United States Department of Agriculture

Colony Collapse Disorder and Honey Bee Health Action Plan

CCD and Honey Bee Health Steering Committee

May 21st, 2015

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Cover photo: Honey bee flying to cuphea flower. Photo: ARS-USDA.

For more information about colony collapse disorder, visit http://www.ars.usda.gov/ccd

Table of Contents

Executive Summary

Honey bees, the principal pollinators of hundreds of economically and ecologically important crops and plants, have been in serious decline for more than three decades in the United States, as noted in the National Academy of Sciences report *Status of Pollinators in North America* (National Research Council, 2007). U.S. honey bees have been under attack by a large number of stressors, including invasive mites (Varroa and tracheal), insect pests (small hive beetle), pathogens (*Nosema* species, American foulbrood, chalk brood, Israeli acute paralysis virus, black queen virus and numerous other viruses), lethal and sublethal pesticide exposure, Africanization of managed colonies, nutritional deficiencies due to lack of forage and/or forage diversity, genetic factors and other problems. Each of these problems has put additional pressure on honey bee survival and has contributed to increasing managed colony losses.

In 2006, reports began to surface of extensive losses of U.S. honey bee colonies due to a new and unknown malady, characterized by unexplained disappearance of most or all of the honey bees from the hive followed by a rapid collapse of colonies with honey and brood remaining. The syndrome was named Colony Collapse Disorder (CCD).

In response to this crisis, the Agricultural Research Service (ARS) and the National Institute of Food and Agriculture (NIFA) —two agencies within the U.S. Department of Agriculture (USDA) —spearheaded a collaborative effort to define the approaches needed to resolve the problem. To guide that effort, USDA's Deputy Secretary of Agriculture directed USDA Program Leaders to form a Committee, which became known as the CCD Steering Committee and was made up mostly of Federal program leaders from USDA and the U.S. Environmental Protection Agency.

Recently, this committee was renamed the CCD and Honey Bee Health Steering Committee to more accurately reflect the growing understanding of the significant health and environmental factors that impact the management of honey bees, and how interactions among these factors contribute to CCD.

The CCD Steering Committee developed the first CCD Action Plan, which was released in July 2007 (CCD Steering Committee, 2007*)*. The 2007 Action Plan was the result of input obtained from over 20 universities and Federal, State, and private organizations.

In addition, the Steering Committee submitted four annual progress reports to Congress on CCD-related research (USDA-ARS, 2014) as was mandated in the 2008 Farm Bill [Section 7204 (h) (4)]. In 2012, after five years of Federal effort, a National Stakeholder Conference on Honey Bee Health was convened to assess the state of knowledge regarding factors associated with declines in honey bee health and to collect input on future actions needed to promote better bee health and mitigate risks to managed honey bees in the United States. *The Report of the National Stakeholder Conference on Honey Bee Health,* which summarized that input, was released in May 2013 (Epstein, 2013).

Based on this report, the Steering Committee has now updated and broadened the Action Plan to address individual factors and complex interactions that may be playing specific roles related to declines in honey bee health and contributing to CCD.

The updated Action Plan focuses on six main areas of concern that have explicit relevance to improving the health of managed honey bees and our understanding of the economics of the apiary industry and its role in the modern agriculture system. These areas of concern are surveys, nutrition, pathogens/pests, pesticides, genetics/ breeding/biology, and economics.

On June 20, 2014, President Barack Obama issued a Presidential Memorandum calling on heads of executive departments and agencies to “expand Federal efforts and take new steps to reverse pollinator losses and help restore populations to healthy levels” (The White House, 2014). Importantly, the Memorandum directs federal agencies to address threats to *all pollinators* such as honey bees, native bees, birds, bats, butterflies and moths. In addition, the Memorandum directs the Secretary of Agriculture

and the Administrator of the Environmental Protection Agency to co-chair a “Pollinator Health Task Force” which includes at least 15 federal agencies. The purpose of the task force is to develop a “National Pollinator Health Strategy” which includes a comprehensive “Pollinator Research Action Plan", a public education plan, public-private partnerships, and measures to increase and improve pollinator habitat. The purpose of the CCD and Honey Bee Health Action Plan herein is to respond to the needs identified by beekeepers and associated commodity groups from the 2012 Stakeholder Workshop (Epstein 2013) Since this Action Plan also addresses research, educational goals and measures to mitigate honey bee stressors, it is expected to serve a complementary role to the Pollinator Health Task Force as it develops the broader Pollinator Health Strategy.

Surveys

As measured by annual surveys conducted by the Bee Informed Partnership and the Apiary Inspectors of America (AIA) and funded by the U.S. Department of Agriculture (USDA), winter losses of managed honey bee colonies have been fluctuating in the range of about 22-33 percent annually between 2007 and 2014, which far exceeds the historical rate of about 10-15 percent prior to the mid-1980s. This increase in winter colony losses represents a serious threat to both beekeeping and to the production of agricultural crops that depend on honey bee pollination.

Researchers studying CCD and poor colony health have been unable to identify a unique causative agent, concluding that losses of honey bee colonies are caused by a complex set of stressors, pathogens and/or pests interacting or working sequentially. In the face of such a multifaceted problem, accurate information about the incidence and extent of honey bee pests and diseases in the United States and the overall current status of honey bee colonies and honey bee health is an essential component of finding solutions.

Nutrition

Honey bees may not have sufficiently diverse sources of nectar and pollen to provide energy and essential nutrients that enable colonies to thrive when confronted with multiple factors known to affect their survival, growth, and reproduction.

The updated Action Plan identifies specific inter-agency efforts to provide quality forage and to identify plants best suited for improving bee health in different regions of the country. Also, the updated Action Plan calls for exploring ways to increase participation in Federal programs, such as the Farm Service Agency's Conservation Reserve Program (CRP), as a way to provide additional forage resources to honey bees. The best practices and benefits related to feeding in the winter and at other times when forage is not available are not well documented and necessitate research to improve the current understanding of supplemented pollinator diets.

Pathogens/Pests

Honey bees are subject to several pathogens and arthropod pests. The Varroa mite (*Varroa destructor*), first reported in the United States in 1987 (Hunt, 2010) is a known vector for several bee viruses and is among the most detrimental factors to honey bee colony health.

Other pathogens and pests include *Nosema ceranae*, detected in 1995 *(*Chen *et al.,* 2008*)*, deformed wing virus, first reported in 2004 (Chen *et al.,* 2004), Israeli acute paralysis virus detected in 2006 (Cox-Foster *et al*., 2007), and the small hive beetle discovered in 1996 (Hood, 2011), to name just a few. The development of new effective treatments, alternative control methods and a better understanding of interactions among mites, pathogens and bees is a critical need. This updated Action Plan identifies approaches to more accurately detect and document the incidence of various pathogens and pests in honey bee colonies and to identify means of curtailing the inadvertent introductions and/or spread of emergent pathogens and pests.

Pesticides

Pesticides are a widely used and essential tool in agricultural, residential, and urban environments where bees forage. Depending on the level of exposure, these compounds can adversely affect individual bees and/or entire colonies. The updated Action Plan identifies the need for efforts to develop and enhance methods for measuring acute and chronic effects of pesticides on the individual bee and on colonies and to establish linkages between sublethal measurement endpoints and assessment endpoints used to support regulatory decisions (for discussion of measurement endpoints used in pesticide regulatory assessment see: http://www2.epa.gov/pollinator-protection/pollinator-risk-assessment-guidance). The goal is to increase the depth of evidence-based science to better inform evaluation methods for pesticides and pesticide product labels. Mitigation measures, including best management practices and improved label language that build on existing efforts will also be developed to reduce potential exposure of bees to pesticides, including enhanced collaboration and communication with all involved stakeholders including growers, applicators, and beekeepers.

Genetics/Breeding/Biology

Increased genetic diversity is needed to ensure that bee populations are able to effectively adapt to rapidly evolving factors affecting their survival. The updated Action Plan identifies needed efforts to acquire and disseminate honey bee germplasm, to improve tools for selective breeding, and to identify factors associated with widespread reports of reduced survival and diminished longevity of honey bee queens in the United States. Use of genomic methods, including RNA interference, needs to be advanced and expanded to improve long-term protection of honey bees from pathogens.

Economics

Research on pollinator health and biology has advanced considerably in recent years, however, relatively few studies have applied economic tools and approaches to clarify and quantify relationships. This action plan increases the efforts devoted to

understanding the costs, benefits and trade-offs that determine the role of pollinators in the agriculture and food system and a broad suite of factors that may be influencing pollinator health. This plan includes an evaluation of the direct and indirect benefits of honey bees to the U.S. economy, an analysis of how land use policy and decisions might affect pollinator health and availability, and an investigation into linkages between variable pollinator availability, food production, retail food prices, and consumer/producer welfare.

Colony Collapse Disorder and Honey Bee Health Steering Committee

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Introduction

Honey bees are the principal insects providing vital pollination to economically and ecologically important plants throughout the world. Previous estimates indicated that honey bees provide an estimated $17.1 billion in added value to more than 90 crops each year (Calderone, 2012); native bees contribute another $3 billion in added value. Beekeepers transport honey bees around the country from crop to crop to provide concentrated pollination to assure bountiful harvests for producers and ultimately consumers. More than half of the Nation's managed honey bees are needed annually to pollinate almonds alone, a $3 billion crop, with increasing acreage and commensurate increasing demand for pollination services each year. More recent estimates indicate that U.S. beekeeper revenue from honey production and pollination services by managed bees in 2012 is estimated at $283.5 million and $655.6 million, respectively for a total of $939.1 million collectively (Bond *et al*., 2014). Perhaps more significantly, in the event that honey bees had not been available to provide pollination services in 2012, a short term revenue loss for crop producers was estimated at $18.1 billion (Bond *et al*., 2014).

In spite of their significant direct and indirect contributions to the U.S. economy, the health and numbers of managed honey bee colonies have been in a steep decline for more than 30 years. The parasitic mite, *Varroa destructor*, an invasive species from Asia that spread to honey bee colonies throughout the United States (including Hawaii) in the 1980s, is responsible for much of these losses (Hunt, 2010). Other factors likely driving the decline include the loss of nutritional floral resources; more fungal, bacterial, and viral bee diseases; new pests such as the small hive beetle; exposure to stressful levels of pesticides; possible genetic factors; and displacement by Africanized honey bees (National Research Council, 2007).

In 2006, reports began to surface of unusual and extensive losses of U.S. honey bee colonies due to a new and unknown malady, characterized by the unexplained disappearance of most or all of the adult honey bees from the hive followed by rapid

collapse of the colony with honey and brood (developing eggs, larvae and pupae) remaining. The condition was named Colony Collapse Disorder (CCD), and beekeepers in more than 22 States reported it a cause of significant losses (Arnas, 2007; CCD Steering Committee 2007).

A general consensus has been reached by the scientific community that CCD is not caused by a single unique agent but is most likely the result of multiple, interacting factors, including pests, pathogens, nutritional deficiencies due to lack of forage and/or forage diversity or inadequate supplemental diets, exposure to toxic or sublethal levels of pesticides and genetic factors (vanEngelsdorp *et al.,* 2007; vanEngelsdorp *et al.,* 2009; Johnson *et al.,* 2009).

Losses attributed to CCD by beekeepers have been variable in the years since 2007. For example, surveys funded by USDA indicated that beekeepers reported CCD as only the 8th most important factor associated with colony losses (vanEngelsdorp *et al.,* 2010). However, beekeepers who report CCD as one of the causes of their losses continue to suffer higher-than-average colony mortality rates (Steinhauer *et al.,* 2014). In addition, winter losses across all beekeepers have not diminished and have averaged about 30 percent between 2007 and 2013.

Through labor- and capital-intensive colony re-building efforts, beekeepers have been able to meet the pollination needs of field and orchard crop producers. However, due to associated increases in management costs, very tight supplies of commercial honey bee hives, and inelastic demand for pollination services, pollination fees for select crops have risen significantly in recent years. The average rental rate for a single honey bee colony for almond pollination increased from $76 in 2005, just prior to a surge in honey bee overwinter loss rates, to an average of $157 per hive in 2009, when a then all-time high was observed (Carman, 2011). If these conditions persist, it is increasingly likely that many producers will not be able to sustain their operations for much longer. A serious gap in the availability of pollination services could potentially create a situation

in which the quality and yield of specialty crops[1] may suffer, thereby reducing their availability and/or increasing their cost to consumers if substitute pollination technologies are unavailable.

In response to extensive reports of CCD from beekeepers in 2006 and 2007, the Undersecretary of Agriculture, Gail Buchanan directed the formation of the CCD Steering Committee with the charge of coordinating a Federal response. The Steering Committee consisted of representatives from eight organizations: Agricultural Research Service (ARS), Cooperative State Research and Education Service (now named National Institute of Food and Agriculture (NIFA), Animal and Plant Health Inspection Service (APHIS), and Natural Resources Conservation Service (NRCS)—Agencies of the U.S. Department of Agriculture (USDA)—plus the Office of Pesticide Programs from the U.S. Environmental Protection Agency (OPP-EPA), the Department of Defense, and two Land Grant Universities.

The Steering Committee requested input and recommendations from a broad range of experts in apiculture about how to approach the problem. Based on this input, the Steering Committee developed the original CCD Action Plan in 2007 (CCD Steering Committee, 2007*)*, which outlined the priorities for immediate research and outreach needs to characterize CCD and develop measures to begin mitigation of the problem.

Recently, this group was renamed the CCD and Honey Bee Health Steering Committee to more accurately reflect the growing understanding of the significant health and environmental factors that have been identified as contributors to the current extensive challenges to honey bee health, (Epstein, 2013; Williams *et al.,* 2010).

[1] Specialty crops are defined as fruits and vegetables, tree nuts, dried fruits, horticulture, and nursery and floriculture (http://www.ams.usda.gov/AMSv1.0/scbgpdefinitions).

The Steering Committee currently consists of representatives from USDA's NIFA, ARS, OPMP, APHIS, Economic Research Service (ERS), Farm Service Agency (FSA), National Agricultural Statistics Service (NASS), NRCS, and OPP-EPA. Additional organizations are likely to be added in the near future.

Since the formation of the Steering Committee, USDA and EPA have invested considerable resources to address CCD and the major factors adversely affecting bee health. Numerous research and outreach activities have been completed in the past several years, which were summarized by the Steering Committee in four Annual CCD Progress Reports (USDA-ARS, 2014). In addition, a number of other public and private organizations are providing significant support for research and outreach (*e.g*., North American Pollinator Protection Campaign [NAPPC], Bayer Crop Sciences, Project Apis m).

Despite important advances in fundamental knowledge in this area in recent years, there are still many gaps in the tools that beekeepers and crop producers have at their disposal to mitigate factors threatening honey bee health. Varroa mites are developing resistance to some of the available chemical control agents. In addition, while the number of reported cases of CCD may be decreasing, overall winter losses remain well above 14.6 per cent which is considered an acceptable level of loss by beekeepers participating in surveys (Steinhauer *et al*., 2014).

Persistent high losses indicate a need to reassess the emphasis of research on the primary causes of honey bee losses. As part of this reassessment, two conferences were convened by the Steering Committee. The first was the National Stakeholder Conference on Honey Bee Health in October, 2012 (Epstein, 2013). The second was the Varroa Mite Summit in February 2014 which reviewed the current state of knowledge from leading apicultural researchers, gathered input from the stakeholder community regarding future research priorities, and facilitated development of best management practices (BMPs) to address the needs of beekeepers and growers. The

research results and priorities identified at the two conferences provided the CCD Steering Committee with updated information to help develop the new Action Plan.

This updated Action Plan focuses on six main areas of concern that have explicit relevance to improving the health of managed honey bees as well as filling in the gaps in our knowledge of the economic value that honey bees provide to modern production agriculture. These areas of concern are surveys, nutrition, pathogens/pests, pesticides, genetics/breeding/biology, and economics.

For each of these areas, specific issues have been identified in the form of a problem statement (Problem) along with one or more specific means of addressing the problem (Goal), and a brief description of the proposed actions (Plan).

In addition, each goal has been assigned a priority level (high, medium, or low), duration of action (short-term 1-3 years, medium term 3-5 years, or long term more than 5 years), and the Federal agencies that will provide resources to carry out or to facilitate the Plan.

On June 20, 2014, President Barack Obama issued a Presidential Memorandum calling on heads of executive departments and agencies to “expand Federal efforts and take new steps to reverse pollinator losses and help restore populations to healthy levels” (The White House, 2014). Importantly, the Memorandum directs federal agencies to address threats to *all pollinators* such as honey bees, native bees, birds, bats, butterflies and moths. In addition, the Memorandum directs the Secretary of Agriculture and the Administrator of the Environmental Protection Agency to co-chair a “Pollinator Health Task Force” which includes at least 15 federal agencies. The purpose of the task force is to develop a “National Pollinator Health Strategy” which includes a comprehensive “Pollinator Research Action Plan", a public education plan, public-private partnerships, and measures to increase and improve pollinator habitat. The purpose of the CCD and Honey Bee Health Action Plan herein is to respond to the needs identified by beekeepers and associated commodity groups from the 2012

Stakeholder Workshop (Epstein, 2013) Since this Action Plan also addresses research, educational goals and measures to mitigate honey bee stressors, it is expected to serve a complementary role to the Pollinator Health Task Force as it develops the broader Pollinator Health Strategy.

I. SURVEYS

Problem 1: Winter losses of managed honey bee colonies have been fluctuating in the range of 22-33 percent annually between 2007 and 2014, which far exceeds the historical rate of about 10-15 percent prior to the mid-1980s. This increase in winter colony losses represents a serious threat to both beekeepers and to the production of agricultural crops that depend on honey bee pollination.

Although researchers studying CCD and poor colony health have been unable to identify a unique causative agent, consensus is building in the scientific community that it is a complex set of stressors and pathogens that result in widespread colony losses. In the face of such a multifaceted problem, accurate information about the incidence and extent of honey bee pests and diseases in the United States and the overall current status of honey bee colonies and honey bee health is an essential component of finding solutions.

Goal 1: Develop surveys to determine the extent of pests and disease in the United States and the current status of honey bee colony production and health.

Priority: High
Duration: Long-term
Federal agencies: ARS, APHIS, NIFA

Plan

1. Link and sustain different efforts that monitor bee health over time. Develop sampling methods for effective surveillance to associate pest or pathogen levels with economic thresholds for bee colonies in different environmental regions of the country. Survey as many pathogens and arthropod pests as resources will allow, with integration of other data such as management strategies and control

measures, nutritional state, pollen sources, crop / pesticide use in area, and climatic conditions.

2. Determine best times of year for surveys, ideally having more than one survey per season.
3. Use survey data to develop predictive models of bee mortality.

Goal 2: Provide timely, accurate, and useful statistics in service to U.S. agriculture.

Priority: High
Duration: Short-term
Federal agency: NASS

Plan

1. Conduct an annual survey of honey producing operations across all 50 states using a stratified sample of all known producers with five or more colonies. Producers with fewer than five colonies or less than $1,000 in sales will not be included. Publish results on honey price by color class at the U.S. level. Additional measures will include number of honey producing colonies, yield per colony, production honey stocks on December 15, average price per pound, and value of production as published at the state level.

2. The FY 2015 appropriations act provided an increase in funding to NASS for a Pollinator Health Initiative to respond to the large scale losses of pollinators. As part of this effort, the requested funding will allow NASS to expand its annual honey survey to include additional questions related to management practices, as well as estimates of revenues and expenses.

3. NASS also proposes Quarterly (5 or more colonies) and Annual (less than 5 colonies) Loss surveys that will collect colony loss, and stressor data. These surveys fully support the objective of the Presidential Memorandum “Creating a

Federal Strategy to Promote the Health of Honey Bees and Other Pollinators" (June 2014) to take "steps to reverse pollinator losses and help restore populations to healthy levels." To this end, NASS is committed to collaborating with other USDA agencies and other departments on a unified and complementary approach to the President's pollinator health initiative, and to deliver consistent, statistically defensible pollinator loss estimates to better inform decision makers.

4. Also proposed is a cost of pollination survey. Farmers will be asked if they hired honeybee pollinators during that crop year, and if the response is "yes" which crops, acres pollinated, and the cost of pollination will be collected. There will be the option to respond in total dollars, dollars per colony, or dollars per acre.

5. The above mentioned surveys will provide improved baseline and annual data to determine the extent of colony collapse disorder, in addition to providing quantitative information on potential causal factors, essential to the industry.

II. NUTRITION

Problem 1: Honey bees may lack nutritional foraging resources during summer months.

Goal: Provide quality honey bee forage and increase beekeeper access to federal and private lands.

Priority: High
Duration: Long-term
Federal agencies: FSA, NRCS, OPMP

Plan

Provide incentives to farmers and landowners to participate in USDA programs such as the Conservation Reserve Program (CRP) and the Environmental Quality Incentives Program (EQIP) to promote conservation practices that provide honey bees with nutritious pollen and nectar to sustain colonies. Efforts will be concentrated in the Midwestern states where at least 65 percent of commercial honey bees are located during the summer months.

1. Identify appropriate policies and incentives to facilitate landowner adoption of pollinator habitat covers.

2. Develop an outreach initiative to educate USDA county extension personnel and landowners about the pollinator beneficial covers.

3. Monitor and assess effectiveness of programs in improving honey bee health.

4. Use the results of program assessments to implement long-term improvements in conservation practices for honey bee health.

Problem 2: Removal of high quality floral resources from both public and private lands (*e.g*., (highway corridors, railways, utilities and extensive land conversion) is exacerbating the problem of reduced land area to produce nectar/pollen forage that beekeepers depend on to maintain their colonies. There is a general lack of awareness about the value of these floral resources for honey bees.

Goal: Increase the availability of nutritious floral resources potentially available through resource management programs like the Conservation Reserve Program and Environmental Quality Incentives Program, as well to begin a dialogue with appropriate authorities about planting floral resources on public roads and highways for bees and develop management plans that are compatible with the needs of both highway planners and beekeepers.

Priority: High
Duration: Long-term
Federal agencies: NRCS, NIFA, FSA

Plan

1. Initiate strategies to increase bee-friendly forage in public and private rights of way in cooperation with the responsible authorities.

2. Develop landscape designs that are compatible with the needs of public and private areas (*e.g*., hedgerows).

3. Increase public outreach efforts to inform the public about the importance of preserving floral resources to assist beekeepers in keeping their hives healthy.

4. Support research on landscape designs that meet the needs of roadside management (e.g. ease of maintenance, erosion control, etc.) while also providing forage resources for bees.

Problem 3: The role of certain nutritional factors in colony health is not completely understood. At certain times of the year, supplemental diets for honey bees are necessary; however, there is evidence that these diets are not very palatable or sufficiently meeting all nutritional needs, particularly for over-wintering bees.

Goal: Capitalize on innovations in basic research to determine the nutritional value of different floral resources and enhance the benefits of using supplemental diets.

Priority: Medium
Duration: Long-term
Federal agencies: ARS, NIFA

Plan

1. Build on research evaluating components of pollen and nectar in several plant species that provide essential energy needs for the colony to build brood, maximize honey stores, and enhance the reproductive health of queens, *etc*.

2. Identify key ingredients needed to increase palatability and consumption of supplemental diets.

3. Evaluate bee-associated gut microbes that affect the bees' ability to meet their nutritional needs and their role in defending against diseases or pests. Characterize and identify key microbial species that significantly benefit honey bee fitness. Develop practices to better utilize beneficial microbes in managed honey bees. Use this knowledge to improve supplemental diets to complement these natural dietary resources.

Problem 4: Regionally appropriate pollinator friendly seed mixes that are provided by NRCS are sometimes cost-prohibitive for many land owners.

Goal: Increase economical options for land managers who want to provide nutritious habitat for pollinators by providing suitable forage for honey bees. Low-cost, pollinator beneficial alternatives to existing seed mixes should be identified.

Priority: High
Duration: Short-term
Federal Agencies: NRCS, FSA

Plan

1. Evaluate different seed mixes to inform optimum planting mixes for sustaining colony health, while also meeting the broad conservation goals of the NRCS.

2. Develop cost-benefit analyses of various seed mixes recommended for use in conservation programs of FSA and NRCS to identify possible alternatives.

3. Provide updated educational materials to landowners about use of appropriate seed mixes to better sustain pollinators.

III. PATHOGENS/PESTS

Problem 1: The parasitic mite *Varroa destructor* (common name Varroa mite) remains the single most detrimental pest of honey bees and is closely associated with overwintering colony declines. In addition to causing direct mortality to bees by its feeding, and indirect mortality through transmission of bee viruses, Varroa mites immunosuppress bees leading to amplified levels of viruses. Due to widespread growing resistance to two of the three available miticides (coumaphos and fluvalinate), developing new effective treatments and alternative control methods is a critical need.

Goal: Improve chemical and non-chemical control methods and best management practices (BMPs) for Varroa mites. Increase knowledge of the effects of Varroa mites on virus incidence and pathogenicity.

Priority: High
Duration: Short-term
Federal agencies: ARS, APHIS, NIFA, EPA

Plan

1. Develop new chemical and non-chemical (*e.g.*, bee stocks with behavioral resistance) means for controlling Varroa mites.

2. Determine the role of Varroa mites and other arthropod pests in disease transmission.

3. Enlist the help of extension specialists in providing outreach to beekeepers via Communities of Practice and educational workshops to incorporate and implement BMPs to avoid using chemicals that have adverse effects on bees

Problem 2: Our understanding of the fundamental etiology of many bee pathogens is lacking. Additionally, the interaction of these pathogens with other honey bee pests is poorly understood.

Goal: Develop a better understanding of the biology of pathogens and arthropod pests and their interactions with honey bees.

Priority: High
Duration: Long-term
Federal agencies: ARS, NIFA, EPA

Plan

1. Determine the effects of symbiotic gut microbes on bee pathogens and bee immunity. Elucidate bee pathogen-pest synergisms.

2. Determine the mechanisms of pathogen and arthropod pest resistance to control products and tactics.

3. Determine the basis for tolerance/resistance by bees to pathogens and arthropod pests.

4. Determine the effects of different stressors (pesticides, nutrition, and climate) on bee diseases.

Problem 3: Foreign diseases such as European foulbrood are being detected more often in the United States and may be linked to colony losses. A greater understanding is needed of what pests and diseases exist, their identification and impact. Vigilance is particularly needed to prevent the introduction of new pests and non-native bees and wasps not yet detected in the United States, including but not limited to:

- parasitic mite *Tropilaelaps* species: *T. clareae* and *T. koenigerum* (Asia),
- non-native bee subspecies and species: *A. mellifera capensis* (southern Africa), *A. cerana* and *A. florae,*
- Asian predatory hornet *Vespa velutina* (Asia, Europe).

Goal: Develop new methods for determining the occurrence and preventing the introduction of foreign pathogens and pests of honey bees into the United States.

Priority: High
Duration: Medium-term
Federal agencies: ARS, APHIS, NIFA

Plan

1. Develop rapid, standardized sampling methods for identifying disease and parasite or pest-caused symptoms.

2. Develop methods for rapid identification and response to new virulent strains of pathogens or arthropod pests.

3. Create a Diagnostics Decision Tree for disease diagnosis in honey bee colonies.

4. Define the disease symptoms and develop a computerized diagnostics system that might be delivered as a smart phone app for use by beekeepers. Create a centralized lab for diagnosis of samples submitted by beekeepers, researchers, and regulators.

5. Develop rapid diagnostic tools and treatment options for exotic/introduced pests.

6. Develop guidelines for enhanced emergency Federal response to new pest introductions.

Problem 4: Current BMPs do not fully equip beekeepers with the tools needed to effectively mitigate parasites, pests, and pathogens which are causing significant losses of honey bee colonies and contribute to a rapid rise in beekeeper management costs. More outreach is needed to make information about new best management practices available to beekeepers and growers.

Goal: Develop new methods and tools for parasite, pest, and pathogen management and incorporate this information into BMPs for transfer to beekeepers and growers.

Priority: High
Duration: Long-term
Federal agencies: ARS, APHIS, NIFA

Plan

1. Integrate queries about disease identification and incidence with surveys of beekeeper's management practices (*i.e.,* Bee Informed Partnership survey).

2. Improve integrated management tools (*e.g.,* monitoring tools) for pathogen and arthropod pest management and incorporate into BMPs and training materials for beekeepers.

3. Develop new control measures for pathogens and arthropod pests, including new chemical approaches, traps and biocontrol methods.

4. Monitor for resistance to antibiotics and pesticide resistance in pathogens and arthropods pests respectively, and develop strategies to reduce exacerbation of resistance levels.

5. Tailor approaches suitable for backyard beekeepers versus commercial operations.

6. Develop novel BMP dissemination tools (*e.g*., smartphone apps).

IV. PESTICIDES

Problem 1: Standardized testing protocols exist for laboratory-based acute toxicity tests for individual adult and larval honey bees. However standardized protocols are needed for examining chronic toxicity in laboratory-based studies. Additionally, while guidance exists for semi-field studies, using whole colonies, from which sublethal endpoints can be ascertained, the duration of these studies is limited and their ability to evaluate longer-term effects (*e.g.*, overwintering capacity) has not been standardized. Stakeholders have also expressed concerns requesting improved access to toxicity data submitted to support the registration of pesticides.

Goal: Develop standardized testing procedures for assessing chronic toxicity and effects of pesticides on overwintering losses to bees that can be adopted both in the United States and internationally.

Priority: High
Duration: Short-term
Federal agencies: EPA

Plan

EPA will work through the Organization for Economic Cooperation and Development (OECD) in collaboration with the International Commission on Plant-Pollinator Relationships and the Colony Loss (COLOSS) network to identify suitable testing protocols for screening-level and higher tier studies (*i.e.*, semi-field studies) to support regulatory risk assessment. Working closely with other international regulatory authorities, EPA will prioritize study designs that should be subject to ring-testing for development into formal OECD guidelines.

Problem 2: Studies examining the potential effects of pesticides on bees have frequently reported adverse effects. However, these effects may have only been measured at relatively high exposure levels that may not be environmentally realistic.

Goal: Provide researchers with estimates of environmentally realistic exposure levels that may result from proposed and/or existing use of a pesticide.

Priority: High
Duration: Short-term
Federal Agencies: EPA

Plan

OPP-EPA currently conducts screening-level risk assessments which use conservative models to estimate exposure (dietary and contact) from existing and proposed uses of pesticides. More refined risk assessments base exposure on pesticide residues measured in pollen and nectar of plants treated at the application rates specified on the pesticide label.

1. Make screening-level exposure models publicly accessible by posting models on the EPA Models and Databases website (http://www.epa.gov/pesticides/science/models_db.htm) once such models have been adequately vetted through the EPA's peer review process (*e.g.*, FIFRA Scientific Advisory Panel; http://www.epa.gov/scipoly/sap/.

2. Insure access to risk assessment chapters where measured residue levels observed in pollen and nectar that result from labeled application rates.

3. Encourage appropriate protocol development for assessing residues of pesticides (targeted monitoring) in pollen and nectar to examine the effects of pesticides on honey bees.

4. Review protocols submitted to USDA on pesticide-related research for relevancy to ecological risk assessment in support of regulatory decisions.

Problem 3: Beekeepers have expressed concerns that honey bees are continually exposed to agrochemicals through contaminated pollen and nectar and that these exposures are resulting in sublethal and greater than additive/synergistic effects within the hives which may affect the ability of the colony to overwinter. These concerns are amplified for migratory beekeepers that provide pollination services for a range of agricultural crops throughout the year.

Goal: To collaborate with stakeholders on research to determine the extent to which migratory colonies are exposed to pesticides residues and examine the effects of these exposures on colony health, particularly has it relates to overwintering.

Priority: High
Duration: Medium-term
Federal agencies: EPA, ARS, NIFA

Plan:

1. As part of the Southern Row Crop initiative as well as stakeholder consortiums, USDA-ARS and university researchers are determining the impacts of common pesticide applications when applied to row crops on honey bee health. The project examines the uptake of systemic neonicotinoid insecticides from seed and foliar treatments to corn, cotton and soybeans and to develop appropriate management practices to minimize exposure to bees. These data can be used as another line of evidence in conjunction with similar data required by USEPA through ongoing reevaluation activities.
    a. Examine the extent to which plants absorb and translocate three systemic insecticides from soil into wildflowers where bees may be exposed. The research will provide valuable information on the extent to which soil

residues carry over from previous years and represent a source of exposure to bees through uptake and translocation of these residues to pollen/nectar of wildflowers located on or adjacent to previously treated fields.

b. Examine the extent to which various lubricants used in the planting of pesticide-treated seed affect the generation and movement of contaminated dust.
c. Survey pesticide residues and assess corresponding colony health in apiaries within intensive row crop production areas and adjacent wildflower habitat as well as urban landscapes toward determining whether relationships exist between residue levels of particular pesticides and the availability of food with honey bee health in terms of disease and parasite loads.
d. Integrate science-based regulatory assessment process which employs a tiered approach to determine whether more refined field-based studies are needed to support regulatory decisions.

2. EPA is collaborating with the Bee Informed Partnership's Technology Transfer teams and with commercial beekeepers to survey commercially managed colonies as they move through their pollination service cycle in multiple crops. The intent of this study is to examine the nature of pesticide residues in pollen being brought back to colonies by forager bees. This study also examines the palynology of the pollen as well as records pesticides in use in the immediate vicinity of the colonies. Residue data will be compared to various measures honey bee colony health to determine whether there is a correlation between pesticide use, residues in pollen, and colony health.

Problem 4: An increasing number of sublethal effects have been reported in the scientific literature and unpublished reports on registrant-submitted studies relative to exposure to pesticides. Their utility in assessing risks to bees depends on the extent to

which pesticide residues can be quantitatively and/or qualitatively linked to assessment endpoints (*i.e*., reduced lifespan/survival, growth or reproduction, impaired behaviors) on which regulatory decisions are based. At this time, there are insufficient data with which to link sublethal measurement endpoints with regulatory assessment endpoints. This includes data on molecular initiating events and other key events along an adverse outcome pathway. More mechanistic studies are needed to better understand how exposure to sublethal levels of pesticides leads to reduced fitness or impairs behavior (decreased foraging, mating, or lower hive return rates). In addition, assessments of sublethal effects of pesticides at the colony or population level are rarely studied.

Goal: To develop both qualitative and quantitative linkages between measurement endpoints collected at various levels of biological organization that will enable extrapolation from lower to higher levels. Such linkages would then enable assessors and risk managers to make greater use of sublethal effects since they could then be extrapolated to effects on impaired growth, survival, and reproduction of individual bees as well as whole colonies.

Priority: High
Duration: Short-term
Federal agencies: EPA, ARS, NIFA

Plan

1. Better define mechanisms of action of sublethal levels of pesticides (*e.g.*, receptor binding which block specific biological pathways) that lead to adverse effects on honey bees at the individual and population level.

2. As part of the Southern Row Crop Initiative, USDA-ARS and university cooperative extension units are examining the utility of biomarkers (*e.g*., esterase activity) as an indirect measure of exposure to certain classes of insecticides and

to determine the extent to which simultaneous exposure to these insecticides may result in greater than additive (*e.g*., synergistic) responses in bees.

3. Develop and validate simulation models that can help test/define quantitative relationships between various levels of biological organization and apical endpoints of impaired growth, survival and reproduction at the colony level.

4. Use simulations to develop a pesticide exposure module for inclusion in the USDA honey bee population dynamics simulation model BeePop Model[2] to enable researchers, regulators, and the public to estimate the potential effects of pesticide exposure on honey bee colony dynamics.

Problem 5: Risk assessments, which evaluate the potential for adverse effects from the use of a pesticide, serve as the basis for label language that can include both mandatory and precautionary measures to mitigate risks to bees. Multiple stakeholder groups have provided input to EPA that pesticide labels are difficult to understand and in some cases difficult for state-lead agencies/tribal authorities to enforce.

Goal: Further improve the clarity and enforceability of pesticide label language founded on quality science.

Priority: High
Duration: Short-term
Federal agencies: EPA

[2] http://gears.tucson.ars.ag.gov/beepop/

Plan

EPA, in collaboration with stakeholders, is working to develop label language that can be readily understood by users. Additional action items with respect to label language include:

1. Work with state lead agencies to explore state-level pollinator protection plans that will mitigate risk to bees, but will also retain flexibility for pesticide users to protect crop production.

2. EPA will work with state lead agencies, Health Canada's PMRA, and other regulatory partners and stakeholders to develop and add language to bags of pesticide-treated seed to protect pollinators.

3. EPA and Health Canada's PMRA will work together to make neonicotinoid pesticide labels consistent and bear the most current information on the use of these products.

Problem 6: Stakeholders have indicated a need to have effective measures to mitigate effects of pesticides on bees and ensure that these measures have been suitably vetted and disseminated via web- and field-based platforms. Commodity groups have also indicated that their constituents would be more likely to adopt mitigation measures if they had a clearer understanding of the efficacy of such measures, *i.e.,* the effect of mitigation measures or management options on crop yield or input costs. Stakeholders have acknowledged that it is not sufficient to rely exclusively on label language to reduce the potential risks that pesticides may pose to bees. Mitigation measures that extend beyond the label include having BMPs for growers, crop advisors, applicators, and beekeepers, as well as updated and validated IPM plans designed to reduce bee risk in specific crops and regions. In additional to developing BMPs and improved IPM plans, there is a need to ensure that these plans are accessible to various stakeholders.

Goal: Identify and/or develop mitigation measures or management options that optimize both pesticide benefits and pollinator health and safety. Mitigation measures and/or management options can both inform risk management decisions on pesticide labels, as well as be used as part of field-level best management strategies by growers/crop advisors/applicators/beekeepers.

Priority: High
Duration: Intermediate-term
Federal agencies: EPA, ARS and NIFA

Plan

In an effort to improve pesticide risk management options, research is underway to support the development of such measures:

1. EPA and USDA, including NIFA-funded National IPM Centers will work to develop and disseminate BMPs that are focused on both crop production and pollinator protection. Regional-specific and crop-specific applied research efforts that will be used to produce data-driven recommendations that optimize pest management practices that integrate pollinator protection. As part of these efforts, a reference on the IPM Centers' webpages will be established where links to information that can be easily accessed by those who are engaged in recommending crop production practices such as cooperative extension, crop advisors, and commodity groups.

2. EPA will continue to work with its global regulatory partners to develop an ecological risk mitigation tool box to guide future actions and share with domestic and international regulatory partners (*e.g.*, OECD Pollinator Effects on Insect Pollinator [PEIP] work group).

3. As an example, USDA, through the Southern Row Crop Initiative, is examining application technologies to reduce exposure to honey bees from pesticides. As part of this effort, the research aims to:
    a. Determine application scenarios that enhance an applicator's ability to effectively spray during temperature inversions; and,
    b. Examine methods to reduce drift and timing of spray applications for protection of bees during temperature inversions.

4. EPA is working with the seed-treatment side of the agro-chemical industry to develop technologies and management approaches to mitigate potential exposure to pesticides from pesticide-treated seed. EPA and the American Seed Treatment Association have developed stewardship materials and will continue to work to disseminate best management practices that reduce exposure. In addition, EPA will continue to work with stakeholders such as the agro-industry who are developing new seed treatment technologies that aim to reduce potential exposure (*e.g*., seeding lubricants, seeding equipment modifications).

5. EPA and USDA will promote the dissemination and use of BMPs that promote crop production and pollinator protection through their state-level and regional-level offices. USDA and EPA will develop materials that inform their regional/field offices of the resources, information, and BMPs that can be used to reduce exposure of bees to pesticides, including the AgLearn website (http://www.aglearn.usda.gov/[3]).

[3] The Agriculture Learning (AgLearn) system is USDA's department-wide system for managing training records and activity at USDA. Learning opportunities in AgLearn include both online and instructor-led resources, such as courses, webinars, videos and books.

Problem 7: Growers, crop advisors, applicators and beekeepers are not always well informed about the potential risks of pesticides to bee colonies and how such effects can be reduced through more clear guidance on pesticide labeling, improved BMPs, and stewardship.

Goal: Develop and enhance education/outreach programs for growers/applicators/beekeepers/general public on the risks to pollinators associated with the use of pesticides and measures to mitigate those risks.

Priority: High
Duration: Short-term
Federal agencies: EPA, OPMP

Plan

To enhance communication between affected stakeholders, it is first necessary to develop appropriate education and training materials to serve as a basis for communication. Participants in the National Stakeholder Conference believed that pesticide enforcement agencies (*e.g*., state lead agencies, Tribal authorities) must enhance their efforts to ensure that pesticide labels are followed.

EPA will continue to enhance its State and Tribal Assistance Grant (STAG) Program to assist states, territories, and the District of Columbia and Indian tribes in developing and maintaining comprehensive pesticide programs that address all aspects of pesticide enforcement and special pesticide initiatives. To further enhance certification and training programs and better ensure enforcement and compliance, EPA will partner with stakeholders to produce educational and training materials for pesticide applicators that States can use in their training programs. As part of this effort, EPA will:

1. Develop training materials.

2. Incorporate additional information from the August 2013 Certification and Training Workshop into training materials.

3. Finalize and announce the training and development plan.

4. As part of the increased effort to train/educate stakeholders and to enhance inspections and observations at pesticide application sites to insure user compliance with label directions and acceptable use practices, EPA has developed bee kill investigation guidance to assist lead State agencies, Tribal authorities and local officials in conducting bee kill investigations (http://www.epa.gov/compliance/resources/policies/monitoring/fifra/bee-inspection-guide.pdf). EPA Region 5 will review the extent to which this guidance has been adopted by State/Tribal lead agencies and will determine whether additional information and/or modifications are needed to improve the efficacy of the guidance.

Problem 8: Not all plants are dependent on and/or attractive to insect pollinators and not all plants that are attractive to honey bees are equally attractive to non-*Apis* bees. Also, some plants have extra-floral nectaries that may be attractive to bees when the plant is not actively blooming. To effectively target risk assessment and mitigation, it is important to know the extent to which crops may be pollinator-dependent, pollinator-attractive, or pollinator-unattractive.

Goal: Develop a list of major crops and identify whether they are pollinator-dependent, pollinator attractive, or pollinator unattractive.

Priority: High
Duration: Short-term
Federal agencies: EPA, ARS, OPMP

Plan

EPA is working with USDA and Land Grant Universities to develop a list of major crops and to identify whether those crops are pollinator dependent, pollinator attractive, or pollinator unattractive. To the extent possible, the list discriminates between honey bees, bumble bees, and other bees.

Problem 9: In addition to the consideration of risks posed by pesticides, economic considerations are a component of EPA's regulatory decisions. Current approaches for evaluating the benefits of pesticides focus on changes in yield and production costs of agricultural goods. This approach needs to be modified to appropriately evaluate the benefits or impacts of changes in pollinator health. EPA needs to identify and/or develop methods that will (i) better estimate economic impacts of potential regulatory decisions on beekeepers and (ii) provide a way for EPA to better communicate the impacts of regulatory decisions to the general public and regulated community.

Goal: Implement new tools that will improve EPA's ability to understand and/or measure the impacts of changes in bee health on beekeepers.

Priority: High
Duration: Short-term
Federal agencies: EPA, ERS

Plan

There are several potential approaches for estimating the value or impacts of pesticide risk on bees including estimating (1) replacement costs, (2) changes in beekeeper profits via a production function, and (3) willingness to pay to reduce risks. There are advantages and disadvantages of all approaches, including the ease by which they can be linked to risk assessment.

1. EPA will conduct a literature review of current research on the economics of beekeeping.

2. EPA and ERS will identify gaps in the existing research and determine the appropriate approaches to address these gaps.

3. ERS will review existing public surveys, field studies, other data sources (*e.g.*, seed treatment companies) concerning the use and economic effects of neonicotinoid seed treatments. If appropriate data exist, ERS will conduct analyses of the likely effects of potential regulation of seed treatments on input use, cost, productivity, and profitability of producing treated crops.

4. EPA will explore avenues for outreach such as organizing symposia at appropriate professional meetings or hosting workshops in order to seek input from a wide array of professionals to develop appropriate tools and methodologies.

Once comments from experts have been received and assimilated, EPA will begin to determine next best steps regarding what types of valuation studies the EPA can conduct to better communicate and evaluate the potential economic risks that pesticides have on beekeepers and society.

Throughout this process, EPA will coordinate with the ERS research program to address goals and outstanding questions regarding valuation of pollination services.

Problem 10: Current pesticide risk management at EPA is chemical specific and typically developed on a crop-by-crop basis. However, migratory beekeepers engaged in pollination services visit multiple crops in a single year. This necessitates that EPA consider new, holistic approaches to understanding the unique scenario that

commercial beekeepers and production agriculture face in terms of the dynamics between the two and how that affects honey bee health.

Goal: Develop a framework that can be used for analyzing the potential effects of pesticide risk management options that accounts for the dynamics of honey bees as an input to crop production and source of other goods—not just on a crop-by-crop basis, but on an inter-crop basis. Translate these effects into commonly understood measures or impacts on producers and consumers of bee products and services.

Priority: Medium
Duration: Medium-term
Federal agencies: EPA, ERS

Plan

There are several potential approaches for determining the range of pesticide exposures faced by migratory honey bees as well as related economic losses that may arise from these exposures. Economic benefits to beekeepers and society from risk management options being proposed or mandated by EPA will also be difficult to estimate given that the impacts of such regulatory efforts will have to be examined on a case-by-case basis.

1. EPA and ERS will conduct a literature review of research on the movement of commercial hives through the agricultural season and the contribution of pollination, including contribution of wild pollinators, to crop production.

2. EPA and ERS will identify gaps in the existing research and determine the appropriate approach(es) to pursue.

3. EPA will explore avenues for outreach, such as organizing symposia at appropriate professional meetings, or hosting workshops, in order to seek input from a wide of professionals to develop appropriate tools and methodologies.

4. EPA and ERS will explore options to conduct/support research to implement the approach(es).

Once comments from experts have been received and assimilated, EPA will begin to determine next steps regarding how to best conduct studies that analyze the effects of new risk management options that are recommended or mandated by EPA pesticide regulation(s). EPA will then also create a plan for how to determine the economic benefits to migratory beekeepers and society from new or proposed alternative risk management options.

Throughout this process, EPA will be coordinate with the ERS research program to address goals and outstanding questions regarding pollinator protection and valuation.

V. GENETICS/BREEDING/BIOLOGY

Problem 1: Colony-level genetic diversity is critical to honey bee colonies because it enables selection of desirable honey bee traits which are correlated with improved abilities for thermoregulation, disease resistance and worker productivity. However, maintenance of genetic diversity in U. S. honey bee populations is limited by large-scale queen production methods, high annual colony losses, historical restrictions on importation of new honey bee breeding germplasm and widespread loss of previously augmentative feral honey bees.

Goal: Explore processes for expanded acquisition, storage and dissemination of Old World germplasm to improve honey bee breeding in the U.S., while also curtailing the threat of introducing unwanted pests and diseases.

Priority: High
Duration: Short-term
Federal agencies: ARS, NIFA, APHIS

Plan

1. Expand selection, importation, and distribution of new honey bee stock and germplasm (initially semen) from the original Old World sources for three U.S. strains of beekeeping significance (Italian, Carniolan, and Caucasian).

2. Develop and deliver practical means for long-term storage (cryopreservation) of “top-tier” domestic honey bee germplasm for breeding use through “time and space” and to conserve germplasm collected from original source populations in Europe.

3. Establish a honey bee germplasm repository so samples of the “best” lines might be preserved and retrieved years or decades later for backcrossing to extant

populations thus providing the option to breed queens across time (different year classes) and space (easy transportation of genetic material) in ways previously unavailable

Problem 2: The potential role of selective breeding and genetic improvement in achieving sustainable solutions for honey bee health and productivity of honey bees is poorly understood.

Goal: Develop honey bee genetics and breeding tools, tactics, and methods to improve honey bee health and productivity.

Priority: High
Duration: Medium-term
Federal agencies: ARS, NIFA, APHIS

Plan

1. Develop marker-assisted trait selection to produce lines of bees that possess genetic markers for desired traits (*i.e.,* Varroa Sensitive Hygiene (VSH), grooming behavior toward parasitic mites, and chalk brood resistance). The ability to select for desirable traits within current commercial queen producer stocks would find rapid acceptance among queen producers and also facilitate timely dissemination of these traits into the wider U.S. honey bee population.

2. Increase baseline genetic diversity for trait selection (see Problem 1).

3. Encourage efforts to form public-private partnerships by fostering linkages between private pest control advisors and researchers and extension specialists in different regions to transfer new knowledge and technologies to breed better

bees (a.k.a. Tech Transfer Teams). These teams will incorporate selection-trait criteria into the breeding process, assess genetic stocks and implement science-based and technological breakthroughs in bee research to enhance industry sustainability.

4. Establish one or more diagnostic laboratories to provide rapid analyses of pathogens, parasites, invasive pests; and potentially evaluating genetic markers of stocks for trait selection, as that technology becomes available. In areas where Africanized honey bees occur, there would also be a demand to analyze samples to determine the extent of genetic introgression from Africanized honey bees.

Problem 3: Widespread reports from beekeepers indicate that longevity of honey bee queens has declined significantly, but the actual prevalence and cause(s) of this phenomenon is unknown and possible causes have not been determined. Early supercedure (the process by which one queen bee is replaced by a new queen) or death of the queen without replacement are suspected to be contributing factors to CCD and overall honey bee losses.

Goal: Gain a better understanding of the factors affecting honey bee queen longevity.

Priority: Medium
Duration: Medium-term
Federal agencies: ARS, NIFA, APHIS

Plan

1. Conduct research on queen quality and supercedure rates relative to honey bee management practices.

2. Explore possible causes of decreased queen longevity, including genetic defects, pathogens, pests, poor nutrition, lack of effective management strategies and exposure to environmental stresses during shipping.

3. Identify genetic characteristics associated with queen fecundity.

Problem 4: The potential for using novel genetic technologies (*e.g.,* RNA Interference or RNA*i*) which have been shown to be very promising for managing diseases and pests in other systems is less well known in honey bees and other pollinators. The potential of other biologically-based methods, including natural products (*e.g*., propolis, pheromones) and microbial biological control agents has not been well studied.

Goal: Advance research into genetically-based and biologically-based management of bee and arthropod pests associated with honey bees.

Priority: Medium
Duration: Medium-term

Federal agencies: ARS, NIFA, APHIS

Plan

1. Evaluate current methods and conduct basic research on novel approaches to improve protection of honey bees from pathogens and pests, including RNA*i* and biologically based methods. RNA*i* can also be used to better understand the molecular basis of pathogenesis.

VI. ECONOMICS

Problem 1: Factors such as parasitic mites, poor nutrition, diseases, environmental stressors, and the enigmatic CCD have had the collective effect of doubling annual overwinter colony losses, as compared to the pre-CCD period ending in 2005. While these health concerns bring public attention to the honey bee industry, the economic contribution of this industry to the US food system is not well documented.

Goal: ERS will estimate the value of U.S. honey bee pollination services by updating and expanding previous work in this area by researchers including Southwick and Southwick (1992), Morse and Calderone (2000), and Calderone (2012). Updated information on pollination fees, crop values, and other production data will be used to identify a range of values for pollination services.

Priority: High
Duration: Short-term
Federal agencies: ERS

Plan

1. Review the existing valuation literature and develop a theory-linked valuation methodology.

2. Gather data including but not limited to revenue, cost (including pollination fees), acreage, recommended hive stocking rates for the cross-section of pollinated crops, at the national-level; for the base year (2012); tabulate the direct value of commercial honey bee pollination on crop production.

Problem 2: Changes in agricultural land management practices could have an effect on wild and commercial pollinator health by altering the quality and quantity of habitat

available for natural foraging activities and summer feeding. Declining pollinator health has led to rising costs of managing commercial hives and increases in pollination fees, but the statistical relationship to land use patterns and policy has never been studied.

Goal: This study will focus on land enrolled in the Conservation Reserve Program and will investigate links between identified land management practices and wild and commercial pollinator health while controlling for a variety of beekeeper and other variables. The study will focus on a five-State area in which NRCS has been implementing a pro-pollinator program for the last three years. The program aims to expand buffer zones and increase forage available for wild and commercial pollinators. These five States are located in the upper Midwest and provide forage during the summer months for approximately 65-80 percent of the U.S. managed honey bee population.

Priority: High
Duration: Short-term
Federal agencies: ERS, NRCS, FSA, U.S. Geological Survey (USGS)

Plan

1. In partnership with staff from multiple agencies including ARS, NRCS, FSA, and USGS, ERS will manage the aggregation of collected data on pollinator health measures, which may include hive honey productivity, over winter hive losses, the presence of specific proteins, and mite and fungal infestation rates. Hive locations will be linked with measures of land cover in the immediate surrounding area.

2. With guidance on the development of a bio-economic model of pollinator health from collaborators at University of California Davis, ERS will lead the development and application of a statistical economic model to investigate the links between pollinator health and various land uses on forage availability, while

controlling for external factors such as exposure to pesticides, mite infestations, *etc*.

3. Appropriate methods will be applied to estimate the benefits of ecosystem services provided by native pollinators in test locations. Data collected from pollen traps at the hive will clarify which types of plants receive pollination benefits and aide in the benefit valuation process. A post-doctoral researcher, with experience conducting non-market valuation studies, will contribute to an improved estimate of the value of ecosystem services and provide requested input into the value of pollinators, more generally.

4. The results of the multi-faceted land management investigation will be reported and shared in public forums that include internal ERS publications, journal articles, and a summary presentation at an ERS-sponsored workshop to be held in 2016.

Problem 3: Concerns about the impact of declining honey bee health on agro-ecosystems lead to questions about crop productivity, food availability, and downstream producer/ consumer impacts. To date, the consumer impact is believed to be minimal, but as pollination service fees continue to rise concurrent with sustained overwinter colony losses, the outlook is uncertain. While limited alternatives to commercial honey bee pollination such as hand pollination and self-fertile crop varieties do exist, these methods remain impractical for most crop producers based on the current state of technology. In the meantime, the long-term effect of continually rising pollination fees and reduced pollinator availability on the food and agricultural system is unknown.

Goal:

ERS proposes to develop an economic model to represent pollination markets with the objective of identifying and measuring the factors that may influence pollination fees and pollinator availability (e.g., acres planted, crop prices, overwinter colony health). The

effect of pollination fee fluctuations on producer costs and consumer food prices and availability will be analyzed under a variety of scenarios including variable levels of pollinator availability. This work offers an important extension to valuation studies that focus only on a particular point in time, and will complement, update, and enhance the existing body of work on the consumer welfare effects related to reduced pollinator availability.

Priority: High
Duration: Short-term
Federal agencies: ERS, APHIS, ARS, FSA

Plan

1. In consultation with APHIS entomologists and collaborators at Montana State University and North Carolina State University, ERS will develop a derived demand model for pollination services that incorporates trade variables (from FAS and Census). The investigation will be extended to the end of the farm-to-fork corridor through the inclusion of scanner data related to consumer products that utilize inputs that benefit, directly or indirectly, from the services of commercial pollinators.

2. Appropriate data, including phytosanitary and trade data, as well as crop values, input costs, and apiary management cost data will be gathered.

3. To aide in developing the consumer demand model and consumer welfare estimates, consumer data (IRI) will be identified, cleaned of store and brand identifiers, and formatted for use. Proprietary data, particularly IRI Household and IRI Retail data (2008-2012), will be used to empirically model the pass through rates of pollination services fees to retail consumer food prices and to assist in determining the consumer welfare consequences associated with various pollinator health-influence service fee scenarios. Additionally, the potential

producer welfare effects from incomplete pass through of CCD related cost shifts, substitution effects across commodities that differ in their dependency on pollination services, and household purchasing decisions of produce and foods will be examined.

4. The results of the producer welfare and pollination demand analyses will be reported and shared in various forums including academic journal articles, an internal ERS publication, and as a contribution to an ERS-sponsored workshop planned for 2016.

References Cited

Arnas, G. C. 2007. "Mystery Ailment Strikes Honey Bees". Washington Post. http://www.washingtonpost.com/wp-dyn/content/article/2007/02/11/AR2007021100650.html

Bond, J., C. Osteen, K. Plattner, and M. Jekanowski. "*An Economic Valuation of Honey Bees in the United States: Report to Congress"*. USDA Economic Research service Administrative Publication 065. July, 2014. 45 pp.

Calderone, N. W. 2012. "Insect Pollinated Crops, Insect Pollinators and US Agriculture: Trend Analysis of Aggregate Data for the Period 1992-2009," *PlosOne* 7 (5), e37235, 27 pp.

Carman, H.F. 2011. "The Estimated Impact of Bee Colony Collapse Disorder on Almond Pollination Fees." *Agricultural and Resource Economics Update* 14(5): 9-11.

Chen, Y., J. D. Evans, B. Smith, J. S. Pettis. 2008. *Nosema ceranae* is a long present and widespread microsporidian infection of the European honey bee (*Apis mellifera*) in the United States. *J. Invert. Pathol*. 97: 186-188.

Chen, Y. P., B. Smith, A. M. Collins, J. S. Pettis and M. F. Feldlaufer. 2004. Detection of deformed wing virus infection in honey bees, *Apis mellifera* L., in the United States. *Am. Bee J.* 144: 557-559

Colony Collapse Disorder Steering Committee. 2007. Colony Collapse Disorder Action Plan. USDA-ARS; 27 pp. http://www.ars.usda.gov/is/br/ccd/ccd_actionplan.pdf)

Cox-Foster, D. L., S. Conlan, E. C. Holmes, G. Palacios, J. D. Evans, N. A. Moran. 2007. A metagenomic survey of microbes in honey bee colony collapse disorder. *Science* 318: 283-287.

Epstein, D. 2013. "Report on the National Stakeholders Conference on Honey Bee Health." http://www.usda.gov/documents/ReportHoneyBeeHealth.pdf

Hood, W. M. 2011. "*Handbook of Small Hive Beetle IPM*". Clemson University Cooperative Extension Program. EB-160. 20 pp.

Hunt, G. 2010. "*Parasitic Mites of Honey Bees*". Purdue Extension Bulletin. E-201-W. 7 pp.

Johnson, R., J. D. Evans, G. E. Robinson and M. R. Berenbaum. 2009. Changes in transcript abundance relating to colony collapse disorder in honey bees (*Apis mellifera*). *Proc. Nat. Acad. Sci.* 106: 14780-14705.

Morse, R.A. and N.W. Calderone. 2000. "The Value of Honey Bees as Pollinators of U.S. Crops in 2000." *Bee Culture* 128(3) 13 pp.

National Research Council. 2007. "*Status of Pollinators in North America"*. Washington DC: The National Academies Press, 322 pp.

Southwick, E. E. and L. Southwick. 1992. Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States. J. Econ. Entomol. 85(3): 621-633.

Steinhauer, K. A., K. Rennich, M. E Wilson, D. M Caron, E. J Lengerich, J. S Pettis, R. Rose, J. A Skinner, D. R. Tarpy, J. T Wilkes and D. vanEngelsdorp, for the Bee Informed Partnership. 2014. A national survey of managed honey bee 2012-2013 annual colony losses in the USA: results from the Bee Informed Partnership. *J. Apicul. Res.* 53(1): 1-18.

The White House, Office of the Press Secretary. 2014. Presidential Memorandum -- Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators. http://www.whitehouse.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b

USDA Agricultural Research Service. 2014. Honey Bees and Colony Collapse Disorder; Annual CCD Progress Reports 2009-2012. http://www.ars.usda.gov/News/docs.htm?docid=15572#reports

USEPA. 2012. Ecological Effects Test Guidelines OCSPP 850.3030: Honey Bee Toxicity of Residues on Foliage. Office of Chemical Safety and Pollution Prevention (7101) EPA 712-C-018. January 2012. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OPPT-2009-0154-0017 (last accessed 07/07/2014)

vanEngelsdorp, D., J. Hayes Jr; R. M. Underwood and J. S. Pettis. 2010. A survey of honey bee colony losses, fall 2008 to spring 2009. J. Apicul. Res. 49(1): 7-14. doi: 10.3896/IBRA.1.49.1.03

vanEngelsdorp, D; J. D. Evans; C. Saegerman; C. Mullin; E. Haubruge; B. K. Nguyen; M. Frazier; J. Frazier; D. Cox-Foster; Y. Chen; R. Underwood; D. R. Tarpy; J. S. Pettis. 2009. Colony Collapse Disorder: a descriptive study. PLoS ONE 4(8). http://dx.doi.org/10.1371/journal.pone.0006481

vanEngelsdorp, D; R. Underwood; D. Caron; J. Hayes. 2007. An estimate of managed colony losses in the winter of 2006-2007: A report commissioned by the apiary inspectors of America. *Am. Bee J.* 147(7): 599–603.

Williams G.; D. R. Tarpy; D. vanEngelsdorp; M. Chauzat; D. L. Cox-Foster; K. S. Delaplane; P. Neumann; J. S. Pettis; R. E. L. Rogers; D. Schutler. 2010. Colony Collapse Disorder in context. *Bioessays* 32 (10): 845-846. doi: 10.1002/bies.201000075