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

USDA ANNUAL STRATEGIC POLLINATOR PRIORITIES REPORT

2022

Issued June, 2022

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 (USDA) Pollinator Workgroup, associated sub-workgroups, and participants in the "2021 State of the Science Workshop: Research and Outreach to Support the Health of Agricultural Pollinators." Further, USDA extends special thanks to the U.S. Environmental Protection Agency (EPA) and its Federal Advisory Committee, the Tribal Pesticide Program Council (TPPC), for their input and consultation on this report.

Purpose of the Report

The USDA is pleased to share its annual pollinator research and programmatic priorities through this 2022 Pollinator Priorities Report. Its development 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. The need for coordination with these stakeholders in identifying pollinator research priorities is recognized in Title 10 of the Agricultural Improvement Act of 2018 (*i.e.*, the 2018 Farm Bill).

USDA relied on available executive and legislative guidance to assist in determining pollinator priorities. In addition to identifying stakeholders of note, Title 10 of the 2018 Farm Bill specifies research activities. Second, the 2018 Farm Bill directs the implementation and coordination of USDA pollinator health research efforts as recommended by the Federal Pollinator Health Task Force (established in 2014 by Presidential Memorandum). 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 factors influencing 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), all of which identified research needs.

Overall, the coordination reflected in this report will enable USDA and our partners to make 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 (*Apis mellifera*), there are approximately 4,000 species of wild bees in the United States and several other organisms that can 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. In addition to economic value, pollinators support healthy ecosystems needed for clean air, stable soil, clean water, and a diversity of wildlife. Pollinators also have high cultural value placed upon them across many diverse communities.

Pollinator health can be a difficult term to define and challenging to quantify. This is the case for both managed and wild pollinator research, where drivers of pollinator health are multi-faceted, difficult to characterize, and in some cases understudied. For the purposes of this report, USDA relies on the definition of pollinator health as described by López-Uribe et al. (2020), that is, "a state that allows individuals to live longer and/or reproduce more, even in the presence of pathogens, thus providing more ecological services. Therefore, pollinator health should be assessed as a comprehensive multilevel measure of the vigor, resilience, and ecological functionality of pollinating species."

Declines in pollinator health are driven by multiple interrelated factors including pests, pathogens, pesticides, climate stress, poor nutrition, and management practices. None of these stressors are sole drivers of declining pollinator health, and the extent and nature of the effects of these stressors on pollinators vary over time and are often quite challenging to characterize. Furthermore, many of these factors are interacting with one another. Therefore, to better guide USDA's prioritization of future research and programmatic needs, this report attempts to account for not only different categories of stressors that impact pollinator health but also their interrelationships. 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)**.

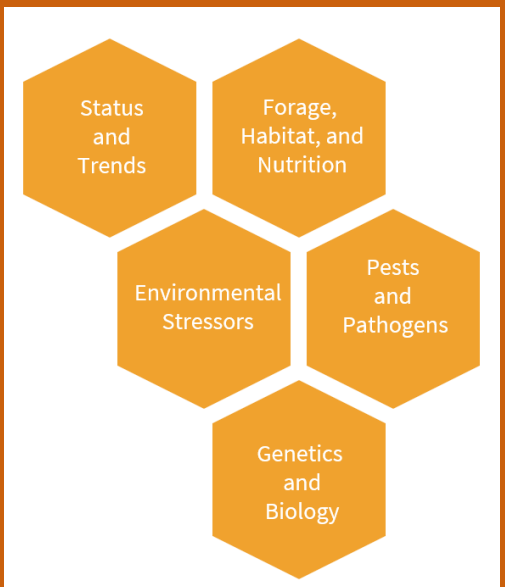


Figure 1. *Five Subject-Matter Areas*

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 managed and wild pollinator research; (3) communicating such priorities and goals to each agency or office of the USDA, 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.** Additional, non-legislative discussions regarding these research charges and USDA efforts to support pollinator health are in the 2018 Farm Bill Conference Report, Section 7209, High-Priority Research and Extension Initiatives.

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

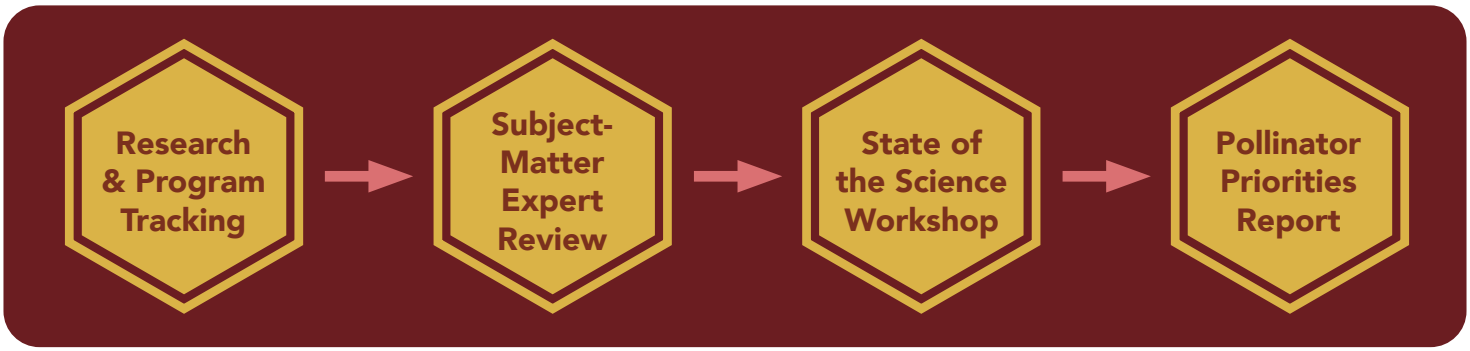


Figure 2. *USDA Process for Satisfying Farm Bill Pollinator Research Requirements*

1. **Research & Program Tracking**

   The goal of this objective is to collate all pollinator research and programmatic efforts across USDA into a single database, including research conducted by USDA grant recipients. This database tracks research and creates a systematic way to identify research needs and programmatic knowledge gaps. Further, this allows for comparisons against non-USDA-funded pollinator research efforts, reducing unintended duplicative efforts and increasing opportunities for collaborations.

2. **Subject-Matter Expert Review**

   The Farm Bill specifies that research priorities be identified based on feedback from the Pollinator Task Force, which USDA interprets to be the prior established 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's Office of the Chief Scientist and is comprised of employees across multiple Federal agencies. To leverage the expertise and feedback of these members, they can voluntarily join one or more of the 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

The USDA annually hosts a meeting to communicate and allow for feedback on USDA subgroup priorities and goals from Farm Bill-identified stakeholders. The 2021 annual meeting was conducted via a 2-day USDA/EPA-hosted virtual workshop, September 13 - 14, 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.

4. Pollinator Priorities Report

Responsive to the 2018 Farm Bill and following the USDA/EPA State of the Science Workshop, this Pollinator Priorities Report is published 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. The USDA will post the annual reports and

archived 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 audience intended for the annual report include: (1) internal and external funders of agriculturally relevant pollinator research/programmatic efforts; (2) entities identified in the Farm Bill to which the USDA is instructed to communicate research priorities and goals; (3) each agency or office of the USDA; (4) the managed pollinator industry; and (5) relevant grant recipients under programs administered by the Secretary of Agriculture. Another target audience for this report are potential grant recipients, 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

The 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 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); Logan, Utah (non-*Apis* bees); Stoneville, Mississippi (environmental stressors); and Davis, California (longitudinal studies and stressors). Additional research occurs across the country in other laboratories, including at Land-Grant institutions.

USDA, Economic Research Service (ERS) performs 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, the 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. APHIS also implements the National Honey Bee Pests and Diseases Survey.

USDA, Farm Production and Conservation Business Center (FPAC) is a focal office in understanding both the costs and benefits of pollinator habitat conservation as well as in understanding incentives that drive optimal behavior of growers, ranchers, and other agricultural land conservationists.

USDA, Farm Service Agency (FSA) administers the Conservation Program (CP) and Conservation Reserve Enhancement Program (CREP). Both are voluntary Federal programs with initiatives designed to encourage agricultural producers and landowners to undertake conservation practices on agricultural lands aiming to establish pollinator habitat. Although many conservation practices can improve pollinator habitat, Conservation Practice 42 (CP-42) specifically aims to establish native vegetation and non-native legumes to enhance pollinator habitat. FSA also 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. FSA also offers other loan opportunities that can be pursued by beekeepers, such as the Farm Loan Program.

USDA, Risk Management Agency (RMA) serves beekeepers through effective, market-based risk management tools to strengthen the economic stability of agricultural producers and rural communities, most notably the Apiculture Rainfall Index - Apiculture Pilot Insurance Program (RI-API), which provides a safety net for beekeepers' primary income sources (*i.e.*, honey, pollen collection, wax, and breeding stock). Beekeepers can purchase RI-API through a crop insurance agent that works for an approved insurance provider.

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. NRCS administers the PLANTS database, which acts as a data repository for standardized plant names, symbols, taxonomic concepts, and attributes essential in the collection, processing, storage, integration, exchange, and retrieval of resource information including plant-pollinator interactions.

USDA, Forest Service (USFS) conducts studies on the role of pollinators in forest and agricultural ecosystems. USFS is synthesizing science and establishing guidelines for supporting pollinators through agroforestry. This work includes research on pollinator agroforestry and land management Best Management Practices (BMPs), 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 NASS on data collections to better understand pollinator BMPs.

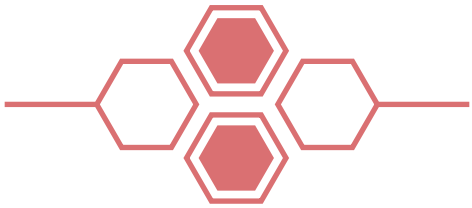
USDA, Agricultural Marketing Service (AMS) conducts a monthly National Honey Report, which collects prices paid of extracted and unprocessed honey, price by honey type, primary nectar source visited, and estimates the export and import of honey with major trading partners.

USDA, Office of Energy and Environmental Policy (OEEP) coordinates Departmental policy analysis, planning, and response strategies related to climate change and guides efforts to integrate climate adaptation into the Department's policies, programs, and operations. Departmental Regulation 1070-001 directs OEEP to prepare guidance and support for USDA Mission Areas, agencies, and staff offices in preparing and implementing climate adaptation plans that address the vulnerabilities that climate change poses to their missions. OEEP works to build linkages between these efforts and those of the Office of the Chief Scientist to assess and address the impacts of climate change on pollinators.

USDA would also like to extend a special thanks to:

The Environmental Protection Agency (EPA), Office of Chemical Safety and Pollution Prevention (OCSPP) which implements pesticide regulations regarding the manufacture and use of pesticides (e.g., insecticides, herbicides, fungicides, disinfectants, and biological products) in Indian country and provides Tribes expertise, training and opportunities for partnerships when pesticide issues affect Indian country. EPA partners with the Tribal Pesticide Program Council (TPPC) which is comprised of over 30 Tribes. The TPPC is a network of Tribal representatives and intertribal consortia that serve as a Tribal technical resource, program development and policy dialogue group focused on pesticide issues

and concerns. The EPA Office of Chemical Safety and Pollution Prevention and the TPPC formed a workgroup to address pollinator protection, and one of the workgroup's goals is to collaborate with USDA to provide input to this report on pollinator research priorities from the Tribal perspective.



II. 2022 USDA Pollinator Priorities

Overview

The following is an overview of the 2022 USDA pollinator priority initiatives. 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.

Many of these priorities are similar if not identical to priorities established in 2021. This year's report also includes a new section on equity and inclusivity, as USDA strives to promote the voices and needs of diverse, marginalized, and disenfranchised communities in our pollinator research and programmatic activities. A significant focus this year was placed on feedback from the Tribal Pesticide Program Council (TPPC). USDA continues to build out its relationships with diverse communities in garnering feedback on pollinator priorities, which will be reflected in forthcoming reports. Feedback from the TPPC is provided throughout this document as well as in the **Equity and Inclusivity** Section.

Five overarching themes were 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:

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

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

Summary of Priorities

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

Status and Trends

Identify factors associated with biological changes, such as the survival, growth, and reproduction of **managed** and **wild pollinators**.

1. Identify factors affecting bee managers' revenue and cost, including changes in honey yields, pollination services, and other products (*e.g.*, wax, queens, nucleus colonies) of **commercial pollinators.**

2. Assess the economics of various pollinator management strategies in enhancing yields and other benefits, such as the benefits of augmented pollination.

3. Evaluate the utility of existing and new technologies and develop strategies to improve the collection and curation of data used in assessing pollinator population baselines and trends.

Forage, Habitat, and Nutrition

1. Identify and address spatiotemporal gaps in forage, habitat, and nutrition and their relation to the health and sustainability of **managed** and **wild** pollinators.

2. Develop optimal planting choices, management, and monitoring actions for forage and habitat in agricultural lands, rangelands, Federal forests, and other **working lands** to support **pollinator health**.

3. Determine returns-on-investment from forage and habitat that benefits pollinators within agricultural lands, rangelands, Federal forests, and other **working lands**.

4. Increase the understanding of the nutritional needs of pollinators throughout their **life cycles** to ensure **sustainable** populations.

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**.

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

3. Generate improved approaches to understand the impact of environmental stressors on pollinators, especially but not limited to approaches that utilize multivariate, geospatial, longitudinal, machine learning methods, sensors, and real-time monitoring.

4. Improve the understanding of the impacts of temperature and climate and their interactions with other stressors on pollinators and the ecosystem services they provide.

Pests and Pathogens

1. Develop and implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (*i.e.*, outbreaks and epidemics).

2. Improve knowledge of pest and pathogen biology, behavior, transmission, genetics, spillovers, their interactions, as well as their impacts (*e.g.*, pathogenicity).

3. Identify mechanisms, including improved government communication and coordination, that 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 and technologies, including diagnostics.

Genetics, Breeding, and Biology

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

2. Evaluate, improve, and maintain effective pollinator breeding practices to improve **genetic diversity** and maintain traits.

3. Address knowledge gaps in pollination biology that may affect agricultural production and ecosystem services.

4. Evaluate pollinator species contributions in crops and other **working lands** to further understand the requirements of these species, including their habitat needs.

Priorities by Subject-Matter Area

i. Status and Trends

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

1. Identify factors associated with biological changes, such as the survival, growth, and reproduction of managed and wild 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 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. This represents a critical step toward assessing biological changes and understanding the impacts from multiple stressors.
- Better characterize the impacts of the decline of pollinators on crop pollination.

2. Assess the economics of various pollinator management strategies in enhancing yields and other benefits, such as the benefits of augmented pollination.

- 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 be further 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. Identify factors affecting bee managers' revenue and cost, including changes in honey yields, pollination services, and other products (*e.g.*, wax, queens, nucleus colonies) of commercial pollinators.

- Commercial beekeepers are facing economic challenges from the declining profitability of hive products (*e.g.*, honey, wax, propolis).
- 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 pollen and nectar nutrition offered by some crops and the impact of bordering habitat on **pollinator health**, including the potential benefit

from increased establishment of bee habitat.

- Long-term impacts from bee habitat expansion, including research to inform USDA land programs.
- Economic analyses to assess beekeeper transitions away from honey production to crop pollination, including revenue tradeoffs.
- Economic impacts from honey adulteration, imports, and consumer preferences.
- Improved communications and knowledge among beekeepers, crop producers, and the public, especially regarding the economic difficulties each entity faces.

TPPC Feedback:

- These types of efforts typically involve surveys. Ensuring that the Tribal Pesticide Program Council, Tribal Science Council, National Tribal Caucus, and other key Tribal groups are consulted ahead of survey implementation could allow opportunities to incorporate indigenous insights on wild **pollinators** and flora.

4. Evaluate the utility of existing and new technologies and develop strategies to improve the collection and curation of data used in assessing pollinator population baselines and trends.

- Generally, this includes efforts such as improved species identification technologies and access to such technologies, establishing and cross-referencing databases, augmenting collections, monitoring crop visitations and landscape use, and scientifically robust sampling methodologies.
- 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.
- To assist with these types of questions, USDA is co-chairing a Federal Native Bee Monitoring Task Force to support the development of a plan to implement national-scale monitoring methods.

Example Projects:

- In general, types of projects could include but are not limited to improved species identification technologies and access to such technologies, establishing and

cross-referencing databases, augmenting collections, monitoring crop visitations and landscape use, and identifying scientifically robust sampling methodologies.

- Further utilization of automated **artificial intelligence (AI)** and visual identification to track flower visitation.
- Creating AI systems to support 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 geospatial registries and other technologies for monitoring the location and/or movement of bees.
- Increase taxonomic capacity, 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.

ii. Forage, Habitat, and Nutrition

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

1. Identify and address spatiotemporal gaps in forage, habitat, and nutrition and their relation to the health and sustainability of managed and wild pollinators.

- 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**. Attention should be given to building the resilience of local ecosystems and determining ecoregionally appropriate pollinator forage resources.
- 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).
- Connectivity of forage resources for various pollinator species vary, with disparate (fragmented) habitat occurring across the landscape. Explore opportunities to aggregate spatial units of pollinator habitat across governmental programs and entities to create connected pollinator pathways. Research is needed to support pathway parameters and design.

Example Projects:

- Development of mechanisms for collaboration at varying scales that would allow for holistic, strategic coordination across individual forage, habitat, and nutritional initiatives in evaluating opportunities on both private and public lands.
- 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/production of highly specialized and in some cases costly seed/plants among commercial seed distributors and plant nurseries. Improved, easily replicable plant procurement mechanisms and partnerships could alleviate costs for land managers.
- A review of Federal crop seed laws and how these impact native seed production is needed.
- Research to be considering variations in forage, habitat, and nutrition gaps from year to year, as even for the same species its value to **pollinator health** can vary annually and/or over time.

TPPC Feedback:

- The relationship between crop management and forage, habitat, and nutrition needs to be better understood, both in terms of its effects on both wild **pollinators** and honeybee populations. The loss of native plants or flora is an impact to Tribes' cultural integrity (losing a plant that is used for sustenance, healing, ceremonies) that has ripple effects to the loss of a pollinator, knowledge, care, habitat, and cultural history. Losing the knowledge of how to care for that plant impacts how that knowledge transfers to the next generation of the community. It is also tied to language and how Native Americans maintain their relationship with the natural world.
- Research is needed to better understand habitat potential for ground-nesting

pollinators in agricultural areas and how it can be enhanced.

- The cultural importance of ensuring sufficient forage, habitat, and nutrition for pollinators must also be considered, along with exploring ways to improve our co-existence and to discover and promote regionally appropriate Best Management Practices (BMPs).
- There is also cultural importance in using pollinators as a food source.

2. Develop optimal planting choices, management, and monitoring actions for forage and habitat in agricultural lands, rangelands, Federal forests, and other working lands to support pollinator health.

- Identifying the multiple factors influencing optimization of pollinator forage and habitat in agricultural landscapes and other types of landscapes that pertain to USDA's mission areas.
- Examples of variables that should be accounted for in determining optimum plant characteristics include but are not limited to plant attractiveness to pollinators as noted by their observed used; bloom period; foraging behavior and flower preferences; nutritional value of pollen and nectar; planting size, configuration, and habitat connectivity; plant parameters (*e.g.*, growth habit, longevity, soils and water requirements); ecosystem and location; long-term maintenance needs; long-term plant resilience against weather/climate variability; existing pollinator habitat conditions; overlapping pollinator forage needs, and what is ideal for beekeepers, land managers, and invasive species managers.
- A centralized data infrastructure is needed to track these types of information on a plant-species basis. Centralized tracking of landscape-level considerations, such as soil conditions, soil properties, and the known presence of noxious/invasive plants is also imperative. Ideally, these plant species-specific and landscape-specific data infrastructures would be interconnected.

Example Projects:

- Development of a framework for multiple optimal forage/habitat solutions, articulating specific goals and how they are weighted.
- Development of optimal plant matrices and plant guides applicable to differing cropping systems, information should include data on potential increase of crop yields.
- 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, and identify bridging opportunities between private and public lands.
- 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.
- Long-term, longitudinal efforts that determine effectiveness, utilizing adaptive management strategies.

TPPC Feedback:

- Different plantings, including companion planting, cover-cropping, staggered planting, and regenerative permaculture methods to support **pollinator health** are current practices and are equally important to TPPC.
- Example projects exploring optimal plantings should consider livestock grazing times, grazing species, grazing patterns, and the movement of livestock, and how to stack benefits from plantings to offer supplemental feeding to livestock due to overgrazing.
- Optimal seed mixes should be biodiverse in nature, but endemic to the area, to ensure long-term resilience and nutritional benefits to pollinators.

3. Determine returns-on-investment from forage and habitat that benefit pollinators within agricultural lands, rangelands, Federal forests, and other working lands.

- To date, research on the return-on-investment from forage and habitat in terms of improving pollinator health has been an understudied area.
- Additionally, research is needed to better understand the volatility of seed markets and to determine procurement mechanisms that would aid in stabilizing seed markets.
- Environmental and ecological functional returns should be measured such as soil health, organic soil measurements, and water infiltration and retention within the soil.
- Methods exist that could be utilized to improve measurements of non-market benefits of pollinator forage and habitat establishment and the dynamic nature of these returns.
- Pollinator landscapes for which returns-on-investment could be measured can vary. For example, landscapes around crops or even in-field crop varieties/cropping systems

that offer forage/habitat are both possible sources of benefits.

- Benefits need to not only be weighed against the cost of establishment and maintenance, but also against potential risks, such as unintended attraction of crop pests and incompatible pest management needs.
- Delineations between the difference in returns-on-investment should be established for current pollinator landscapes versus new forage and habitat installations.

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.
- Nationwide research to understand the commercial supply of pollinator seed and plant species and how it coincides with the forage needs of specific pollinator species at a regional level.
- 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.

4. Increase the understanding of the nutritional needs of pollinators throughout their life cycles to ensure sustainable populations.

- Here, **life cycle** refers to both cycles within the organism's life (*e.g.*, aging, reproduction) and cycles in terms of the entire colony, for applicable species, where life cycle effects can persist over many years.
- 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.
- Need for additional research exploring correlations between forage nutrition and measurable aspects of **pollinator health** (e.g., body size, colony growth, immune response, overwintering).

- 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.
- Climatic impacts, which are categorized for the purposes of this report as an environmental stressor, must also be understood in terms of the impacts on the nutritional value of forage for pollinators.

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 standard methods for nutritional research and nutrient analysis so comparisons can be made between findings from different studies.
- Impacts on the nutritional value and forage availability from variable weather and temperature fluctuations, and intense landscape changes such as forest fires, floods, and invasive weeds.

iii. 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 aims to ensure that researchers are aware of study design elements, measurement endpoints of regulatory interest, uncertainties, and ultimately, research 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; developing and promoting new approach methodologies representing more effective high-throughput screening tools that are less dependent on whole animal testing).

- Investing in training is essential for the education of interested parties in findings and other conclusions.

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.

TPPC Feedback:

- TPPC is interested in addressing possible uncertainties related to pesticides and **pollinator health**, especially as it pertains to diverse and endemic pollinator species survival and especially those species that are endangered. There are currently 18 endangered pollinator species and 9 critically endangered pollinator species, globally.
- Serious consideration should be given to pesticide use, especially neonicotinoid use, and insect growth regulators (IGRs) use on Tribal lands and requests that additional safety measures be established for these products to protect **pollinator health**.
- TPPC requests that research be directed towards better understanding how ground-nesting bees are impacted by pesticides that persist in the soil, and in cases of systemic pesticides for trees and seeds, how this may persist in pollen and nectar, and also in home lawn and garden use, and natural, rural, and urban settings. Similar questions exist for alfalfa hay that is treated with neonicotinoids, and how this may impact the health of pollinators, such as Alkali bees, that pollinate alfalfa grown for seed.
- More in-depth training opportunities on pollinators and **pollinator health** would be appreciated by TPPC members, especially trainings to communicate comprehensive evaluations of possible impacts of pesticides on wild pollinators. Opportunities for discussion and efforts to broaden narratives would be well invested for creating initiatives that better support pollinators and their health.

2. Identify and enhance Integrated Pest Management (IPM) options and Best Management Practices (BMPs) toward mitigating the impacts of environmental stressors 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.
- Additional efforts are needed, such as utilizing existing survey tools, to understand the value of BMPs, as assessment of such measures can be difficult when implementation is on private lands.
- Identify and leverage success stories, especially those developed by stakeholders, to determine effective, practical strategies.

Example Projects:

- Determining the efficacy of various IPM/BMP measures in terms of improved **pollinator health** and translating this science into practice to engage stakeholders.
- Measuring how changes in grower/applicator/beekeeper behavior promote 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/applicators and beekeepers.
- Determination of how to optimize the number of available IPM/BMP options while pursuing widespread implementation, allowing for practical flexibility to meet 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.

TPPC Feedback:

- These types of efforts typically involve surveys. Ensuring that the TPPC, Tribal Science Council, National Tribal Caucus, and other key Tribal groups are consulted and collaborated with ahead of survey implementation could allow opportunities to incorporate indigenous insights and build capacity with Tribes on native pollinators

and flora. Data sovereignty needs to be considered and data and results are shared with participating Tribes.

3. Generate improved approaches to understand the impact of environmental stressors on pollinators, especially but not limited to approaches that utilize multivariate, geospatial, longitudinal, machine learning methods, sensors, and real-time monitoring.

- Data indicate that **pollinator health** is influenced by multiple interacting factors. Although efforts are continuing to collect large volumes of data on individual aspects, there is a critical need to develop predictive tools that integrate these data at varying scales of biological organization.
- The development of accurate, predictive models that shed light on underlying relationships between various aspects could lead to efficiencies in research, such as reduced testing and investments.
- A notable challenge is the level of variability associated with any multivariate analysis particularly as temporal and spatial scales expand.
- Needs exist for a variety of different types of models, such as mathematical, predictive, landscape, population, developmental, behavioral, and real-time modeling.
- New approaches in 3-D modeling and printing are also of interest, such as in developing research apparatuses that are not commercially available, which can help in answering unique needs and questions to support pollinator research.

Example Projects:

- Development of better landcover 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 and their interactions with other stressors on pollinators and the ecosystem services they provide.

- 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.

- Multi-generational effects from stressors on **pollinator health** are important to understand.

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, and 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 distinguishing 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.
- Development of plans to ensure adequate nutrition is available to pollinators in differing agricultural landscapes for scenarios where phenological mismatches between pollinators and available forage becomes too pronounced.

TPPC Feedback:

- Inclusion of diverse communities, such as Tribes and nations, in conversations around short-term and long-term impactful effects, such as weather extremes, heat stress, drought stress, and elevational reliance, on pollinator species is needed and could help to support a **sustainable** situation for agriculture, rangelands, and forestry.
- TPPC recognizes that climate changes will have significant impacts to pollinator systems. Research to support proactive assessments of strategies to combat these effects, such as through collecting longitudinal data, could help in modeling efforts and strategizing priorities. Priorities must have a focus on feasible and actionable implementation.

iv. Pests and Pathogens

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

1. Develop and implement standardized, representative nationwide monitoring and analyses of pollinator pests/pathogens and epizootics (*i.e.*, outbreaks and epidemics).

- The feasibility and utility of this initiative hinges on support and investments into the processing of collected samples and the detection of pests/pathogens as well as on the development of standardized data documentation and reporting methods.

- The need for a national data infrastructure to promote data sharing 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 monitoring established pests/pathogens.

Example Projects:

- Expansion of detection and monitoring efforts in establishing nationwide methodologies (*e.g.*, Animal and Plant Health Inspection Service (APHIS) National Honey Bee Survey) for honey bee pests and pathogens.
- Expansion of non-*Apis* species standardized monitoring to account for non-*Apis* pests and pathogens nationwide (*e.g.*, 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 crop 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.

TPPC Feedback:

- These types of efforts typically involve surveys. Ensuring that the TPPC, Tribal Science Council, National Tribal Caucus, and other key Tribal groups are consulted and collaborated with ahead of survey implementation could allow opportunities to incorporate indigenous insights and build capacity with Tribes on native pollinators and flora. Data sovereignty needs to be considered and data and results are shared with participating Tribes.

2. Improve knowledge of pest and pathogen biology, behavior, transmission, genetics, spillovers, their interactions, as well as their impacts (*e.g.*, pathogenicity).

- Need for studies to better understand the basic biology of pollinator pests and pathogens and how they ultimately impact **pollinator health**.
- Understanding interactions between pathogens, pests, and their hosts, and how specific pathogens interact.
- Explore correlative and multivariate initiatives to address uncertainties regarding

interactions between pests/pathogens and other stressors. Development of accurate holistic experimental designs and models is 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 and the gut microbiome.
- Physiological compatibility of host and pathogen 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 **wild 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.

TPPC Feedback:

- The interactions between honey bees and native bees need to be well understood.

3. Identify mechanisms, including improved government communication and coordination, that 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 methods could assist in early emerging pest/pathogen spread.
- There is a need to account for factors (e.g., biotic and abiotic stressors) that drive emerging pests/pathogen pressure and how they vary regionally.

Example Projects:

- Create a national database for rapid communication of emerging pest and pathogen

detection to allow for effective, quick response.

- Identify key agencies/organizations within States and Tribes 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 (*e.g.*, port responses) allowing for more proactive responses.
- Development of a synthetic pheromone used by Asian giant hornet (*Vespa 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 drosophilid (*Cacoxenus indagator*), *Apis cerana*, *Apis capensis*, *Tropilaelaps* spp., and potentially *Apis florea*.

4. Enhance and create new pollinator pest and pathogen management tools and technologies, including diagnostics.

- 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 product 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.
- Increase opportunities for researcher education 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 those 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.
- Improve beekeeper education of proper/reliable information sources that both promote safe, effective, and legal pest management interventions and methods, and prevent the development of pesticide resistance.
- Need for better BMPs to reduce disease transmission through proper equipment treatment and colony disposal.

v. 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 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."
- USDA's ARS is currently sequencing 100 bee genomes for both *Apis* and non-*Apis bees*, which is of critical value to supporting forthcoming advancements in genetic and breeding initiatives.
- 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 **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, improve, and maintain effective pollinator breeding practices to improve genetic diversity and maintain traits.

- 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.

TPPC Feedback:

- Efforts to support sustainable bee breeding programs and projects should include the establishment and promotion on locally adapted and acclimated strains to curb pest/pathogen spread and through processes of biomimicry for rearing that are respectful of the natural calendar and cycles.

3. Address knowledge gaps in pollination biology that may affect agricultural production and ecosystem services.

- 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).

TPPC Feedback:

- Additional efforts are needed for research, compilation, and outreach is needed for the pollination biology of wild **pollinators** as resources for Tribal nations.

4. Evaluate pollinator species contributions in crops and other working lands to 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.
- 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.

TPPC Feedback:

- This is a very high priority for Tribal partners to ensure critical decisions are being made with an understanding of the essential keystone connections.
- The role of and impacts to native pollinators needs much more research and collaboration. It is noted that for some crops, native pollinators may be significantly more productive/efficient than honey bees.
- It is suggested that research investments be made to clearly define and promote which pollinators are best suited for which crop types.

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: Evaluate the utility of existing and new technologies and develop strategies to improve the collection and curation of data used in assessing pollinator population baselines and trends.
- 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 implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (*i.e.*, outbreaks and epidemics).

- Genetics Breeding and Biology Priority 1: Evaluate, document, and coordinate genetic and breeding initiatives to improve the health of pollinators.

Rather than approaching these initiatives as separate efforts, coordination and streamlined repository/data curation systems could satisfy the needs across these four 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 are highly complementary and could result in exponential returns on investment. The following initiatives specifically cite this need:

- Forage, Habitat, and Nutrition Priority 1: Identify and address spatiotemporal gaps in forage, habitat, and nutrition and their relation to the health and sustainability of **managed** and **wild pollinators.**
- Environmental Stressors Priority 3: Generate improved approaches to understand the impact of environmental stressors on pollinators, especially but not limited to approaches that utilize multivariate, geospatial, longitudinal, machine learning methods, sensors, and real-time monitoring.
- Pests and Pathogens Priority 1: Develop and implement standardized, representative nationwide monitoring and analyses of pests/pathogens and epizootics (*i.e.*, outbreaks and epidemics).

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 IPM and BMP options toward mitigating the impacts of environmental stressors on pollinators and promoting increased stakeholder communication, collaboration, and broader adoption of such measures.
- Pests and Pathogens Priority 3: Identify mechanisms, including improved government communication and coordination, that 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 and technologies, including diagnostics.
- Forage, Habitat, and Nutrition Priority 2: Develop optimal planting choices, management, and monitoring actions for forage and habitat in agricultural lands, rangelands, Federal forests, and other **working lands** to support pollinator health.

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 BMP 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: Identify factors affecting bee managers' revenue and cost, including changes in honey yields, pollination services, and other hive products (*e.g.*, wax, queens, nucleus colonies) of **commercial pollinators**.
- Status and Trends Priority 3: Assess the economics of various pollinator management strategies in enhancing yields and other benefits, such as the benefits of augmented pollination.
- Forage, Habitat, and Nutrition Priority 3: Determine returns-on-investment from forage and habitat that benefits pollinators within agricultural lands, rangelands, Federal forests, and other **working lands**.
- Forage, Habitat, and Nutrition Priority 2: Develop optimal planting choices,

management, and monitoring actions for forage and habitat in agricultural lands, rangelands, Federal forests, and other working lands to support pollinator health.

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-benefit 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 changes, such as the survival, growth, and reproduction of **managed** and **wild pollinators.**
- Forage, Habitat, and Nutrition Priority 4: Increase the understanding of the nutritional needs of pollinators throughout their **life cycles** to ensure **sustainable** populations.
- Pests and Pathogens Priority 2: Improve knowledge of pest and pathogen biology, behavior, transmission, genetics, spillovers, their interactions, as well as their impacts (*e.g.*, pathogenicity).
- Genetics, Breeding, and Biology Priority 3: Address knowledge gaps in pollination biology that may affect agricultural production and **ecosystem services**.

III. Equity and Inclusion

As outlined by USDA Secretary Tom Vilsack in January 2022, USDA stands committed to ensuring that equity and inclusivity is promoted in USDA decision-making and policymaking. Among these charges includes a "renewed commitment to tribal nations, investing in Historically Black Colleges and Universities, and strengthening commitments to Hispanic-Serving Institutions."

Within USDA's portfolio of pollinator programs and research initiatives, new efforts are underway to ensure that a diverse set of voices are heard and amplified, including but not limited to tribes and nations, small commercial bee managers, low-income and rural communities, communities facing environmental justice issues, and institutions such as Tribal, Hispanic, and Historically Black Colleges and Universities. By accounting for these communities, USDA hopes to develop a more well-rounded **pollinator health** program by addressing research and programmatic inputs across a holistic set of needs, including needs of cultural significance.

USDA has begun taking proactive actions to begin addressing existing needs, starting with dedicated invitations to USDA-grant recipients from Tribal, Hispanic, and Historically Black College and University to the 2021 USDA/EPA Annual Pollinator State of the Science meeting. EPA has been an exemplar partner in these initiatives and has assisted USDA in hosting dedicated conservations with members of their Tribal Pesticide Program Council (TPPC), which is comprised of over 30 tribes, that has a deep understanding of priorities associated with **pollinator health** and an established Pollinator Protection Workgroup.

Secondly, USDA in partnership with EPA has begun the initial steps of garnering feedback from federal employees and from diverse communities, such as tribes and nations (*i.e.*, the TPPC). The purpose of these communications is to ensure community needs and desired outcomes are understood prior to implementing potential solutions in the context of USDA pollinator priorities. USDA seeks to continue this outreach with the long-term goal of capturing meaningful feedback from a variety of diverse communities.

USDA Federal Employee Feedback

In 2022, USDA began exploring the perspectives of internal Federal employees regarding baseline activities and needs that would help to amplify equity and inclusion in our pollinator research and programmatic activities. Questions and responses from USDA employees that represent our **pollinator health** expertise are outlined below:

Question 1: Do you or others you've worked with have projects, connections, or knowledge of pollinator-centric efforts in diverse communities?

USDA received a wide range of responses from its employees regarding its past or current work in diverse communities. Examples that were shared of this type of engagement included:

- NRCS' dedicated programs for urban, Tribal, and historically underserved programs and initiatives, alongside dedicated funding, favorable payment rates, and outreach and education.
- Investigators on grants, such as the National Science Foundation's (NSF) Science, Technology, Engineering and Mathematics-Course Undergraduate Research Experiences (STEM-CURE), which "promotes increased interest in STEM disciplines, especially among students from underrepresented groups, increase the recruitment and retention of students in introductory STEM courses, increase the number of students from two-year HSIs who transfer into STEM degree programs at 4-year institutions, and establish cross-sector partnerships with industry to improve workforce readiness and promote interest in STEM careers" in Hispanic-serving institutions.
- Outreach to target diverse communities by the Electric Power Research Institute (EPRI) as part of their Power to the Pollinators Initiative.
- Direct work with diverse communities via USDA ARS research programs, including Native American and Hispanic beekeepers and commercial growers that utilize pollinators.
- Summer programming via USDA ARS to work with Native American institutes to teach high school student about honey bees, population dynamics and math. USDA ARS converted their highly utilized honey bee colony population dynamics model into a teaching tool for this program. Several of the students went on to become summer interns in the USDA ARS lab.
- Award-winning USDA Forest Service engagement with urban pollinator gardening projects and exhibits, including in underserved urban areas.

USDA employees have also noted important work being conducted by outside groups, such as:

- Dr. Margarita Lopez-Uribe's (Pennsylvania State University) efforts to translate her laboratory beekeeping content to Spanish and dedicated efforts to make connections with Hispanic growers. Dr. Lopez-Uribe also works with Amish and Mennonite communities.

Question 2: From your perspective, in what ways can the 2022 priorities developed by your respective Mastermind Group(s) be aligned to also address community needs and to promote synergies?

Federal employees were also asked how our 2022 priorities also address community needs and promote synergies. Although certain alignments could be made, the need to better understand various communities' needs is necessary before addressing how these needs align with our pollinator priorities.

In summary, USDA employees identified that:

- Across all priority areas, the need exists for an assessment of diverse community access to **pollinator health** and conservation opportunities and education.
- Determine ways in which diverse community's traditional ecological knowledge (TEK) of pollinators can be understood and incorporated into research that communities identify as a need for them.
- A need to determine ways to better integrate diverse community knowledges in scientific and data aspects of pollinator health, to promote engagement, inclusion, and holistic feedback throughout the process of analysis and interpretation.
- For all priority areas that involve communication, these should be emphasized as key areas where outreach to diverse communities can be synergized.
- Educational institutes, such as colleges and high schools of diverse communities, would be an ideal venue to promote scientific education to support pollinator health. For example, a current USDA program is focused on honey bee microbes wherein students at Hispanic-serving institutions learn foundational principles of bees, microbes, and laboratory procedures including DNA extraction, qPCR and sequence analysis, with one goal of the program being for students to transition to independent research projects under the guidance of the USDA.
- Small-scale beekeepers, who tend to operate locally, may be disproportionally impacted by stressors, such as climate, land use change, *etc.*, in comparison to large-scale commercial beekeepers that have multiple apiaries over larger geographical expanses that are diverse in nature. The same may also hold for communities, such as pueblos and missions, that operate within delimited areas.

Question 3: From your perspective, what are the community challenges, program barriers, and resource limitations that we need to consider in order to expand our partnerships? From your perspective, what resource needs and outcomes may be associated with these opportunities?

USDA employees identified several potential challenges, barriers, and resource limitations that must be addressed to successfully expand our partnerships with diverse communities, including:

- Ensuring diverse communities are aware of opportunities and have access to relevant and useful information.
- Reviewing programs, applications, and requirements to ensure they are not overly complicated or intimidating, and that adequate resources are available for assistance and support.
- Long periods of time between applying for funding and actually being funded for projects; inconsistent timing of applications.
- No assurances in long-term funding availability, with challenges associated with maintaining funded projects and long-term support from communities.
- Programs and requirements are often intimidating and complicated, and it can take significant time to receive funding.
- Increase the scope of USDA pollinator research beyond basic science to better include social science and outreach efforts.
- Increased number of opportunities available to diverse communities.
- Encourage USDA researchers and program offices to prioritize research and programs that partner with diverse communities, especially those that may support science education within the community.
- Need to determine dedicated funding sources to support **pollinator health** and education especially in communities that are facing economic struggles and identify and communicate demonstrable benefits.
- Need to improve "train-the-trainer" programs in which trainers can learn directly from members of their community.

Question 4. From your perspective, what resource needs and outcomes may be associated with these opportunities?

- Upfront investments in holistic, meaningful feedback outlets from diverse communities regarding their culture and how that intersects with their desired opportunities and needs that may support **pollinator health**.
- Resources to work with partners who have long-standing, successful relationships with diverse communities that the USDA seeks to serve.
- Dedicated staff and liaisons to collaborate with community members, with the time and resources to have meaningful interactions with smaller groups within the community. A preference for staff and liaison recruitment should be from diverse communities and institutions.
- Resources to ensure programs and opportunities are accessible and accepted by communities.
- Resources to ensure strong partnerships with research and program agencies.
- Resources for youth education that have tailored educational needs and promote desired outcomes, as determined by the community. Ensuring that youth education is not a one-off opportunity but rather an ongoing exchange that could lead to scholarships and independent research funding.
- Revisiting USDA job descriptions and performance reviews to be specific in what types of outreaches with diverse communities and to ensure collaboration on USDA-supported research and initiatives is needed and expected.
- Community-led identification of what land resources are available for establishing forage and habitat and understanding what type of optimal conservation management would be most meaningful to the community.

Cultural Importance of Pollinators and Their Products

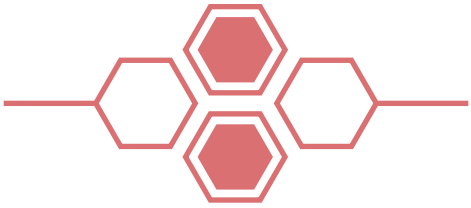
As noted, beginning with this 2022 Report, USDA is making a concerted effort to account for the pollinator research priorities of diverse communities. Each year, USDA will select a different diverse community to consult with, while continuing to garner feedback from communities with which consultations have already begun. A focus on Tribal perspectives was chosen to launch this effort.

Of the 574 Federally recognized Tribes, many have long standing relationships with pollinators that work toward long-term conservation of wild pollinators. This doesn't account for the over 200 Tribes that are not Federally recognized who have similar relationships.

For Tribal communities, in addition to the $4 billion and $5.9 billion directly and indirectly attributed to various crops, native or wild pollinators represent continuity in cultural, historic, ecological, and scientific value that make up their heritage and provide food security. There is a land ethic on which a monetary value cannot be placed and various relationships that are important for sustainability, such as water systems, soil health, biodiversity, and pollinator health and value continues to build from the interconnectivity of these factors that are very important to Tribal communities. Pollinators are needed for reproduction of plants of cultural importance to Native American Tribes, such as the continued supply of pollen for ceremonies, including food and wellness uses.

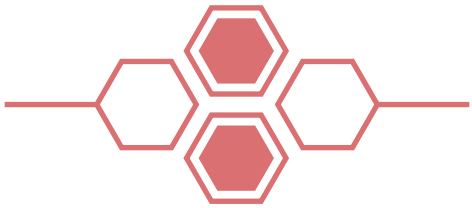
TPPC Feedback

For the 2022 Priority Report at hand, a focus was placed on feedback from Tribes and nations. TPPC has a long and deep understanding of pollinator issues, both from a cultural context but also through the lens of potential environmental stressors.



IV. Final Thoughts

Pollinator health is a multi-faceted issue. The effort at hand is a presentation of the collective viewpoints of Federal pollinator experts and a diverse community of stakeholders. The USDA greatly appreciates the internal Federal workforce and external stakeholders that provided their input to this process, including both the USDA and non-USDA Federal agencies, the Tribal Pesticide Program Council, State government, the **managed pollinator** industry, researchers, and other pollinator partners. This initiative represents a synthesis of diverse stakeholder perspectives on **pollinator health** needs that is responsive to the 2018 Farm Bill. 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.



V. 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".

*Additional, non-legislative discussions regarding these research charges and USDA efforts to support **pollinator health** are in the 2018 Farm Bill Conference Report, Section 7209, High-Priority Research and Extension Initiatives.*

Appendix B. Common Terms and Definitions

The following are commonly used terms within this document. Note that the definitions for these terms can vary depending on context. They are also specific to USDA's perspective as a funder and implementer of research and programmatic pollinator initiatives. Some of these terms may have broader or more narrow meanings when applied the framework of USDA.

Artificial intelligence (AI): "the ability of a computer or a robot controlled by a computer to do tasks that are usually done by humans because they require human intelligence and discernment."[1]

Colony Health: The overall well-being at the colony level. In the case of bees, this differs from **individual health** (see below), which is limited to considering the health of individuals that may make up a colony. Colony health can be equated to the health of the superorganism, *i.e.*, the collective health of all individuals that work together in social agreement.

1 https://www.britannica.com/technology/artificial-intelligence

Commercial Pollinators: Commercial pollinators are those that are commercially available for crop pollination purposes. This differs from **managed pollinators**, see below, which may or may not be used for commercial purposes.

Crops (Contract versus Non-Contract): In crop production, crops that utilize commercial pollinators are considered contract crops, versus non-contract crops which *may* still rely on non-commercial **managed** or **wild pollinators**, but no financial transaction takes place. Contract crops are those requiring contract pollination.

Ecosystem services: The collective benefits provided by various ecological functions that benefit humans. Pollination is a critical ecosystem service supplied by pollinators.

Emerging Issues: For the purposes of this report, emerging issues are both biotic and abiotic stressors that can impact **pollinator health**.

Genetic Bottleneck: Circumstances in which the diversity of genetic variation within a species' population is reduced, which can ultimately risk reduced fitness of a species.

Genetic Diversity: The measure of gene diversity within a species. Higher genetic diversity is a primary driver of the long-term ability of a species to adapt to biotic and abiotic stressors.

Individual Health: The overall well-being of an individual species member, which may or may not be part of a larger colony (see **Colony Health**).

Life Cycle: The stages of life that a creature undergoes throughout its life. In the case of bees, there are four life cycle phases: egg, larva, pupa, and adult. The time it takes for a bee to transition throughout these bases is variable both across bee species and across bee cases of the same species. Variations in life cycle phases can be highly influenced by external factors which can impact both individuals and **colony health**, in the case of social bees.

Managed Pollinators: Managed pollinators encompasses both pollinators that are utilized for commercial purposes and those that are intentionally utilized for pollination services on agricultural lands. Wild bees that visit agricultural lands by happenstance are not considered managed pollinators.

Native Pollinators: Pollinators that are endemic to a particular area or region. For the purposes of this report, native species are those whose origins are at least partially located with the borders of the United States. A common taxonomic authority for defining the origin of species in the United States is the Integrated Taxonomic Information System.

Pollinator Health: Pollinator health can be a difficult term to define, as it is multi-faceted in nature. For the purposes of this report, USDA relies on the definition of pollinator health as described by López-Uribe et al. (2020), that is, "a state that allows individuals to live longer and/or reproduce more, even in the presence of pathogens, thus providing more ecological

services. Therefore, pollinator health should be assessed as a comprehensive multilevel measure of the vigor, resilience, and ecological functionality of pollinating species."

Pollination Performance: This term is used in describing the ability of pollinators to perform pollination of plants.

Pollinator Quality: Pollinator quality typically refers to the overall fitness of the performance of a pollinator. Although pollinator quality can apply to any pollinator species, it often is used in reference to honey bee queen production. This is a major focus within genetics and breeding programs, where queens are bred to ensure colony quality, which is a function of traits such as honey production, behaviors, and temperament.

Sustainable: Although sustainable can have several meanings, for the purposes of this report sustainable refers to certainty that an action can be sustained over a reasonably long amount of time.

Unmanaged Pollinators: See **Wild Pollinators.**

Wild Pollinators: Pollinators that are not managed for commercial purposes. This can include both native and non-native pollinator species.

Working Lands: From the USDA perspective and for the purpose of this report, working lands refers to lands that are still being utilized for agricultural purposes in some capacity. This typically includes crop production, forestry, and rangelands.