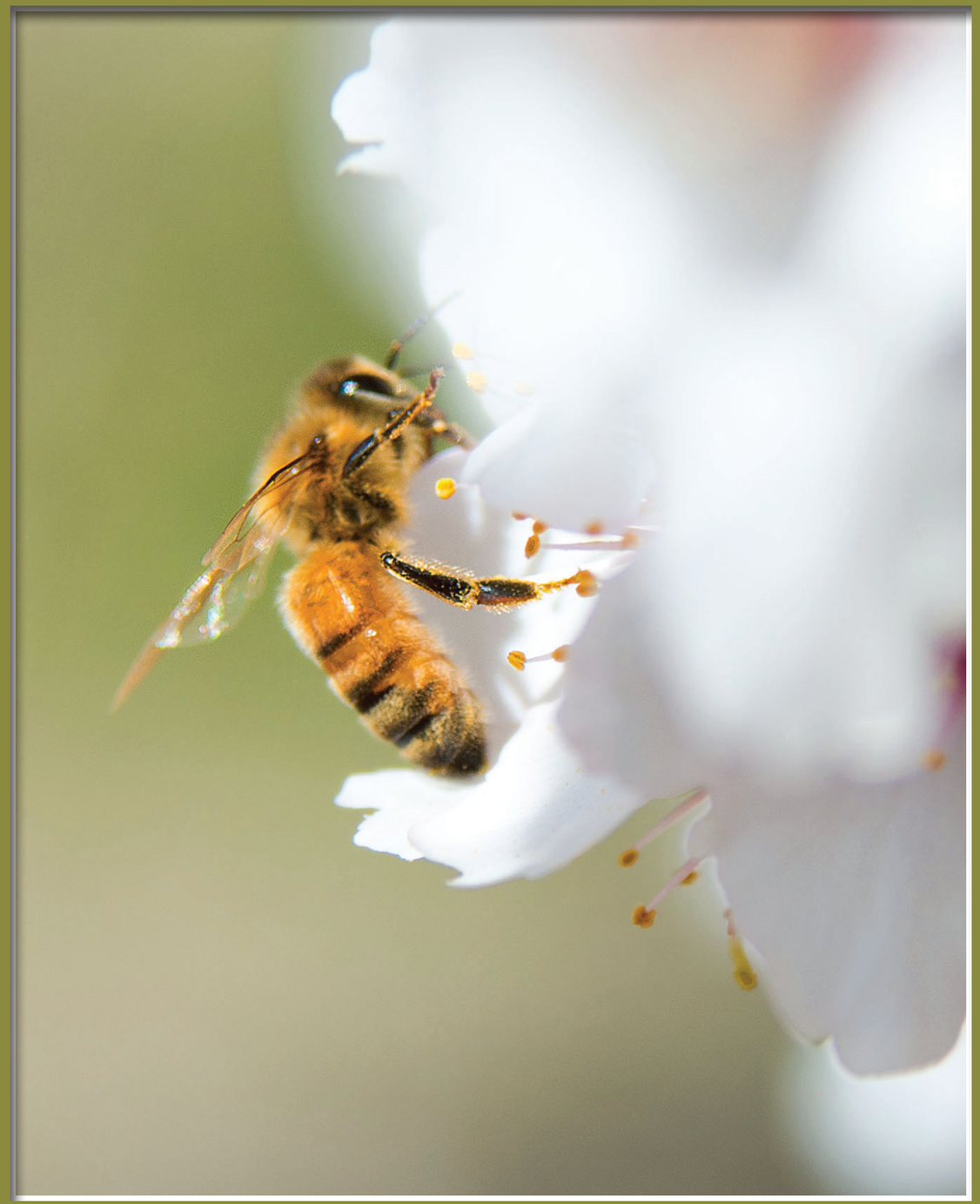
Office of the Chief Scientist
U.S. DEPARTMENT OF AGRICULTURE

2021 USDA Annual Strategic Pollinator Priorities and Goals Report

Issued April 2021

Contents



I. Preamble

Report Contributors

The contents of this report reflect feedback from a wide variety of contributors, including members of the U.S. Department of Agriculture's Pollinator Workgroup, associated sub-workgroups, and participants in the "2020 State of the Science Workshop: Research and Outreach to Support the Health of Agricultural Pollinators." See **Appendix B** for a complete list of contributors and participants.

Purpose of the Report

The U.S. Department of Agriculture (USDA) is pleased to share its annual pollinator research and programmatic priorities through this 2021 USDA Annual Strategic Pollinator Priorities and Goals Report. The development of this report was led by USDA's Office of the Chief Scientist and accounts for feedback obtained through collaborative efforts engaging USDA's mission areas, other agencies in the Executive Branch, relevant USDA grant recipients, and key pollinator health stakeholders. USDA relied on available executive and legislative guidance to assist in determining pollinator priorities. First, Title 10 of the Agricultural Improvement Act of 2018 (i.e., the 2018 Farm Bill) specifies research activities. Second, the 2018 Farm Bill directs that USDA pollinator health research efforts be implemented and coordinated as recommended by the Federal Pollinator Health Task Force (established in 2014 by Presidential Memoranda). This Task Force published a 2015 report, the "Pollinator Research Action Plan," or PRAP, which identified pollinator research needs with respect to factors affecting pollinator health. In addition to addressing these legislative mandates, the report attempts to follow up on earlier federally led efforts to address influential factors that impact pollinator health, including those detailed in the reports from the National Stakeholder Conference on Honey Bee Health (2013), the USDA Varroa Mite Summit (2014), and the USDA Honey Bee Forage and Nutrition Summit (2014), each of which identified research needs. *Overall, the coordinated effort as reflected in this report will enable USDA and our partners to make more informed and efficient decisions to support the health of pollinators in our Nation and the agricultural systems that depend on them.*

Introduction

Pollinators are facing a variety of stressors in the United States. In addition to honey bees, certain native bees, of which there are approximately 4,000 species in the United States, and other organisms contribute to agricultural pollination. The health of these organisms is of great importance to the well-being of U.S. agriculture, food security, and the Nation's overall economy. Pollination services add tens of billions of dollars to the value of agricultural crops annually and provide the backbone to ensure that our diets are both diverse and plentiful with fruits, nuts, and vegetables.

Multiple factors (stressors) including pests, parasites, pathogens, pesticides and environmental stressors, poor nutrition, and poor management practices have been associated with declines in pollinator health. No single factor has been identified as the primary cause of the declines in pollinator health, and the extent to which these stressors affect the well-being of pollinators vary over time and are often quite challenging to characterize. Complicating matters, many of these factors are interacting, making it difficult in some circumstances to identify dominant factors driving pollinator health declines. Therefore,

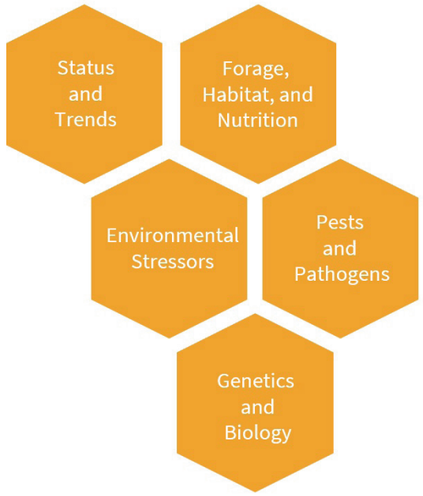


Figure 1. Five Subject-Matter Areas

in addition to considering different categories of stressors, this report attempts to account for the interrelated nature of stressors on pollinator health to better guide USDA's understanding of future research and programmatic needs. Generally following the same research categories used by the 2015 Pollinator Research Action Plan (PRAP), this report delineates its review of research and programmatic priorities and knowledge gaps into the following five sections: 1. Status and Trends; 2. Forage, Habitat, and Nutrition; 3. Environmental Stressors; 4. Pests and Pathogens; and 5. Genetics, Breeding, and Biology (Figure 1).

Farm Bill Coordination Requirements

The 2018 Farm Bill mandates that USDA coordinate certain research activities, including: (1) implementing and coordinating pollinator health research efforts of the Department, as recommended by the Pollinator Health Task Force; (2) establishing annual strategic priorities and goals for the Department for native and managed pollinator research; (3) communicating such priorities and goals to each agency or office of the U.S. Department of Agriculture, the managed pollinator industry, and relevant grant recipients under programs administered by the Secretary; and, (4) ensuring consistency and reducing unintended duplication across efforts funded by USDA. For the complete list of Farm Bill mandated research charges, see **Appendix A.**

In addressing the research and programmatic needs under these five sections outlined in Figure 1 while also responding to the Farm Bill requirements, USDA has created a framework with four objectives, shown in Figure 2, and described in further detail below.

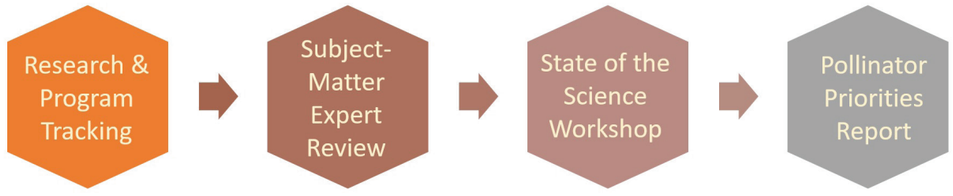


Figure 2. USDA Process for Satisfying Farm Bill Pollinator Research Requirements

1. Research & Program Tracking

The goal of this objective is to collate all pollinator research and programmatic efforts across USDA that are either in progress or slated to be completed in FY2021 into a single database, including research conducted by USDA grant recipients. This database is intended to keep track of research and create a systematic way to identify research needs and programmatic knowledge gaps. Further, this tracking will allow for comparisons against non-USDA-funded pollinator research efforts, reducing unintended duplicative efforts and increasing opportunities for collaborations. Results from this effort will be made available in 2021.

2. Subject-Matter Expert Review

The Farm Bill specifies that research priorities be identified based on feedback from the Federal Pollinator Task Force, which USDA interprets to be the Federal Pollinator Health Task Force. Although this Task Force is no longer operational, many of its former members participate in the USDA Pollinator Workgroup, which is led by the USDA, Office of the Chief Scientist and is comprised of employees of the USDA, Environmental Protection Agency, the Fish and Wildlife Service, U.S. Geological Survey, Bureau of Land Management, Smithsonian Institution, and National Science Foundation. To take advantage of the expertise and feedback of these members, they voluntarily could join one or more of five subgroups that were created to align with the five USDA Sections outlined above. The activities of these subgroups include:

- Reviewing current USDA-funded pollinator studies that relate to their area of expertise;
- Assessing whether research/program gaps or priority areas exist, especially in reference to the 2018 Farm Bill pollinator research mandates;
- Identifying priority topics for discussion at the USDA/EPA Pollinator State of the Science Workshop; and
- Reconvening after the State of the Science Workshop to arrive at a consensus on major pollinator research priorities and gaps.

3. State of the Science Workshop

USDA plans to annually facilitate a meeting to communicate and allow for feedback on USDA subgroup priorities and goals from Farm-Bill identified stakeholders. The 2020 annual meeting was conducted via a 3-day USDA/EPA-hosted virtual workshop, September 8 - 10, 2020, entitled the "USDA/EPA State of the Science Workshop" (herein referred to as the "State of the Science Workshop"). The primary purpose of this meeting was to allow for experts, including those identified in the Farm Bill, to provide input on priority areas and gaps in pollinator research and programmatic efforts. Under the Federal Advisory Committee Act (FACA), consensus building may only be conducted by Federal and State employees (including land -grant universities), and Tribal groups. Thus, after the workshop, feedback from stakeholders was considered at a follow-up session with Federal members to build consensus on annual pollinator priorities. A comprehensive overview of this workshop will be made available in a separate report.

4. Pollinator Priorities and Goals Report

Responsive to the 2018 Farm Bill, USDA published this Pollinator Priorities and Goals Report to capture the efforts described above. This report and subsequent annual reports will be shared with outside funders and the public—with special emphasis on communicating the Workshop proceedings and internal government perspectives with those stakeholders identified in the Farm Bill. USDA will post these annual reports and archive earlier reports on the USDA, Office of Chief Scientist (OCS) pollinator webpage.

Although the information contained in these reports is available to the public, the primary audiences intended for the annual report include: (1) internal and external funders of agriculturally relevant pollinator research/programmatic efforts; and (2) entities identified in the Farm Bill to which USDA is instructed to communicate research priorities and goals, each agency or office of the U.S. Department of Agriculture; the managed pollinator industry; and relevant grant recipients under programs administered by the Secretary of Agriculture). Another target audience for this report are potential grant recipients—not just those recipients currently receiving funding—as this report may help them better calibrate their own programs and awareness of pollinator priorities, as identified by the USDA Pollinator Workgroup.

Overview of USDA Pollinator Programs

USDA actively engages in research and development in support of pollinator protection and health. USDA agencies work across mission areas to collectively make significant contributions to pollinator health and protection efforts.

USDA's Office of the Chief Scientist (OCS) compiles accomplishments and efforts from agencies across the USDA that support the overarching goals of the *National Strategy to Promote the Health of Honey Bees and Other Pollinators* and five research action areas of the *Pollinator Research Action Plan (PRAP)*. The USDA and other Federal partners continue to engage in and collaborate on research and development in supporting pollinator health goals. OCS also coordinates interagency meetings that provide opportunities for agencies to share accomplishments and discuss pollinator health research collaborations. In 2019, OCS identified a honey bee and pollinator research coordinator to address the mandates of the 2018 Farm Bill.

USDA, Agricultural Research Service (ARS) has multiple laboratories devoted to bee research, including: Baton Rouge, Louisiana (honey bee breeding); Beltsville, Maryland (honey bee pests and diseases); Tucson, Arizona (honey bee nutrition) and Logan, Utah (non-*Apis* bees). Additional research occurs across the country in other laboratories, including at land-grant universities. A new laboratory at the University of California at Davis focuses on longitudinal studies, while a lab recently opened in Stoneville, Mississippi, will focus on pesticides and other environmental stressors.

Beginning with the new 5-year research cycle in 2020, ARS pollinator health research will focus on five goal areas:

Improving bee nutrition and performance through better bee management;

Mitigating the impacts of bee diseases, parasites and pests;

Quantifying and mitigating the effects of pesticides on honey bees and other bees, such as bumble bees (*Bombus spp*);

Maintaining and expanding the bee germplasm bank to preserve valuable bee germplasm for breeding; and

Conserving bee diversity and improving bee taxonomy.

USDA, Economic Research Service (ERS) has performed extensive economic research and analysis related to pollinators as part of its mission to anticipate and investigate trends and emerging issues in agriculture and for which objective economic research can inform and enhance policy. The ERS reports have addressed topics such as pollination services, how beekeepers and pollination markets have responded to elevated rates of honey bee colony loss, and how changing patterns of land use have affected pollinator forage availability.

USDA, National Agricultural Statistics Service (NASS) conducts several surveys that track the number of honey bee colonies, value of honey and pollinator services.

USDA, National Institute of Food and Agriculture (NIFA) provides grants to universities, including Land-Grant institutions, to address high priority pollinator research. They also work to provide funding to U.S. Land-Grant institutions and counties through the Cooperative Extension System to conduct information and technology transfer to stakeholders on pollinator health.

USDA, Animal and Plant Health Inspection Service (APHIS) safeguards honey bees against the entry, establishment, and spread of economically and environmentally significant pests, and facilitates the safe trade of agricultural products.

USDA, Farm Service Agency (FSA) administers the Conservation Reserve Program (CRP), which implements long-term rental contracts with growers to voluntarily remove environmentally sensitive land from agricultural production, and to plant species that will improve environmental health and quality, such as for pollinator and wildlife habitat.

USDA, Risk Management Agency (RMA) administers the Emergency Assistance for Livestock, Honey Bees, and Farm-Raised Fish (ELAP) program which provides financial assistance to eligible producers of honey bees due to disease and certain adverse weather events or loss conditions. ELAP assistance is provided for losses not covered by other disaster assistance programs authorized by the 2014 Farm Bill and the Bipartisan Budget Act of 2018.

USDA, Natural Resources Conservation Service (NRCS) offers more than three dozen voluntary conservation practices for working agricultural lands that can benefit pollinators. Although many of these practices target improving grazing lands or reducing soil erosion, small modifications to the practices can yield benefits to pollinator species.

USDA, Forest Service Research and Development conducts studies on the role of pollinators in forest and agricultural ecosystems. FS is establishing science synthesis and guidelines for supporting pollinators through agroforestry. This work includes research on pollinator agroforestry and land management Best Management Practices, research on relationships between insect pollinators, pollinator habitat and forest and riparian area restoration activities, climate change impacts on pollinators, and studies of how high severity fire influences floral resources and pollinators.

USDA, Office of Pest Management Policy (OPMP) addresses policy questions related to the interface of crop pest management and pollinator health and works closely with the USDA, National Agricultural Statistics Service on data collections to better understand pollinator Best Management Practices.

II. USDA Pollinator Priorities 2021

1. Overview

The following is an overview of the USDA pollinator priority initiatives, 2021. Four key priority initiatives (also referred to herein as "priorities") were selected within each of five subject-matter areas. These subject-matter areas include: (1) Status and Trends; (2) Forage, Habitat, and Nutrition; (3) Environmental Stressors; (4) Pests and Pathogens; and (5) Genetics, Breeding, and Biology. Although some common themes exist across these subject-matter areas, the priorities associated with each were developed by different groups of Federal pollinator experts.

Additional information is below, including an overview of each priority and example projects. Information on how these priorities were developed is housed in **Appendix C.**

2. Overarching Themes

Five overarching themes were also identified. Addressing these five themes is important towards establishing a viable foundation for better analyzing and disseminating pollinator research results. By building capacity to promote researcher and public access to data and knowledge, USDA can further enhance the necessary infrastructure and protocols needed to increase their utility across the government and private sectors. These five overarching themes are:

1. Establish nationally coordinated data infrastructures and data management strategies.
2. Develop effective methodologies and models for integrating data, especially those that utilize multivariate, geospatial, longitudinal, and machine learning methods.
3. Encourage focused communication, coordination, and collaboration in supporting pollinator health.
4. Integrate economic considerations into activities related to pollinator health assessments.
5. Address biological knowledge gaps, both for pollinators and biotic stressors.

See **Section 4.f.**, Overarching Themes and Final Thoughts, within this report for a detailed overview of the five overarching themes.

3. Summary of Priorities

Four key priorities were selected within each of five subject-matter areas, as outlined below. Additional information on each of these initiatives can be found in the subject-matter specific overviews.

3.a. Status and Trends

Priorities:

1. Identify factors associated with biological declines (e.g., bee survival, growth, reproduction) of commercially important pollinators.
2. Understand factors affecting yields and income derived from honey and other products of commercial beehives.
3. Assess the economics of possible crop yield improvement through supplementing honey bee pollination with non-*Apis* pollination.
4. Establish the status of and improve technologies for the collection and curation of baseline data on pollinator populations (e.g., improved species identification technologies and access to such technologies, establishing and cross-referencing databases, augmenting collections, and monitoring crop visitations and landscape use).

3.b. Forage, Habitat, and Nutrition

Priorities:

1. Develop optimal planting choices for forage and habitat in agricultural lands, Forest Service forests, and rangelands to support pollinator health.
2. Determine returns-on-investment to pollinator health from the provision of forage and habitat within agricultural lands, Forest Service forests, and rangelands.
3. Identify regional and spatiotemporal gaps in forage, habitat, and nutrition and their relation to the health and sustainability of pollinator colonies/populations.
4. Increase the understanding of the nutritional needs of pollinators throughout their life cycles and seasonal cycles to ensure healthy colonies/populations.

3.c. Environmental Stressors

Priorities:

1. Encourage increased, focused communication and collaboration between USDA, EPA, and other Federal partners, non-Federal researchers, and pesticide registrants in identifying and addressing key uncertainties related to pesticides and pollinator health.
2. Identify and enhance Integrated Pest Management (IPM) options and Best Management Practices (BMPs) toward mitigating the impacts of environmental stressors (e.g., pesticides) on pollinators and promoting increased stakeholder communication, collaboration, and broader adoption of such measures.
3. Generate improved models to understand the impact of environmental stressors on pollinator status, especially those that utilize multivariate, geospatial, longitudinal, and machine learning methods.
4. Improve the understanding of the impacts of temperature and climate variables on pollinator health and subsequent impacts on sustainable agriculture, forests, and rangelands.

3.d. Pests and Pathogens

Priorities:

1. Develop and strategize how to implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (*i.e.*, outbreaks and epidemics), particularly with respect to pollinators that visit crops for pollination or honey production purposes.
2. Improve knowledge of pest and pathogen biology, behavior, transmission, genetics, spillovers, and their interactions, as well as their impacts.
3. Determine which mechanisms, including increased government communication and coordination, can increase the speed and effectiveness of responses to emerging pest and pathogen issues.
4. Enhance and create new pollinator pest and pathogen management tools, including diagnostics, bee husbandry, and treatment practices.

3.e. Genetics, Breeding, and Biology

Priorities:

1. Evaluate, document, and coordinate genetic and breeding initiatives to improve the health of managed pollinators.
2. Evaluate the effectiveness of managed pollinator breeding practices and efforts to avoid creating genetic bottlenecks by improving genetic diversity and documenting pollinator genetics and breeding practices utilized by bee managers.
3. Address knowledge gaps in pollination biology that may affect agricultural or apicultural production.
4. Evaluate pollinator species contributions in contract and non-contract crops, and further understand the requirements of these species, including their habitat needs.

4. Priorities by Subject-Matter Area

4.a. Status and Trends

The following details the top four priorities for status and trends.

1. Identify factors associated with biological declines (e.g., bee survival, growth, reproduction) of commercially important pollinators.

- This initiative is a top priority as it addresses a 2018 Farm Bill research mandate, which states "with respect to native and managed pollinator colonies visiting crops for crop pollination services or honey production purposes, documents the survival, growth, reproduction, and production of such colonies."
- Although current research and data collections in part address this Farm Bill research mandate, federal subgroup members identified further need to support this initiative.
- Surveys conducted by the National Agricultural Statistics Service (NASS) are a major contributor toward establishing baseline information used in assessing the status of honey bees.

Example Projects:

Multivariate models that account for biotic and abiotic stressors and aim to estimate the degree to which different types of stressors impact pollinator health.

Establishing a sound baseline through improved monitoring and longitudinal studies is a critical

preliminary step toward assessing biological changes and understanding the impacts from multiple stressors.

A specific need exists to better assess the impacts of the decline of pollinators on crop pollination.

2. Understand factors affecting yields and income derived from honey and other products of commercial beehives.

- Developing economical and sustainable methods to supplement honey bee pollination with non-*Apis* pollinators could mitigate crop production risks by diversifying inputs for growers of crops that depend on pollination.
- New studies show evidence that yield benefits may accrue from pollination for crops not traditionally recognized as pollinator dependent. These benefits may further be enhanced by pollen movement due to interactions across different pollinator species.
- Research may demonstrate the extent to which crop pollination dependency ratios and stocking rate needs vary by region, weather conditions, planting designs, and across different varieties of the same crop.

Example Projects:

- Determining ideal ratios of *Apis* to non-*Apis* pollinators for maximizing crop yields and/or quality and assessment of the resulting economic benefits.

- Determining optimal species and stocking density rates when supplementing honey bee pollination.
- Research to inform policy decisions related to voluntary USDA land programs, such as the Conservation Reserve Program.

3. Assess the economics of possible crop yield improvement through supplementing honey bee pollination with non-*Apis* pollination.

- Commercial beekeepers are facing economic challenges from the declining profitability of honey and hive products.
- Market-related drivers for these declines include changes in consumer preferences for bee-derived products and from market failures resulting from honey adulteration and trade issues.
- Declining honey bee forage is also impacting honey yields.

Example Projects:

- Social surveys and economic analyses to address rising input costs for beekeepers, consumer behaviors and preferences, and market failures.
- Economic impacts from limited crop nutrition and the impact of bordering habitat on pollinator health, including the potential benefit from increased establishment of bee pastures.
- Long-term impacts from bee pasture expansion, including research to inform USDA land programs.
- Economic analyses to assess beekeeper substitutions away from honey production to crop pollination, including revenue tradeoffs, adulteration, imports, and consumer preferences.
- Improved communications and knowledge among beekeepers, crop producers, and the public, especially regarding the economic difficulties each entity faces.

4. Establish the status of and improve technologies for the collection and curation of baseline data on pollinator populations (e.g., improved species identification technologies and access to such technologies, establishing and cross-referencing databases, augmenting collections, and monitoring crop visitations and landscape use).

- Many of the research initiatives identified in this report rely on upfront investments in new technologies and data collections.
- Establishing accurate baseline data could dramatically increase the efficiencies and cost-effectiveness of USDA pollinator research investments.
- In addition to establishing baseline data, there is a critical need for data infrastructures, such as data portals and other mechanisms for efficiencies in data collection, sharing, and collaborations.

Example Projects:

- Further utilization of automated artificial intelligence (AI) and visual identification to track flower visitation.
- Creating AI systems to allow for automatic tracking to make monitoring less labor intensive.
- New/improved DNA-based methods for species detection, identification, and storage, such as microcoding and microsatellites for storing or assessing/genotyping DNA; compiled and curated collections of DNA; educational programs on techniques for long-term storage; and sequencing DNA rather than local storage to improve data accessibility.
- Better utilization of Smart Tools, geospatial registries, and other technologies for monitoring the location and/or movement of bees.
- Taxonomy needs such as better identification tools for non-taxonomists and improved educational opportunities; data digitization, especially investments in digitizing natural history collections; and coordinating digitizing efforts and cleaning up existing collections.

4.b. Forage, Habitat, and Nutrition

The following details the top four priorities for priorities for forage, habitat, and nutrition.

1. Develop optimal planting choices for forage and habitat in agricultural lands, Forest Service forests, and rangelands to support pollinator health.

- A need exists to consider the multiple factors that influence optimization of pollinator forage and habitat in agricultural landscapes.
- Examples of variables that should be accounted for in determining optimum plant selection include: plant attractiveness; bloom period; foraging behavior and flower preferences; nutritional value of pollen and nectar; planting size, configuration, and connectivity; location; long-term maintenance needs; long-term plant resilience against weather/climate variability; overlapping pollinator forage needs, and what is ideal for beekeepers, growers, and invasive species managers.

Example Projects:

- Development of a framework for multiple optimal forage/habitat solutions, articulating specific goals and how they are weighted, and how progress towards one goal might diminish progress towards another.
- Development of optimal plant matrices and plant guides to install in differing cropping systems.
- Large-scale coordination efforts, communication opportunities, and data collections that allow for multi-disciplinary consortiums (e.g., researchers, plant material developers, and agriculturalists) to produce standardized study replicates, BMPs, and decision tools to address agricultural habitat restoration and optimal planting choices.
- Research to further document the benefits and optimization of habitat corridors in agricultural lands, Forest Service lands, and rangelands.
- Need for a better understanding of plant-pollinator phenology to align foraging/nutritional needs with bloom timing to support pollinators and to ensure adequate bee presence and visitation for crop fruit/seed set.
- Research to support optimal land use transition choices for forage and habitat in agricultural landscapes.

2. Determine returns-on-investment to pollinator health from the provision of forage and habitat within agricultural lands, Forest Service forests, and rangelands.

A need exists to consider agricultural pollinator forage and habitat establishment in terms of market and non-market net benefits to individuals and society.

Market and non-market benefits from actions such as optimizing landscapes around crops or by utilizing crop genotypes/cropping systems that best convey forage/habitat benefits.

Benefits need to be weighed against the cost of establishment and maintenance and against potential risks (e.g., unintended attraction of crop pests; incompatible pest management needs).

Example Projects:

- Development of a suite of economic studies to understand optimal agricultural habitat choices that both estimate and maximize the economic returns from pollinator forage plantings.
- Development of new crop varieties and cropping systems that result in optimal forage for pollinators while satisfying

growers' economic considerations (e.g., seed costs, input costs, crop yields).
- Research to understand and potentially align the economic benefits associated with specific grower practices that also generate additional forage and habitat for pollinators.
- Determine how crop insurance, land conservation incentives, and societal influences impact grower choices related to forage and habitat for pollinators in agricultural settings.
- Research to support long-term forage and habitat maintenance and economic payoffs.

3. Identify regional and spatio-temporal gaps in forage, habitat, and nutrition and their relation to the health and sustainability of pollinator colonies/populations.

- There is considerable variability in forage, habitat, and nutrition at local and regional scales, as well as across different seasons and time periods—all of which may influence pollinator health.
- Strategic, connected conservation initiatives need to work together to address forage, habitat, and nutrition needs across differing spectra of local pollinator floral resource utilization and at varying scales (i.e., locally, regionally, and nationally).

Example Projects:

- Development of mechanisms for collaboration at varying scales that would allow for holistic, strategic coordination across individual forage, habitat, and nutritional initiatives.
- Need for a highly collaborative and organized repository of local and regional resources available at a national scale that assembles all resources, BMPs, and other information known to date for location-specific plant species/varieties (*e.g.*, nutritional profiles, growing requirements).
- Identification of research areas of highest need and greatest impact, including recognition of data gaps, strengths, and methods for relating prioritization criteria for decision-making purposes.
- Improved technologies to reduce resource needs for many of these objectives, such as unpiloted drones and eDNA.
- Research is needed to better understand how to expand and incentivize the availability of highly lucrative seed/plants through outlets beyond the Natural Resources Conservation Service (NRCS) Plant Material Centers (e.g., commercial seed distributors and plant nurseries).

4. Increase the understanding of the nutritional needs of pollinators throughout their life cycles and seasonal cycles to ensure healthy colonies/populations.

- A need for research to examine potential disconnects between forage availability and life cycle nutritional needs of pollinators, both at the individual and colony level.
- There is limited research exploring correlations between forage nutrition and measurable aspects of pollinator health (e.g., fat content, body size).
- Need for a better understanding of nutrition in the context of improving forage landscapes for biological health purposes, commercial nutritional supplements, and improved honey production.

Example Projects:

- Further studies on dietary preferences and deficiencies for pollinators of agricultural value.
- Establishment of a networking database for tracking nutritional information to allow for the identification of trends and gaps.
- Development of better geographic and environmentally based metrics to measure nutritional variations of forage species across varying landscapes.
- Development of better methods for nutritional research and nutritional identification.
- Impacts on the nutritional value and forage availability from variable weather, temperature fluctuations, and intense landscape changes such as forest fires and invasive weeds.

4.c. Environmental Stressors

The following details the top four priorities for environmental stressors.

1. Encourage increased, focused communication and collaboration between USDA, EPA, and other Federal partners, non-Federal researchers, and pesticide registrants in identifying and addressing key uncertainties related to pesticides and pollinator health.

- This initiative is communication based. It is not an effort to direct researchers on how to conduct research. Rather, it aims to ensure that researchers are aware of study designs elements and measurement endpoints of regulatory interest and ultimately, utility in decision-making.
- Execution of this coordinated effort would need to occur in partnership across multiple Federal agencies and would likely be of joint interest to participating Federal agencies.
- Balancing Federal-funded initiatives against regulatory needs is also of high priority (e.g., accounting for the effects of environmental mixtures; more effective high-throughput screening tools that are less dependent on whole animal tests).

Example Projects:

- Key projects include but are not limited to opportunities and trainings for risk assessor-researcher connections; educational opportunities for researchers regarding what is involved in various Federal risk assessment processes; communicating scientific methodologies recommended by the EPA and other Federal regulatory agencies to researchers.
- Development of repository of guidance for researchers that is consistent with Good Laboratory Practice (GLP) standards specified in the Code of Federal Regulations; parallel with guidance/communication on what is or is not regulated by EPA, FDA, etc.
- Additional federally led workshops/meetings to capture the concerns of key external stakeholders, allowing for increased communication and transparency.

2. Identify and enhance Integrated Pest Management (IPM) options and Best Management Practices (BMPs) toward mitigating the impacts of environmental stressors (e.g., pesticides) on pollinators and promoting increased stakeholder communication, collaboration, and broader adoption of such measures.

- Although IPM and BMPs methods have been extensively developed, there is little research to evaluate their effectiveness and how to clearly communicate with and engage stakeholders.
- Research is needed to determine what deters growers and beekeepers from adopting such practices (i.e., documenting obstacles to stakeholder adoption) and what factors lead to increased adoption.

Example Projects:
Efforts to determine the efficacy of various IPM/BMP measures in terms of improved pollinator health and translating this science into practice to engage stakeholders.
Measurements of how changes in grower/beekeeper behavior enhance pollinator health.
Determination of the net benefit, economics, and other drivers associated with IPM/BMP adoption to better inform educators and other professionals on how to best communicate information to growers and beekeepers.
Determination of how to optimize the number of available IPM/BMP options while pursuing widespread implementation, allowing for practical flexibility to local needs.
Improved BMPs for commercial beekeepers, such as how to maximize the benefits of cold storage for reducing overwintering losses and mitigate stressors on bees in migratory beekeeping operations.

3. Generate improved models to understand the impact of environmental stressors on pollinator status, especially those that utilize multivariate, geospatial, longitudinal, and machine learning methods.

- Data indicate that pollinator health is influenced by multiple interacting factors. Although efforts are continuing to collect large volumes of data on individual factors, there is a critical need to develop predictive tools that integrate these data at varying scales of biological organization.
- A notable challenge is the level of variability associated with any multivariate analysis particularly as temporal and spatial scales expand.

Example Projects:

- Development of better landscape maps relative to the distribution of crops and land management techniques that would allow researchers to evaluate where addressing different stressors may be most useful in improving pollinator health.
- Development of models with well-defined assumptions that can demonstrate interacting effects, linkages, and/or the utility of endpoints to promote predictive capacity.

4. Improve the understanding of the impacts of temperature and climate variables on pollinator health and subsequent impacts on sustainable agriculture, forests, and rangelands.

- Changes and variability in temperature, and climate can quickly lead to phenological mismatches between the timing of pollinator foraging and when nectar and pollen are available.
- Baseline information on the carrying capacities of particular landscapes and foraging areas to allow for predictions of potential direct and indirect impacts on pollinators needs to be established.

Example Projects:

- Research to document current and anticipate future shifts in plant phenology due to changes/variation in temperature and climate and predicted impacts on pollinator health.
- Impacts of temperature and climate on plant function and health, such as how changes in CO_2 impact the nutritional value of pollen, changes in the uptake of heavy metals and pesticides in heat-stressed plants.
- Development of tools such as models or meta-analyses to assist researchers in separating the impact of temperature and climate impacts from other stressors.
- Development of standard methods for quantifying flowering resource health benefits to pollinators across plant species.
- Creation of plans to ensure adequate nutrition is available to bees in differing agricultural landscapes for scenarios where phenological mismatches between pollinators and available forage becomes too pronounced.

4.d. Pests and Pathogens[1]

The following details the top four priorities for pests and pathogens.

1. Develop and strategize how to implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (i.e., outbreaks and epidemics), particularly with respect to pollinators that visit crops for pollination or honey production purposes.

- The feasibility and utility of this initiative hinges on support and investments into the processing and detection of pests/pathogens as well as on the development of standardized data documentation, and reporting methods.
- Need for a national data infrastructure to promote data sharing in order to more comprehensively and strategically track major pest and pathogen outbreaks.
- Detections of new and emerging pests/pathogens should also be captured in addition to established pests/pathogens.

Example Projects:

- Expansion of detection efforts for honey bee pest and pathogen that could be used in establishing nationwide methodologies, such as the Animal and Plant Health Inspection Service (APHIS) National Honey Bee Survey.
- Expansion of non-*Apis* species monitoring to standardize and account for non-*Apis* pests and pathogens nationwide, for example expanding the National Institute of Food and Agriculture (NIFA)-funded National Native Bee Monitoring Research Coordination Network (RCN) to include protocols for pest and pathogen monitoring.
- Develop track and trace technologies to assist in tracking migratory bee routes and subsequent pest/pathogen spread, as has been done for other commodities.
- Development of standardized specimen sampling and handling methods for pathogens, as typical procedures for pest sampling may not allow for pathogen identification.
- Creation of a simple interface for inspectors and researchers to submit data and samples of established and newly emerging pests.

2. Improve knowledge of pest and pathogen biology, behavior, transmission, genetics, spillovers, and their interactions, as well as their impacts.

- Need for studies to better understand the basic biology of pollinator pests and pathogens and how this ultimately impacts pollinator health.
- Understanding of interactions between pathogens, pests, and their hosts, and how specific pathogens interact.
- Further, extensive uncertainties exist regarding interactions between pests/pathogens and other stressors, which could be explored via correlative and multivariate initiatives. Development of accurate holistic experimental designs and models are a critical first step.
- Example Projects:
- Titer development and tracking to collect expansive data on viruses to understand the larger viral picture and relationships between diseases, the gut microbiome, and bacteria.

[1] The definition of 'pest' varies by USDA office, but here refers to all non-pathogen pollinator maladies.

- Physiological compatibility of species and variations in non-traditional host susceptibility.
- Pest/pathogen spillover and the potential for spillback in habitats surrounding agricultural areas (e.g., nearby forests).
- Development of new practices that can be applied commercially to reduce pathogen transmission between managed and unmanaged bees, e.g. reducing pathogen transmission in pollen/royal jelly.
- Identify current but undescribed pathogens (e.g., a large percentage of brood diseases are not traceable to known pathogens).
- Determine how pathogens transmit across bee body parts.

3. Determine which mechanisms, including increased government communication and coordination, can increase the speed and effectiveness of responses to emerging pest and pathogen issues.

- Improved communication infrastructures that support accurate and rapid coordination could dramatically improve government responses to emerging pollinator pest and pathogen issues.
- Effective, proactive coordination when pests and pathogens emerge is an essential, upfront need in addressing the larger long-term issue of pollinator pest and pathogen establishment.
- Better, more effective detection mechanisms to assist in early emerging pest/pathogen spread.

Example Projects:

- Creation of a national database to allow for rapid communication of emerging pest and pathogen detection to allow for effective, quick response.
- Identifying key agencies/organizations within States that work with beekeepers and industry stakeholders who can effectively communicate with each other and with beekeepers regarding the introduction of exotic pest and pathogen species.
- Development of Early Detection Rapid Response Plans for new pests and pathogens that may arise, such as port responses, allowing for more proactive responses.
- Regarding Asian giant hornet (*Vespa mandarinia*), development of a synthetic pheromone used by *V. mandarinia* in tagging honey bee hives for use in traps that may allow for earlier response and identification of spread.
- Research to better understand emerging pest and pathogens status and genetics, such as *V. mandarinia*, the parasitic drosophila (*Cacoxenus indagator*), *Apis cerana*, *Apis capensis*, *Tropilaelaps* spp., and potentially *Apis florea*.

4. Enhance and create new pollinator pest and pathogen management tools, including diagnostics, bee husbandry, and treatment practices.

- Coupling the development of new pest/pathogen practices and management strategies with efficacious and affordable interventions and diagnostic tools is critical to ensuring the long-term health of agricultural pollinators and the crops that depend on them.
- Researchers exploring new pest/pathogen control options need avenues to easily collaborate with Federal regulatory bodies prior to initiating research and throughout their research endeavors to identify and discuss registration needs, risks, benefits, and BMPs.

Example Projects:

- Development of new control options for pests/pathogens afflicting pollinators, including organic acids, biopesticides such as RNAi, bacteriophages, immune stimulants, improved formulation and delivery mechanisms, and other technologies that can be used in IPM.
- Improved researcher education opportunities on technology transfer and the regulatory steps needed to get products to market.
- Diagnostic tools to detect new types and specific strains of pests and pathogens and research to identify their unique impacts, if any, on pollinator health.
- Research to improve diagnostic tools, preferably that are non-destructive, quick, accurate, account for regional variations, and do not require labs for diagnostics.
- Modeling that accurately reflects the impact of beekeeper management practices on the community of pests/pathogens remaining after intervention.
- Need to better extend information to educate beekeepers on proper/reliable information sources to promote safe, effective, and legal pest management interventions and methods to prevent the development of pesticide resistance.
- Need for better BMPs to reduce disease transmission through proper equipment treatment and colony disposal.

4.e. Genetics, Breeding, and Biology

The following details the top four priorities for genetics, breeding, and biology.

1. Evaluate, document, and coordinate genetic and breeding initiatives to improve the health of managed pollinators.

- This initiative is a top priority as it addresses two 2018 Farm Bill research mandates, which state USDA shall "[evaluate and report] on the health differences of managed pollinators in crops not requiring contract pollination and requiring contract pollination," and " with respect to native and managed pollinator colonies visiting crops for crop pollination or honey production purposes, document the strength and health of such colonies and the survival, growth, reproduction, and production of such colonies."
- Federal subgroup members identified further need to support this initiative as survival, growth, reproduction, and production are key measures of the overall biological health of pollinators.

Example Projects:

- Development of a standardized national database to document, monitor, and share information related to biological measures reflecting pollinator health.
- Crop-specific and species-specific longitudinal studies to monitor basic colony and population performance as biological measures of pollinator health.
- Development and promotion of practical beekeeper data tracking mobile apps for tracing pollinator health in various cropping systems.
- Establishment of standards and reference databases for pollinator health assessment that can be used to help improve coordination across laboratories.

2. Evaluate the effectiveness of managed pollinator breeding practices and efforts to avoid creating genetic bottlenecks by improving genetic diversity and documenting pollinator genetics and breeding practices utilized by bee managers.

- This initiative is a top priority as it addresses a 2018 Farm Bill research

mandate, which states USDA shall evaluate "the effectiveness of managed pollinator breeding practices and efforts to, with respect to managed pollinators, avoid creating a genetic bottleneck and improve genetic diversity."
- Although current research and data collections in part address this Farm Bill research mandate, Federal subgroup members identified further research needs.

Example Projects:
- Development of monitoring process of novel traits and genetic health of pollinator populations.
- Research to understand the effects of pollinator genetic diversity on pollination-dependent agricultural systems.
- Need for better protocols, technologies, and BMPs to support breeding and husbandry of *Apis* and non-*Apis* bees, including more refined information on splits and nucleus colonies and methods for production.
- Need for improved molecular assays.

3. Address knowledge gaps in pollination biology that may affect agricultural or apicultural production.
- Basic biological information that is critical to pollinator health is limited and/or unavailable in many cases.
- This lack of knowledge can ultimately impact agricultural outputs such as pollination services and honey production.

Example Projects:
- Analysis of stressors impacting life histories, optimal colony/nesting requirements, and general biotic and abiotic factors that are critical to pollinator health.
- Development of management and breeding programs for non-honey bee pollinators to supplement honey bee pollination services as a risk mitigation tactic.
- Need for further research on the role and function that neurotransmitters play in pollination biology and pollinator health (e.g., the potential contributions of biogenic amine neurotransmitters, —such as dopamine, octopamine, serotonin, and tyramine—are unknown, but may be significant as they modulate neuronal functions).

4. Evaluate pollinator species contributions in contract and non-contract crops, and further understand the requirements of these species, including their habitat needs.
- Although honey bees are the primary commercial pollinators in U.S. agricultural systems, some crops may benefit from supplemental pollination from other species or derive unrecognized yield/quality benefits that have historically been unrecognized.
- Paramount to addressing associated research questions is improved tracking tools and other technologies to monitor pollinator species presence, visitation habits, and genetic diversity.
- Crop pollination needs are often regional in nature with variations in local environments, pollinator populations, and crop varieties. A standard set of measurable drivers of regional differences could lead to a better understanding of differing crop pollination contributions by different pollinator species across the U.S. landscape.

Example Projects:
- Development of novel mechanisms for tracking bee movement and visitation habits along with further development of technologies to assist in pollinator identification (e.g., eDNA).
- Determine if higher yields or crop quality from pollination can be achieved for non-contract crops (e.g., regional apple production, cotton, soybeans, strawberries, non-contract blueberry and cranberries, avocadoes, etc.).
- Development and application of genetic tools to monitor plant visitation by pollinators.
- Determination of crop pollination contributions associated with specific species of pollinators, and accompanying grower decision tools for evaluating pollination contributions.
- Better methods for containing managed pollinators in closed pollination systems (e.g., greenhouses) and resulting BMPs for growers to improve closed system pollination services.

4.f. Overarching Themes and Final Thoughts

Overarching Themes

In addition to subject-matter specific priorities outlined above, of interest are five overarching themes that were repeatedly identified within each of the five subject-matter areas. These five overarching themes are not initiatives that would typically be funded by a stand-alone grant or cooperative agreement. Rather, all five themes are essential tools for building the capacity to better interpret, translate, and share pollinator research findings across various users of research.

By building capacity to promote researcher access to data and knowledge, USDA can enhance its infrastructure and protocols to better facilitate the dissemination of pollinator-related research across the government and private sectors. These five themes include:

1. Establish nationally coordinated data infrastructures and data management strategies

Although all initiatives identified could benefit from national coordination of data management and improved infrastructure for data housing and sharing, the following initiatives specifically cite the need:
- Status and Trends Priority 4: Establish the status of and improve technologies for the collection and curation of baseline data on pollinator populations (e.g., improved species identification technologies and access to such technologies, establishing and cross-referencing databases, augmenting collections, and monitoring crop visitations and landscape use).
- Forage, Habitat, and Nutrition: Success across all four priority initiatives for this subject are dependent on nationally coordinated data management and data infrastructure.
- Pests and Pathogens Priority 1: Develop and strategize how to implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (i.e., outbreaks and epidemics), particularly with respect to pollinators that visit crops for pollination or honey production purposes.
- Genetics Breeding and Biology Priority 1: Evaluate, document, and coordinate genetic and breeding initiatives to improve the health of managed pollinators.

Rather than approaching these initiatives as separate efforts, coordination and streamlined repository/data curation systems could satisfy the needs across these three areas. Further, data sharing and multivariate questions could be better

addressed by having datasets and infrastructures housed in a single place or across interfaces that easily integrate.

2. Develop effective methodologies and models for integrating data, especially those that utilize multivariate, geospatial, longitudinal, and machine learning methods.

Second, an overarching need exists for improved methodologies and models that are readily accessible and adoptable by researchers. This need should be considered alongside nationally coordinated data management and data infrastructure, as all three needs highly complementary and could result in exponential returns on investment. The following initiatives specifically cite this need:

- Forage, Habitat, and Nutrition Priority 3: Identify regional and spatial temporal gaps in forage, habitat, and nutrition and their relation to the health and sustainability of pollinator colonies/populations.
- Environmental Stressors Priority 3: Generate improved models to understand the impact of environmental stressors on pollinator status, especially those that utilize multivariate, geospatial, longitudinal, and machine learning methods.
- Pests and Pathogens Priority 1: Develop and strategize how to implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (*i.e.*, outbreaks and epidemics), particularly with respect to pollinators that visit crops for pollination or honey production purposes.

Again, a coordinated solution to these three priorities may be the most efficient method to address these needs. Development in concordance with quality and reliability criteria for preferred methodologies and models would need to be considered.

3. Encourage increased and focused communication, coordination, and collaboration in supporting pollinator health.

Although improved communication and coordination is key across all aspects of pollinator health, multiple needs were identified within the environmental stressors and pests and pathogens subject matter areas. These include:

Environmental Stressors Priority 1: Encourage increased, focused communication and collaboration between USDA, EPA, and other Federal partners, non-Federal researchers, and pesticide registrants in identifying and addressing key uncertainties related to pesticides and pollinator health.

- Environmental Stressors Priority 2: Identify and enhance Integrated Pest Management (IPM) options and Best Management Practices (BMPs) toward mitigating the impacts of environmental stressors (e.g., pesticides) on pollinators and promoting increased stakeholder communication, collaboration, and broader adoption of such measures.
- Pests and Pathogens Priority 3: Determine which mechanisms, including increased government communication and coordination, can increase the speed and effectiveness of responses to emerging pest and pathogen issues.
- Pests and Pathogens Priority 4: Enhance and create new pollinator pest and pathogen management tools, including diagnostics, bee husbandry, and treatment practices.
- Forage, Habitat, and Nutrition Priority 1: Develop optimal planting choices for forage and habitat in agricultural lands, . Forest Service forests, and rangelands to support pollinator health (i.e., this would require a national database on plant pollinator characteristics, such as phenology, attractiveness, and nutritional value).

Investing in efforts to more effectively and more broadly communicate and coordinate—both internally and with external stakeholders—could have notable benefits for pollinator health, not only in terms of expediting Federal processes but also in sharing known and newly identified BMPs and IPM techniques with outside stakeholders.

4. Integrate economic considerations into activities related to pollinator health assessments.

Integration of the social sciences into conversations related to pollinator health could potentially lead to more efficient decision-making processes. This especially appears to be true for forage and economic considerations that are a major underpinning to grower decisions to establish and maintain various land uses.

Status and Trends Priority 2: Understand factors affecting yields and income derived from honey and other products of commercial beehives.

- Status and Trends Priority 3: Assess the economics of possible crop yield improvement through supplementing honey bee pollination with non-*Apis* pollination.
- Forage, Habitat, and Nutrition Priority 1: Develop optimal planting choices for forage and habitat in agricultural lands, U.S. Forest Service forests, and rangelands to support pollinator health.
- Forage, Habitat, and Nutrition Priority 2: Determine returns-on-investment to pollinator health from the provision of forage and habitat within agricultural lands, Forest Service forests, and rangelands.
- The value of integrating USDA economists and other social scientists into research planning efforts could prove beneficial toward promoting the adoption of certain practices. This may be especially important in the forage and habitat realm where investment decisions can have notable high-risk-reward ratios.

5. Address knowledge gaps in pollination biology and of biotic factors that affect their health.

Addressing knowledge gaps related to biological factors is key to nearly every endeavor related to pollinator health. However, specific needs identified for each subject matter include:

- Status and Trends Priority 1: Identify factors associated with biological declines (e.g., bee survival, growth, reproduction) of commercially important pollinators.
- Pests and Pathogens Priority 2: Improve knowledge of pest and pathogen biology, behavior, transmission, genetics, spillovers, and their interactions, as well as their impacts.
- Genetics, Breeding, and Biology: Address knowledge gaps in pollination biology that may affect agricultural or apicultural production.

Final Thoughts

Pollinator health is a complicated and multivariate issue. The effort at hand is not only a presentation of the collective viewpoints of Federal pollinator experts, but also has allowed for equal weight of individual voices. It also attempted to capture feedback from 2018 Farm Bill-recognized pollinator stakeholders to the greatest extent possible.

USDA greatly appreciates the internal and external stakeholders that provided their input to this process, including both USDA and non-USDA Federal agencies, State government, the managed pollinator industry, and researchers, and other pollinator partners, as identified in Appendix B. Contributors and Participants.

This initiative represents a holistic and balanced view in terms of diverse stakeholder perspectives of pollinator health needs, as reflected by the 2018 Farm Bill and by expert opinions. We look forward to future endeavors to support not only pollinator health but also the well-being of sustainable agriculture and the U.S. food system.

III. Appendix

Appendix A. 2018 Agricultural Improvement Act Pollinator Research Mandates

ENHANCED COORDINATION OF HONEYBEE AND POLLINATOR RESEARCH.

"(A) IN GENERAL.—The Chief Scientist of the Department of Agriculture shall coordinate research, extension, education, and economic activities in the Department of Agriculture relating to native and managed pollinator health and habitat.

"(B) DUTIES.—In carrying out subparagraph (A), the Chief Scientist shall—

"(i) assign an individual to serve in the Office of the Chief Scientist as a Honeybee and Pollinator Research Coordinator who shall be responsible for leading the efforts of the Chief Scientist in carrying out such subparagraph;

(ii) implement and coordinate pollinator health research efforts of the Department, as recommended by the Pollinator Health Task Force;

(iii) establish annual strategic priorities and goals for the Department for native and managed pollinator research;

(iv) communicate such priorities and goals to each agency or office of the Department of Agriculture, the managed pollinator industry, and relevant grant recipients under programs administered by the Secretary; and

(v) coordinate and identify all research on native and managed pollinator health needed and conducted by the Department of Agriculture and relevant grant recipients under programs administered by the Secretary to ensure consistency and reduce unintended duplication of effort.

"(C) RESEARCH.—In coordinating research activities under subparagraph (A), the Chief Scientist shall ensure that such research—

(i) identifies and addresses the multiple stressors on pollinator health, including pests and pathogens, reduced habitat, lack of nutritional resources, and exposure to pesticides;

(ii) evaluates stewardship and management practices of managed pollinators that would impact managed pollinator health;

"(iii) documents the prevalence of major pests, such as *varroa destructor* (commonly referred to as the varroa mite), and diseases that are transported between States through practices involving managed pollinators;

(iv) evaluates the impact of overcrowding of colonies for pollination services and the impact of such overcrowding on pollinator health status and pollinator health recovery;

"(v) evaluates and reports on the health differences of managed pollinators in—

"(I) crops not requiring contract pollination;

"(II) crops requiring contract pollination; and

"(III) native habitat;

"(vi) evaluates the impact of horticultural and agricultural pest management practices on native and managed pollinator colonies in diverse agroecosystems;

"(vii) documents pesticide residues that are—

"(I) found in native and managed pollinator colonies; and

"(II) associated with typical localized commercial crop pest management practices;

"(viii) with respect to native and managed pollinator colonies visiting crops for crop pollination or honey production purposes, documents—

"(I) the strength and health of such colonies;

"(II) the survival, growth, reproduction, and production of such colonies;

"(III) pests, pathogens, and viruses that affect such colonies;

"(IV) environmental conditions of such colonies;
"(V) beekeeper practices; and
"(VI) any other relevant information, as determined by the Chief Scientist;
"(ix) documents, with respect to healthy populations of managed pollinators, best management practices and other practices for managed pollinators and crop managers;
"(x) evaluates the effectiveness of—
"(I) conservation practices that target the specific needs of native and managed pollinator habitats;
"(II) incentives that allow for the expansion of native and managed pollinator forage acreage; and
"(III) managed pollinator breeding practices and efforts to, with respect to managed pollinators, avoid creating a genetic bottleneck and improve genetic diversity;
"(xi) in the case of commercially managed pollinator colonies, continues to gather data—
"(I) on an annual basis with respect to losses of such colonies, splits of such colonies, and the total number of pollinator colonies;
"(II) on rising input costs; and
"(III) overall economic value to the food economy; and
"(xii) addresses any other issue relating to native and managed pollinators, as determined by the Chief Scientist, in consultation with scientific experts.
"(D) PUBLICATION.—The Chief Scientist, to the maximum extent practicable, shall—
"(i) make publicly available the results of the research described in subparagraph (C); and
"(ii) in the case of the research described in subparagraph (C)(vi), publish any data or reports that were produced by the Department of Agriculture but not made publicly available during the period beginning on January 1, 2008, and ending on the date of the enactment of the Agriculture Improvement Act of 2018."; and
(5) in subsection (h), by striking "2018" and inserting "2023".

Appendix B. Contributors

USDA is grateful for the extensive time and feedback provided by the following contributors. Those that helped to organize and that participated in the 2020 Pollinator State of the Science meeting are also recognized herein.

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Kate	Ihle	USDA-ARS
Alessio	Ippolito	European Food Safety Authority (EFSA)
Rufus	Isaacs	Michigan State University
Shannon	Jewell	EPA
Reed	Johnson	The Ohio State University
Patrick	Jones	NC Dept. of Ag. and Consumer Services & AAPCO
Margaret	Jones	EPA Region 5
Erica	Kistner-Thomas	USDA-NIFA
Jonathan	Koch	USDA-ARS-PWA PIRU
Robert	Koethe	EPA Region 1
Gary	Krupnick	Smithsonian Museum of Natural History
Loren	Lapointe	EPA Region 9
Kathleen	Law	Pollinator Partnership
Anne	LeBrun	USDA APHIS PPQ
Anne	Leonard	University of Nevada, Reno Department of Biology
Josette	Lewis	Almond Board of California
Margaret	Lombard	National Honey Board
Gabrielle	Ludwig	Almond Board of California
Barbara	Martinovic Barrett	PMRA Health Canada
Jan	Matuszko	EPA Office of Pesticide Programs
Lindsie	McCabe	USDA-ARS
Nicole	McKenzie	Health Canada Pest Management Regulatory Agency

Deblyn	Mead	BLM
William	Meikle	Carl Hayden Bee Research Center, USDA-ARS
Andony	Melathopoulos	Oregon State University
Mike	Mendes	Wonderful Bees
Net	Meredith	Bee Informed Partnership
Ed	Messina	EPA Office of Pesticide Programs
Joseph	Milone	Office of Pesticide Programs - EPA
Jeffrey	Minucci	EPA
Lora	Morandin	Pollinator Partnership Canada
Matt	Mulica	Keystone Policy Center
Clayton	Myers	USDA-OPMP
Khue	Nguyen	Pesticide Re-evaluation Division EPA/OPP
Meghann	Niesen	EPA/OPP/EFED
Megan	O'Rourke	USDA-NIFA
Clint	Otto	US Geological Survey
Cristi	Palmer	IR-4 @ Rutgers University
Evan	Palmer-Young	USDA Agricultural Research Service
Jackie	Park-Burris	California State Beekeepers Association
Don	Parker	National Cotton Council
Katherine	Parys	USDA ARS
Stephen	Pernal	Agriculture and Agri-Food Canada
Peg	Perreault	EPA Region 8
Jeffrey	Pettis	Apimondia
Amanda	Pierce	EPA OPP
Jens	Pistorious	Julius Kühn Institute
Theresa	Pitts-Singer	USDA ARS Pollinating Insects Research Unit
Rob	Progar	USFS
Frederick	Proni	Veta Pharma
Tom	Purucker	EPA Office of Research & Development
Nathan	Redecker	BLM
Josie	Redmon	USDA-APHIS
Mary	Reed	Texas Apiary Inspection Service/Apiary Inspectors of America

Frank	Rinkevich	USDA-Honey Bee Breeding, Genetics, and Physiology
James	Rivers	Oregon State University
Holly	Rogers	EPA/OPP/EFED
Robyn	Rose	USDA FPAC
Kelly	Rourke	Pollinator Partnership
Edward	Ruckert	McDermott, Will & Emery
Olav	Rueppell	UNC-Greensboro
Mary	Rust	EPA/OPP
Keith	Sappington	U.S. Environmental Protection Agency
Dolores	Savignano	USFWS
Caydee	Savinelli	Syngenta
Daniel	Schmehl	Bayer CropScience
Elizabeth	Sellers	USGS
Arathi	Seshadri	USDA-ARS
Julie	Shapiro	Keystone Policy Center
Eric	Silva	AHPA
Kim	Skyrm	Apiary Inspectors of America/Massachusetts Department of Agricultural Resources
Tamara	Smith	U.S. Fish and Wildlife Service
Edward	Spevak	Saint Louis Zoo
Marla	Spivak	University of Minnesota
Carol	Spurrier	USFS
Thomas	Steeger	U.S. Environmental Protection Agency
Holly	Summers	EPA-OPP-EFED
Csaba	Szentes	EFSA
David	Tarpy	North Carolina State University
Tori	Thompson	Keystone Policy Center
Pam	Thompson	Environmental Fate and Effects Division. EPA-OPP
Timothy	Tucker	American Beekeeping Federation
Tom	Van Arsdall	Pollinator Partnership
Gary	Van Sickle	California Specialty Crops Council
Mark	Wagoner	National Alfalfa & Forage Alliance
Garland	Waleko	USDA APHIS Plant Protection and Quarantine
Doug	Walsh	Washington State University
Seth	Wechsler	USDA-OPMP
Chris	Taliga	USDA-NRCS
Wayne	Wehling	USDA APHIS
Greg	Weiler	US EPA
Katrina	White	EPA/OPP/EFED
Neal	Williams	University of California Davis
Geoff	Williams	Auburn University
Joseph	Wisk	BASF Corporation
Hollis	Woodard	UC Riverside
George	Yocum	USDA-ARS
Yu-Cheng	Zhu	USDA-ARS

Appendix C. USDA Pollinator Prioritization Process

The 2018 Farm Bill mandates the coordination of research, extension, education, and economic activities in the Department of Agriculture relating to native and managed pollinator health and habitat and the establishment of annual strategic priorities and goals for the Department for native and managed pollinator research. Over 65 Federal pollinator experts provided input to ensure that current needs pertaining to agricultural and apicultural needs were accurately identified. Many ideas and suggestions have been provided throughout the prioritization process, both by Federal pollinator experts and by relevant external stakeholders identified by the Farm Bill at the USDA/EPA Pollinator State-of-the-Science Workshop. Summaries of those discussions will be made available to better inform both funders of pollinator research and researchers, but to identify those topics of greatest need, a tiered process was used to prioritize the top four priorities for each

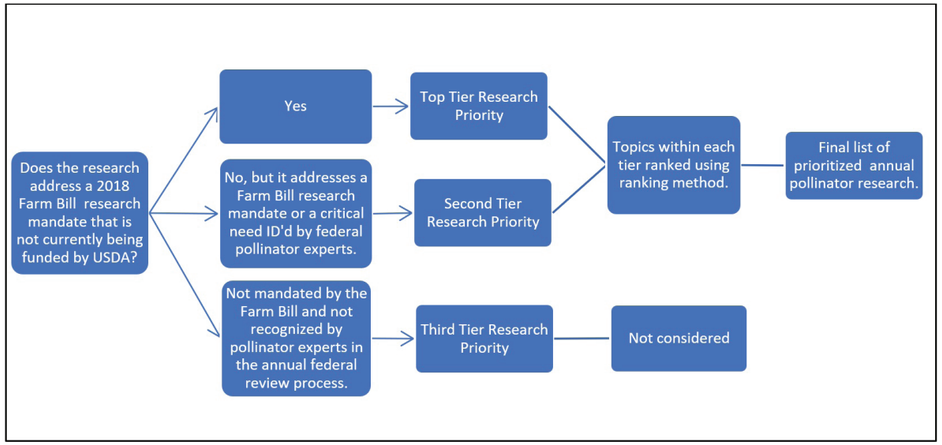

Figure 1. USDA Pollinator Prioritization Process

subject-matter area. This list reflects the final suggested annual priorities, with a total of 20 priorities across the five subject-matter areas. As reflected in Figure 1, prioritization relied on a three-tiered process. First tier priority initiatives are those addressing Farm Bill research mandates that are not currently being funded by USDA or fully satisfied, based on Federal pollinator expert feedback. The second tier of priorities where either (1) addressing a Farm Bill research mandate that is at least, in part, currently being addressed via the support of USDA funding or (2) had been recognized as a critical need by Federal pollinator experts. Initiatives that did not fall into either of these two categories were not considered during the annual prioritization exercise.

Overview of the Ranking Method:

For prioritization purposes, ranking was first conducted for initiatives falling across first-tier needs (i.e., those identified in the Farm Bill but that are not currently being funded by USDA). The same ranking method was then repeated for prioritizing initiatives falling under the second tier. The ranking process is a four-step process (Figure 2):

Step 1 -Top Initiatives are Identified for Ranking: Given that group prioritization is resource intensive, no more than 20 priorities total will be considered annually for any given subject-matter area. The decision for which priorities to select will be made by USDA's Office of the Chief Scientist and the Team Leaders for each subject-matter area. When possible, similar initiatives will be grouped together. Proposals that bordered on policy and/or are too far removed from the agricultural/apicultural realm were not considered. Further, initiatives suggested by one subgroup may have been relocated to a different subgroup priority list if the topic is better aligned with that subject-matter area.

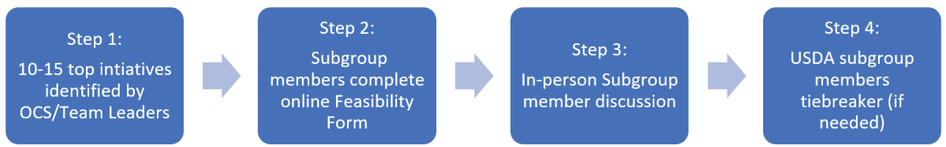

Figure 2. Ranking Process

Step 2 – Online Feasibility Form: To initiate the prioritization discussion, individual subgroup members were asked to complete an online Feasibility Form, which included three measures for each initiative:
'NEED,' in the context of the prioritization effort at hand, refers to how high the need is for this type of initiative in the agricultural/apicultural realm. The scoring for this measure is: (1) Very High, (2) High, 3) Medium, (4) Low, (5) Negligible, and (6) Don't Know.

'TECHNICAL AND RESEARCH FEASIBILITY' addresses the viability for expected, typical projects that may arise under each initiative. Here, the cost of an initiative is not considered, as cost can greatly vary for the same types of endeavors depending on the level of detail and breadth of the pursuit. Rather, a general gauge of the knowledge and technical resource needs (i.e., considering the current state of the science and available infrastructures) for an initiative as a whole is being sought. This should further account for the maturity of prospective research designs and our confidence that desired outputs and outcomes can be delivered. The scoring for this criterion is: (1) Very High, (2) High, (3) Medium, (4) Low, (5) Negligible, and (6) Don't know.

'IMPACT' – For the purposes of this exercise, 'IMPACT' indicates the likelihood that an objective could significantly further science and/or will have far-reaching impacts. Advancing science is typically a function of innovation, which could be in the form of new approach methodologies or data collection. It can also be in the form of new products or novel collaborations. Far-reaching impacts are those that are expected to directly benefit stakeholders. In the context of pollinator initiatives, stakeholders could include but are not limited to beekeepers, growers, researchers, agricultural consumers, and government. The scoring for this criterion is: (1) Very High, (2) High, (3) Medium, (4) Low, (5) Negligible, and (6) Don't know.

Step 3- In-Person Subgroup Member Discussion: The survey results from the Online Feasibility Form were tallied to determine average scores for each initiative and these data were in turn shared for an internal discussion and group consensus building exercise. Further consensus on the top four initiatives was determined using real time polling tools. In many cases, initiatives were further refined based on group discussion.
Step 4 – USDA Subgroup Members Tiebreaker: In the case that a consensus could not be reached on the top four priorities during Step 3, USDA-employed Subgroup members would be provided the opportunity for a closed discussion to reach a consensus. In the case that a consensus still could not be reached, the Team Leaders for the Subgroup would be asked to make the final determination of priorities. This step was not needed for any of the five subgroups in setting 2021 priorities.

Other Considerations:

- Non-Research Initiatives – Some initiatives may be included for consideration that are not directly research-oriented (e.g., extension activities, educational opportunities, improved collaborations, etc.) as in many cases they are key to improving research quality and/or disseminating research findings.
- Output Are Suggestions Only – Note that identified priorities are suggestions only and are only intended to relay the opinions of Federal pollinator expert opinions on needs.