using untargeted metabolomics. Using bumble bee microcolony experiments, they found that symbiotic yeasts associated with bumble bees do not affect bee nutrition but instead seem to suppress bee pathogen growth. Finally, using viromics they were able to characterize the phage community in honey bees and bumble bees, show that they are largely distinct, and are working to characterize bacterial host range and effects on bee hosts.

The PSU pollinator team (Grozinger, Patch, Boyle, Hines) demonstrated that developed land and increased numbers of honey bees are associated with increased pathogen loads in bumble bees. The Toth Lab (Iowa State University [ISU]) collected over 1000 bumble bee samples from landscape types (agricultural, urban, forested, grassland) in Iowa. Bees were measured for morphological traits such as size and wing asymmetry. RNA is now being prepared to test correlations between these traits and the presence of viruses. The Williams Lab at UC-Davis examined the prevalence of Houdini fly (*Cacoxenus indagator*) in blue orchard bee (*Osmia lignaria*) sentinel nests in WA and OR to determine spread and impact of the new pest on blue orchard bee industry in the PNW.

Short outcomes Objective 1a:
Flenniken Lab received funding from the National Science Foundation (NSF) Integrative Organismal Systems (IOS), Physiological and Structural Systems (PSS) Cluster, Symbiosis, Infection and Immunity (SII) Program to support a project elucidating the relationships between sublethal honey bee virus infections, flight, heat stress, and antiviral responses. Flenniken lab also received funding from Project Apis m. to support research focused on the identification honey bee virus strains collected during high annual loss events in 2022-2023, and 2021-2022. The Sagili Lab (OSU) and collaborators (NC1173 member includes Chakrabarti-Basu WSU) have secured funding to examine European foulbrood in honey bee colonies over four years.

The UF team (Ellis, Jack and Vu) were funded by the Florida Department of Agriculture and Consumer Services to find relations between *Varroa destructor* resistance and the obscure pathogen *Malpigamoeba mellificae* in Florida honey bee colonies. Jack (UF) with other collaborators also received a grant to support beekeeping industry through U.S. internship programs and finding novel and integrative treatment options for *Ascosphaera apis* in honey bee. $749,891 (Subaward $308,685) USDA NIFA AFRI. The Ellis Lab (UF) continued to refine methods to rear *Varroa destructor* in vitro. *Varroa* represents a significant biological threat to honey bee health. Yet, our inability to rear them in vitro has slowed the development of new control strategies for this pest. Through this project, they identified important method refinements for this protocol. They determined the seasonal efficacy of labeled miticides used against *Varroa*. This is especially important for beekeepers who need this information when deciding how to treat for this mite pest. With collaborators, they developed a novel strategy for screening honey bee colonies for pests and pathogens using eDNA technologies. Their research suggests this is a promising sampling and detection technique. Ellis (UF) received funding for inhibiting salivary proteins to prevent *Varroa destructor* feeding and pathogen transmission to the honey bees.

The Rangel Lab (Texas A&M University [TAMU]) created two jobs (one undergraduate student and one graduate student) working on a project looking at the effects of miticides on colony growth. The Johnson Lab (Ohio State University [OhSU]) tested a new formulation of extended-release oxalic acid in glycerin for controlling *Varroa* mites in 6 apiaries in Ohio and North Dakota. They also tested different formulations of the biocontrol agent *Beauvaria bassiana* for efficacy at controlling *Varroa* mites in laboratory assays. The Wu-Smart Lab at University of Nebraska Lincoln (UNL) conducted field trials to examine various factoring contributing to overwintering losses in the Midwest. As part of her program, she developed an extension guide to help beekeepers prevent rodents from entering the hives and damaging and contaminated combs and food stores during the winter.

The Gorres Lab (University of Vermont [UV]) started a project in September 2024. In preparation for the 2025 field season, an array of 16 mesocosms was constructed in the Fall of 2024. The mesocosms are to simulate rain gardens which are thought of as pollinator refuges in urban ecosystems. These will be experimental units for an experiment in which the relationship between invasive jumping worms (Clitellata:Megascolecidae) in the genus *Amynthas* (purported stressor), the quality of nectar and pollen, and the visitation of pollinators to the plants will be examined thoroughly. Half of the mesocosms will be stocked with jumping worms, the other half will be worm free. The mesocosm will receive jumping worms in May when the number of juveniles is high. Data collection will begin in June 2025. The Bartlett Lab (UGA) received funding for mounting an ecologically informed response to *Vespa veluntina*. The Huang Lab (MchSU) received funding for developing a honey bee queen tracking system. The Amiri Lab at MsSU also received several fundings to improve bee resistance to viral infection, understand bee related viruses in pest ants, understand the impact of viral infection on honey bee queen reproduction quality and examining a novel selection tool to improve honey bee health in Mississippi and beyond.

Outputs Objective 1a:
Flenniken Lab (MoSU) shared research findings with stakeholders at six meetings in 2024 including the Montana State Beekeepers Association Annual Meeting, the Eastern Apiculture Society (EAS), the Eastern Pennsylvania meeting and the SW Ohio State Beekeepers Association. The López-Uribe Lab also published a blog post on temperature, size, and pathogen load effect on wild bee heat tolerance. The Rangel Lab (TAMU) published six extension articles for the Texas Beekeepers Association member publications. The Wu-Smart Lab (UNL) published extension article on how to build an all-season mouse guard for Langstroth honey bee hives and also received funding through the USDA-NIFA NE Extension Implementation Program. Williams Lab members (AU) received multiple funding to monitor, study and manage *Tropilaelaps* mites. They published education materials and well as presented at numerous conferences.

Objective 1b: Abiotic stressors
The Chakrabarti-Basu Lab (WSU) is building two unique nutrition databases for bees in North America in collaboration with other NC1173 members (Sagili Lab at OSU) funded by USDA NIFA and Project Apis m. They have hand-collected pollen from over 120 plants in the United States and Canada and have over 25 beekeepers collecting pollen from apiaries over two years in the United States. The Chakrabarti-Basu Lab (WSU) is also examining the metabolism of various nutrients across bee species, the impacts of climate change on bee nutrition bee health (funded by USDA NIFA and Project Apis m.) and longitudinally monitoring the impacts of various landscape effects (pesticides and poor nutrition) on honey bee colony health. The Sagili Lab (OSU) is evaluating the efficacy of commercial protein supplements available for honey bees. Chakrabarti-Basu Lab (WSU) also published a supplemental feeding guide for beekeeping with the Honey Bee Health Coalition.

The PSU pollinator team (Grozinger, Patch, Boyle, Hines) manages the Honey and Pollen Diagnostic Lab, which uses DNA metabarcoding to identify the plant genera that bees have been foraging on. Since fall 2023, they have analyzed 1400 samples from 26 states, 5 countries and representing 10 research projects and over 100 beekeepers. They demonstrated that urbanization and managed honey bee colonies only affected a small number of wild bee genera, with impacts greatest on bees that were fall-foraging. They demonstrated that abundance and diversity of spring bee communities are influenced by landscape scale factors, while summer bee communities are influenced more by local habitat and floral communities and found that non-native plants can provide valuable resources for specialist solitary bee species in cities. They also observed that some bee species forage according to nutritional quality of the floral resources while other forage based on quantity or size of flowers.

The Lopez-Uribe Lab (PSU) are currently working on two follow-up experiments with bumble bees and squash bees to reveal the underlying mechanisms explaining the reduced heat tolerance experienced by bees infected with trypanosomes. They investigated the interactive effects of heat waves and humidity in bumble bees using microcolonies in the lab and full-size colonies in the field. The study results indicate that heat waves and high humidity conditions in isolation have neutral or even positive effects on bumble bee fitness. However, when bumble bees experience both conditions at the same time, there are severe negative effects on reproduction and survival.

The Jack Lab (UFL) tested the impacts of mosquito adulticides and larvicides in the field on honey bee colonies and found minor brood level impacts related to the use of these chemicals by mosquito control districts in Florida. They also conducted laboratory testing of both active ingredients and formulated products of mosquito adulticides and larvicides and found Naled to be of high risk to honey bee adults. Most mosquito control chemicals were of low risk to honey bee adults and larvae.

The Huang Lab (MchSU) studied how a fire retardant (Phos-Chek) affected honey bee worker survival. It had a weak, not always consistent negative effect on adult worker survival, mainly on newly emerged bees with high varroa mite infestations. The Toth Lab (ISU) completed three studies examining the effects of elevated temperature on bumble bee physiology.

The Kim Lab at Kansas State University (KSU) examined how grazing impacted wild bees in grasslands across a precipitation gradient in KS in efforts to understand the combined effects of land use and climate change, examined the long-term implications of grazing through yearly sampling at the Konza LTER and examined how land management affected native pollinators in highly managed systems, including soybean fields, and urban farms. They further developed BeeMachine project by improving the classification model and adding a major update to the website. The Williams Lab (US Davis) completed analysis of thermal tolerance profiles for summer flying bees on CA sunflowers. The Figueroa Lab (University of Massachusetts Amherst [UMass Amherst] carried out an experiment in summer 2024 evaluating the indirect effects of heatwaves (increasing with climate change) on pollinators mediated through changes in plants exposed to the heatwaves.

Short outcomes Objective 1b:
The research at Chakrabarti-Basu Lab (WSU) has shown that plant pollen nutritional quality varies

widely even with different varieties of the same species. Currently the team is working on a publication to show the results of the nutritional databases. The research at Lopez-Uribe Lab (PSU) has data suggesting that the negative interactions between honey bees and wild bees are context dependent. This may inform decisions about where (specific landscapes) beekeeping may be allowed.

The Amiri Lab (MsSU) compared beeswax cups to 10 different commercial plastic queen cups by evaluating their effects on rearing success, queen development, and physical characteristics. A comparison of queen rearing between beeswax cups and different plastic cups revealed significant differences in larval acceptance, followed by sealing, and queen emergence. This indicates the need for standardizing queen cup dimensions without compromising the physical quality of queens. The lab members also presented their findings at beekeeping workshops.

Johnson (OhSU) found 90% reduction in insecticide use during almond bloom relative to peak insecticide use in 2014. Wu-Smart (UNL) found that despite the closure of the AltEn facility in 2021, there are lingering effects from contaminated forage on hive functions that adversely affect worker bee behavioral maturation, including precocious foraging of young house-aged bees, leading to reduced worker longevity and decreased colony efficiency. Their lab also compared toxicity of 6 pesticide spray adjuvants to honey bee adults and larvae to assess the hazard adjuvant products pose when applied when a bee-attractive crop is in bloom and assessed the impact of bloom-time insecticide application to soybeans on in-field honey bee activity using bioaccoustics methods.

Outputs Objective 1b:
Several NC1173 members secured funding to examine the impacts of environmental impacts on both managed and wild bees, as well as on bee nutrition (Tarpy Lab North Carolina State University [NCSU]; Chakrabarti Basu Lab WSU; Figueroa UMass Amherst). Members also secured funding to examine the impacts of mosquito control chemicals (Jack UF) and adjuvants on pollinator health (Johnson OhSU) as well as the impacts of pesticides on bee abundance and diversity (Johnson OhSU) and matching pesticide residues in pollen to aid development of reduced-risk actions (Williams UC Davis). Several members also received funding for the development of resilient urban food systems that ensure food security in the face of climate change (Kim KSU), understanding the nutritional ecology of honey bees in a changing landscape (Rangel TAMU) and understanding transportation stress in honey bees (Huang MchSU). Bartlett Lab (UGA) received a grant to examine diet-dependent trophic discrimination factors for honey bees to understand diet-shifts during the COVID-19 pandemic. Members also published several blog posts and extension articles on these various aspects. In October 2024, PSU pollinator team (Grozinger, Patch, Boyle, Hines) hosted the Ecospatial Summit (ecospatialsummit.com), where they invited individuals who had used Beescape or data in the Beescape layers to test and provide feedback on the new BeeShiny tool. More than 75 people participated, representing 34 universities, government agencies, and nonprofit groups.

Objective 2: Genetics, Breeding, & Diversity
The PSU pollinator team (Grozinger, Patch, Boyle, Hines) demonstrated that short term heat can significantly reduce *Osmia* male sperm, which can inform commercial production. Toth (ISU) is examining the genomes of 16 bee and wasp species. Harpur (Purdue University [PU]) has an

established honey bee Genomic Testing Facility. Beekeepers and regulators have a need to test the genotypes of their bees. Much of the U.S. is populated by a highly defensive genotype known as 'the Killer Bee' that is illegal to ship across some state lines. Testing can be accomplished through genomics but there is no regularly available centralized service. Also beekeepers often want to know the genetic make-up of their colonies for breeding purposes.

Short outcomes Objective 2:
Pairing with Purdue's Plant and Pest Diagnostic Laboratory (PPDL), Harpur (PU) has created the first central genomic testing facility for bees. The work extends beyond borders as they provide genome sequencing to beekeepers in Jamaica, New Zealand, Canada, and the UK.

Outputs Objective 2:
The NC1173 members actively examining the genomics and breeding research aspects of pollinators have presented their findings at numerous workshops and conferences. The Tarpy Lab (NCSU) also continues to offer Queen & Disease Clinic as a service to beekeepers for quantitative measures of reproductive quality and colony disease profiles.

Objective 3: Monitoring system
The NC1173 members are using multiple methods to monitor both wild and managed bees. Figueroa (UMass Amherst) is developing an automated machine learning model to monitor honey bees and bumble bees based on sound. Toth (ISU) completed surveys across the state of Iowa to determine occupancy of imperiled bumble bee species *Bombus pensylvanicus* and *Bombus affinis*. Williams (AU) performed the 2023-2024 US Beekeeping Survey. Evans (University of Minnesota [UMN]) collaborated to develop long-term monitoring methods for focal bee species.

Danforth Lab (Cornell University [CU]) completed a number of steps toward developing high-throughput DNA barcoding protocols for bees. They created a list of all known New York bee species and searched BOLD and NCBI databases to create a document identifying all species lacking a published barcode. They reached out to other collections to obtain specimens of unpublished species missing from previously mentioned collections. They assayed and selected PCR reagents and conditions to maximize success in amplifying the target sequences for barcoding, assayed various primer pairs for both the main COI gene and several secondary genes that may be included in barcoding for a more robust genetic species ID, and ultimately designed and tested over 100 unique tagged primers for high-throughput barcoding. In collaboration with Michael Branstetter's lab in Logan, Utah, Danforth (CU) completed a 14-page protocol for sequencing using the MinION platform. The lab also trained in alternative DNA extraction methods, hotshot, that yields less pure DNA but opened the option for rapid, affordable extractions well-suited to the high-throughput barcoding pipeline we plan to implement. In addition the lab has active collaborations with other labs and are actively refining their protocols.

Tarpy (NCSU) conducted and published a meta-analysis that helps to quantify the return on investment for sampling various pollinator communities to maximize estimates of species richness and abundance. They have started to develop an online tool that will assist future researchers in such estimations.

Short outcomes Objective 3:

The Lopez-Uribe Lab (PSU) demonstrated the value of standardized bee collections in informing patterns of bee biodiversity across space and time. They have continued PA Bee Monitoring Program and are working on a study to investigate habitat association and bee biodiversity patterns across Pennsylvania. They have also received an extension grant to monitor bee populations in Pennsylvania to improve information on wild pollinator populations. The PSU pollinator team (Grozinger, Patch, Boyle, Hines) demonstrated that transcriptomics can be used to identify stressors (thermal, nutritional, pathogen) that bees experience in the field, by sampling field-caught specimens. This can provide flexibility for monitoring programs. The Kim Lab (KSU) received funding for developing population based models for insect distribution in KS soybeans and for developing a research hub for automated bee identification, data sharing, and citizen science using computer vision.

Outputs Objective 3:
The NC1173 members actively monitoring honey bee colonies and wild bee populations across the United States have disseminated their findings in multiple stakeholder meetings, conferences and workshops. Williams (AU) presented the annual honey bee colony loss survey results to at least four large meetings. Kim (KSU) provided over 15,000 bee identifications through their BeeMachine project to over 5,000 users. Members have also utilized professional development opportunities. For example Evans (UMN) attended a workshop to standardize monitoring methods for the rusty patched bumble bee.

Objective 4: Management
NC1173 members are pursuing various approaches and research questions in managing both managed and wild bee populations. The Lopez-Uribe Lab (PSU) found that organic beekeeping practices support healthy honey bee colonies and also can generate high profits for stationary honey producing beekeepers. They are currently examining whether by placing honey bee colonies in high-quality landscapes, it is possible to produce honey bee products that are pesticide free. If successful, this research would generate valuable data that can result in changes in policies for organic beekeeping. Tarpy (NCSU) developed a new conceptual model that helps to contextualize the collective decisions of queen supersedure that can help beekeepers mitigate the negative effects of premature queen failure and replacement. Toth (ISU) worked on two projects related to the use of prairie strips as foraging habitat for bees, including wild bee communities and honey bees that can help manage both populations. Danforth (CU) developed a new program focused on conservation of ground-nesting bees (https://www.gnbee.org/). Williams (AU) is leading a multi-institutional winter honey bee brood monitoring project that involves multiple NC1173 members.

Short outcomes Objective 4:
NC1173 members (Lopez-Uribe and Underwood, PSU; Harpur, PU; Bruckner, AU) published five extension articles for managing honey bee colonies (topics ranging from beekeeping practice, organic beekeeping to non-chemical control methods for Varroa destructor mites). Jack (UF) hosted practical workshops with a focus on IPM tools for beekeeping. Williams (AU) hosts a coordinated online beekeeping webinar called “At Home Beekeeping” with participation from 12 institutions which includes NC1173 members. Lopez-Uribe (PSU) compiled and analyzed data from PA beekeepers and demonstrated that winter survival is significantly increased if multiple *Varroa* management strategies are used.

Wu-Smart (UNL) hosts the Great Plains Master Beekeeping Training Program (GPMB) which has 4,219 enrolled members, with an estimated 2,700+ active accounts based on module views and completed exams. The members are spread across the United States, with the majority located in the Midwest, including Nebraska (654 members), Missouri (485), Iowa (383), and Kansas (246) (Fig 1). What sets GPMB apart is their collaborative approach with local beekeeping groups and associations across the region.

Outputs Objective 4:
Williams (AU) hosts the At Home Beekeeping webinar series as well as conducts the U.S. Beekeeping Surveys to help understand management needs and practices. Williams (AU) is also coordinating the winter capped brood monitoring program (with Alabama Extension, UF, UGA, MsSU, TAMU, USDA ARS Baton Rouge, USDA ARS Poplarville, USDA ARS Stoneville, USDA ARS Tucson, USDA ARS Beltsville, OSU, CU, Central State University, PSU and WSU) https://aub.ie/winterbrood and surveyed beekeepers in the U.S. southeastern region for presence of *Varroa* mites resistant to amitraz. In addition Willams (AU) is actively conducting research on *Varroa* management study on fall organic acid treatment options and *Tropilaelaps* management study on effect of cultural (brood break) and chemical (organic acids). NC1173 members have also received funding for conducting surveys and workshops (Williams AU) and shared results at various meetings. Johnson (OhSU) with collaborators have also published an extension article on protecting wild bee crop pollination services.

Wu-Smart (UNL) and GPMB have established partnerships with local beekeeping groups and associations across the region. Through these partnerships, they have helped establish 29 teaching apiaries in eight states. In 2024 alone, over 1,325 beekeepers attended sessions at these open teaching apiaries.

Impacts
NC1173 members published 90 peer reviewed research articles in 2024 and additional extension publications. The members also presented at numerous scientific conferences, stakeholder meetings and organized workshops. NC1173 members have received funding to pursue the various research objectives and are creating significant impacts on improving both managed and wild bee populations and their overall health. NC1173 members have revolutionized epidemiologic and genetic approaches aimed at determining the relationship between pathogens (particularly viruses) and honey bee health and elucidating the molecular mechanisms of honey bee antiviral defense. This research may lead to the development of strategies that minimize honey bee colony losses and/or improve colony health. Research has also shown that beekeepers can likely reduce virus infections in their colonies by purchasing local queens and helped to uncover a link between virus infection of queens and poor performance and increased supersedure. NC1173 members are also conducting various surveys and monitoring projects to best understand the impacts of both biotic and abiotic stressors on pollinators and recommend best management practices accordingly.

NC1173 members have advanced our overall understanding of the impacts of abiotic stressors on pollinators. Based on some of the research conducted in conjunction with mosquito control operators, new practices are being implemented across Florida due to increased awareness of negative effects of certain formulated products to honey bee brood. This may have wide reaching implications in the rest of U.S. Members are also working with various state departments of agriculture to review and propose best management practices for mitigating pesticide stress on pollinators. Research carried out by many NC1173 members will help us better understand the nutritional quality and diversity of pollinator habitat, the impacts of climate change, and will provide evidence-based recommendations to manage for pollinator health in the context of increasing temperatures. The Beescape decision support tool supports all stakeholders in helping them assess landscape quality for wild and managed bees. Beescape provides information on land use, seasonal floral resources, wild bee nesting habitat quality, potential exposure to pesticides, monthly and historical temperature and precipitation conditions, and economic value of pollination services. In fall 2024, the PSU pollinator team launched BeeShiny, which allows researchers to obtain data on these indices from multiple locations or rasters.

Summary table and list of publications by objective reported by NC1173 members for 2024.

Publications by topic	**2024**
Obj 1a: Biotic (Pests & pathogens)	35
Obj 1b: Abiotic (Pesticides, nutrition, landscapes)	24
Obj 2: Genetics, Breeding, Diversity	10
Obj 3: Monitoring	11
Obj 4: Management	10
Total	**90**

<u>Objective 1a:</u>

1. Bartlett LJ, Boots M, Brosi BJ, Delaplane KS, Dynes TL, de Roode JC. Faster-growing parasites threaten host populations via patch-level population dynamics and higher virulence; a case study in Varroa mites (Mesostigmata: Varroidae) and honey bees (Hymenoptera: Apidae). Journal of Insect Science. 2024 May 1;24(3):17.
2. Bartlett LJ, Alparslan S, Bruckner S, Delaney DA, Menz JF, Williams GR, Delaplane KS. Neonicotinoid exposure increases Varroa destructor (Mesostigmata: Varroidae) mite parasitism severity in honey bee colonies and is not mitigated by increased colony genetic diversity. Journal of Insect Science. 2024 May 1;24(3):20.
3. Beaurepaire, A.L., Hogendoorn, K., Kleijn, D., Otis, G.W., Potts, S.G., Singer, T.L., Boff, S., Pirk, C., Settele, J., Paxton, R.J., Raine, N.E., Tosi, S., Williams, N., Klein, A.-M., Le Conte, Y., Campbell, J.W., Williams, G.R., Marini, L., Brockmann, A., Sgolastra, F., Boyle, N., Neuditschko, M., Straub, L., Neumann, P., Charrière, J.-D., Albrecht, M., & Dietemann, V. 2025. Avenues towards reconciling wild and managed bee proponents. Trends in Ecology & Evolution, Volume 40, Issue 1, 7 – 10. https://doi.org/10.1016/j.tree.2024.11.009
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5. Brummel, C., Kittle, S., Lynch-O'Brien, L., Weller, S., & Wu-Smart, J. (2024, August 29). How to Build an All-Season Mouse Guard for Langstroth Honey Bee Hives (NebGuide

G2361). University of Nebraska-Lincoln. https://extensionpubs.unl.edu/publication/g2361/2024/pdf/view/g2361-2024.pdf
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9. Cornelissen B, Ellis JD, Gort G, Hendriks M, van Loon JJA, Stuhl CJ, Neumann P. The small hive beetle's capacity to diverse over long distances by flight. Scientific Reports. 2024;14:14859. https://doi.org/10.1038/s41598-024-65434-1.
10. Crone M, Fornoff F, Klein AM, Grozinger C. DNA metabarcoding reveals unexpected diet breadth of the specialist large-headed resin bee (*Heriades truncorum*) in urbanised areas across Germany. Insect Conservation and Diversity. 2024 Nov.
11. Dickey M, Whilden M, Twombly Ellis J, Rangel J (2024) Comparative prevalence of Nosema ceranae infection between wild and managed honey bee (*Apis mellifera*) colonies in South Texas. Apidologie. 55: 62. https://doi.org/10.1007/s13592-024-01107-2
12. Doublet, V., Oddie, M.A.Y., Mondet, F., Forsgren, E., Dahle, B., Furuseth-Hansen, E., Williams, G.R., De Smet, L., Natsopoulou, M.E., Murray, T.E., Semberg, E., Yañez, O., de Graaf, D.C, Le Conte, Y., Neumann, P., Rimstad, E., Paxton, R.J., de Miranda, J.R. 2024. Shift in virus composition in honeybees (*Apis mellifera*) following world-wide invasion by the parasitic mite and virus vector *Varroa destructor*. Royal Society Open Science 11 (1), 231529. https://doi.org/10.1098/rsos.231529
13. Gratton EM, McNeil DJ, Sawyer R, Martinello A, Grozinger CM, Hines HM. The role of landscape factors in shaping bumble bee pathogen loads across regions of the eastern Nearctic. Insect Conservation and Diversity. 2024 Nov;17(6):1098-112.
14. Hoebeke ER, Bartlett LJ, Evans M, Freeman BE, Wares JP. First Records of *Vespa velutina* (Lepeletier) (Color form Nigrithorax) (Hymenoptera: Vespidae) in North America, an Invasive Pest of Domesticated Honeybees. Proceedings of the Entomological Society of Washington. 2024 Oct;126(2):193-205.
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solitary bee. Ecology and Evolution. 2024; 14(2):e10945.
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35. Zhang L, Shao L, Raza MF, Zhang Y, Huang ZY, Chen Y, Su S, Han R, Li W. 2024. Large cells suppress the reproduction of *Varroa destructor*. Pest Management Science. https://doi.org/10.1002/ps.8249

<u>Objective 1b:</u>

1. Abbate, A.P., Campbell, J.W., Grodsky, S.M., & Williams, G.R. 2024. Assessing the attractiveness of native wildflower species to bees (Hymenoptera: Anthophila) in the southeastern United States. Ecological Solutions and Evidence 5 (3), e12363. https://doi.org/10.1002/2688-8319.12363
2. Abou-Shaara H, Mehrparvar S, Read QD, Chen J, Amiri E. Impact of commercial plastic queen cell cups on rearing success and development of honey bee queens. Journal of Apicultural Research; 2024; 1–11.
3. Bruckner, S., Delaney, D.A., Menz, J.F., Williams, G.R., & Delaplane, K.S. 2024. Neonicotinoid exposure increases Varroa destructor (Mesostigmata: Varroidae) mite parasitism severity in honey bee colonies and is not mitigated by increased colony genetic diversity. Journal of Insect Science 24 (3): 20. https://doi.org/10.1093/jisesa/ieae056
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5. Carlson EA, Melathopoulos A, Sagili R (2024) The power to (detect) change: Can honey bee collected pollen be used to monitor pesticide residues in the landscape? PLoS ONE 19(9): e0309236. https://doi.org/10.1371/journal.pone.0309236
6. Chakrabarti P, Sagili, RR. Managed foraging for honey and crop pollination—Honey bees as livestock. In John Purdy (ed.) The Foraging Behavior of the Honey Bee (*Apis mellifera*, L.) (2024). 175-193.
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Applied Economics. 56(1): 101-119. https://doi.org/10.1017/aae.2024.2
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24. Zhang L, Shao L, Raza MF, Zhang Y, Huang ZY, Chen Y, Su S, Han R, Li W. Large cells suppress the reproduction of Varroa destructor. Pest Management Science. 2024; https://doi.org/10.1002/ps.8249

Objective 2:

1. Büchler, R., Andonov, S., Bernstein, R., Bienefeld, K., Costa, C., Du, M., Gabel, M., Given, K., Hatjina, F., Harpur, B. A., Hoppe, A., Kezic, N., Kovačić, M., Kryger, P., Mondet, F., Spivak, M., Uzunov, A., Wegener, J. & Wilde, J. (2024) Standard methods for rearing and selection of *Apis mellifera* queens 2.0. J. Apic. Res. 1–57 doi:10.1080/00218839.2023.2295180

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3. Dickey M, Whilden M, Twombly Ellis J, Rangel J (2024) Comparative prevalence of Nosema ceranae infection between wild and managed honey bee (*Apis mellifera*) colonies in South Texas. Apidologie. 55: 62. https://doi.org/10.1007/s13592-024-01107-2
4. Martínez L, Zattara EE, Arbetman MP, Morales CL, Masonbrink RE, Severin AJ, Aizen MA, Toth AL. Chromosome-Level Assembly and Annotation of the Genome of the Endangered Giant Patagonian Bumble Bee *Bombus dahlbomii*. Genome Biology and Evolution. 2024 Jul;16(7):evae146."
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8. Shultz, R. R., Carey, A., Ragheb, K. E., Robinson, J. P. & Harpur, B. A. (2024). On the distribution and diversity of tissue-specific somatic mutations in honey bee (*Apis mellifera*) drones. Insectes Soc. doi:10.1007/s00040-024-00948-5
9. Szalanski A L, Cleary D, Adams R. Mitochondrial DNA genetic variation of feral and managed honey bee (*Apis mellifera*) colonies from Oklahoma, U.S.A. Southwestern Entomologist. 2024; 49:(4) "
10. Toth AL, Wyatt CD, Masonbrink RE, Geist KS, Fortune R, Scott SB, Favreau E, Rehan SM, Sumner S, Gardiner MM, Sivakoff FS. New genomic resources inform transcriptomic responses to heavy metal toxins in the common Eastern bumble bee Bombus impatiens. BMC genomics. 2024 Nov 19;25(1):1106.

Objective 3:

1. Aurell, D., Bruckner, S., Wilson, M., Steinhauer, N., & Williams, G.R. 2024. A national survey of managed honey bee colony losses in the USA: results from the Bee Informed Partnership for 2020–21 and 2021–22. Journal of Apicultural Research 63, 1–14. http://dx.doi.org/10.1080/00218839.2023.2264601
2. Buckner, M.A., S.T. Hoge, B.N. Danforth (2024). Forecasting the effects of global change on a bee biodiversity hotspot. Ecology and Evolution 14:e70638 [published online 30 November 2024; https://doi.org/10.1002/ece3.70638]
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<u>Objective 4:</u>

1. Aurell, D., Wall, C., Bruckner, S., & Williams, G.R. 2024. Combined treatment with amitraz and thymol to manage Varroa destructor mites (Acari: Varroidae) in *Apis mellifera* honey bee colonies (Hymenoptera: Apidae). Journal of Insect Science 24 (3): 12. https://doi.org/10.1093/jisesa/ieae022.
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