

## Synthesis of breakout group discussions

Six groups discussed four potential tiers for sampling native bees over four discussion sessions. The tiers were:

- 1) Community-level diversity
- 2) Plant-pollinator interactions
- 3) Focal species dynamics
- 4) Other considerations

Each topic followed a similar framework in which we gathered feedback on three questions:

- 1) What questions should this protocol try to answer?
- 2) What response variables should be measured?
- 3) What specific data would need to be collected for each

### Topic 1: Sampling methods for community level information on native bees

**What questions should a protocol focused on community level information be trying to answer?**

Questions suggested by attendees can be grouped into three categories:

- 1) Baseline information on native bees, including measures of diversity and abundance
  - a) What bees are found at a site?
  - b) How many species of bees are found at a site?
  - c) How many bees are found at a site?
  - d) What, if any, historical record exists at a site?
  - e) Where are the bees found in space and time?
    - i) Addresses habitat use and
    - ii) Phenology
- 2) Baseline information on plants
  - a) What plants are found at a site?
  - b) How many species of plants are found at a site?
  - c) How dense is the plant community at a site?
- 3) Change in native bee or plant communities
  - a) Are native bee or plant abundance or diversity changing over time?
  - b) What could be causing bee or plant population change?

Additionally, some questions addressed logistics of gathering community level information on native bees, including what taxonomic keys to use, where to keep collected data, and what time(s) of the year to collect data.

**What response variables should be measured in a protocol focused on gathering community level information on native bees?**

Various measures of abundance and diversity were mentioned. Abundance measures suggested include presence, absence, occurrence, relative abundance, and absolute abundance. Diversity measures suggested include species richness, species evenness, rarefaction, and functional diversity. It was also suggested to measure phenology. All of these measures were suggested for both native bees and plants. Further, to understand the sites hosting these bee and plant communities, it was suggested to gather habitat type and surrounding landscape type information.

**What specific data should be collected in a protocol focused on gathering community level information on native bees?**

Four categories of information emerged here: bees, plants, sites, and sampling effort. Specific data suggested to collect for each category were:

Bees	<ul style="list-style-type: none"> <li>● Species list</li> <li>● Number of bees observed or collected</li> <li>● One row per bee</li> </ul>
Plants	<ul style="list-style-type: none"> <li>● What is in bloom</li> <li>● number of inflorescences</li> </ul>
Sites	<ul style="list-style-type: none"> <li>● Habitat type</li> <li>● Time of day</li> <li>● Time of year</li> <li>● Location (coordinates)</li> <li>● Temperature</li> <li>● Precipitation</li> <li>● Elevation</li> <li>● Soil moisture</li> <li>● Percent bare soil over a unit of area</li> <li>● Soil acidity</li> <li>● Nesting resource availability or ranking</li> <li>● Sampling apparatus position relative to plant position</li> <li>● Bowl trap color(s) – could be standardized instead</li> </ul>
Sampling effort	<ul style="list-style-type: none"> <li>● Effort – could be standardized</li> <li>● Time spent sampling</li> <li>● Area surveyed</li> <li>● Frequency of detection</li> </ul>

## Extra comments from discussion

Questions from attendees emerged here on the central goals of a national native bee monitoring scheme, suggesting that the ultimate goals will determine any sampling protocol. When designing a national protocol, attendees suggested the GRTS nationwide grid for selecting places to sample to avoid spatial bias; further, they requested standardization in the protocol methods. Other questions asked about sampling logistics, including which taxonomic keys would be used to identify specimens, as using a standard set would prevent taxonomic errors; and how many visits would be required to a site during a growing season. Lastly, attendees were eager to integrate measures of genetic diversity, competition, stressors, and disturbance into a national native bee monitoring protocol.

## Topic 2: Sampling methods for plant-pollinator associations with native bees

### What questions should a protocol focused on plant-pollinator associations with native bees be trying to answer?

Questions suggested by attendees can be grouped into three categories:

- 1) Interaction basics
  - a) How many interactions occur?
  - b) How often do interactions occur?
  - c) How long are these interactions?
  - d) How many interactions are needed to sustain both bee and plant communities?
    - i) Is there a threshold of bee or plant abundance?
    - ii) Are there limitations to pollination success?
- 2) Types of interactions
  - a) Foraging
    - i) Are plants visited for pollen, nectar, both, or neither?
      - (1) Is plant providing resins or oils?
    - ii) Are bees visiting one or multiple plant species?
    - iii) Are bee visits “useful” to the plant?
      - (1) Are some bees “better” at pollinating than others?
    - iv) What makes the plants attractive?
  - b) Nesting
    - i) What bees are nesting in what parts of plants?
  - c) Specialist interactions
    - i) What are the roles of specialist or rare plant species?
    - ii) How many specialist bee species are there?
- 3) Changes in interactions
  - a) Do interactions change with time of day/time of year?
  - b) Are plant-pollinator networks changing?
    - i) Over time?
    - ii) In different landscapes?

- iii) Do they vary with plant range?
- iv) Owing to various stressors (climate, disturbance, pesticides)
- c) Does diet breadth shift over time?

**What response variables should be measured in a protocol focused on gathering information on plant-pollinator associations with native bees?**

Variables suggested to measure in a protocol on plant-pollinator associations included both bee and plant species occurrence and identification, plant nutrition, potential plant attractiveness characteristics, phenology of bees and plants, pollination efficiency, and visitation rate.

**What specific data should be collected in a protocol focused on gathering information plant-pollinator associations with native bees?**

As with the protocol on community level information, four categories of information emerged here: bees, plants, sites, and sampling effort. Additionally, a fifth category was defined for data about observed plant-pollinator interactions. Specific data suggested to collect for each category *in addition to those collected for the community level protocol* were:

Bees	<ul style="list-style-type: none"> <li>● tongue length</li> <li>● Where bees hold pollen (abdomen or corbiculae)</li> <li>● Nesting habit</li> </ul>
Plants	<ul style="list-style-type: none"> <li>● Pollen: <ul style="list-style-type: none"> <li>○ protein/lipid ratio</li> <li>○ How much is available</li> <li>○ Size and shape of pollen grains</li> <li>○ micronutrients</li> </ul> </li> <li>● Nectar: <ul style="list-style-type: none"> <li>○ Sugar content</li> <li>○ How much is available</li> </ul> </li> <li>● Nesting material quality and availability</li> <li>● Length of bloom time</li> <li>● Microconditions surrounding plants</li> </ul>
Interactions	<ul style="list-style-type: none"> <li>● Number of visits to a flower</li> <li>● Type of visit</li> <li>● Number of different bees visiting a flower</li> <li>● Number of flowers a single bee visits</li> </ul>

	<ul style="list-style-type: none"> <li>• How much pollen a bee collects (by weight)</li> <li>• Seed set post visit</li> <li>• Pollen deposition per visit</li> </ul>
Sites	<ul style="list-style-type: none"> <li>• History of disturbance</li> <li>• History of pesticide use</li> <li>• Wind speed</li> </ul>
Sampling effort	<ul style="list-style-type: none"> <li>• No additional data suggested</li> </ul>

### Extra comments from discussion

It was suggested to incorporate pollen metabarcoding into a plant-pollinator protocol, as it can provide plant identification and pollen nutrient information. Other comments focused on sampling logistics: standardize or record the identification tools used, and standardize or record how long to observe interactions for meaningful data. Lastly, it was mentioned that pan traps do not provide information on plant-pollinator networks; therefore, they would not need to be included in a plant-pollinator interaction focused sampling protocol.

### Topic 3: Sampling methods for focal species dynamics of native bees

#### What questions should a protocol focused on focal species dynamics of native bees be trying to answer?

Questions suggested by attendees can be grouped into three categories:

- 1) Basics about the focal species
  - a) What is a focal species?
  - b) How do you determine something is a focal species?
  - c) Where does the focal bee occur?
  - d) What are key life stages of the focal bee? (Esp. overwintering)
  - e) What are the best methods of capturing or observing a focal bee?
  - f) Are there possible proxies for the focal bee?
  - g) Can we collect genetic information or eDNA for more information?
- 2) Focal species behavior
  - a) When is the focal bee active?
  - b) What does the focal bee feed on?
  - c) How does the focal bee find food?
  - d) When is (are) the focal bee's food source(s) in bloom?
  - e) How does the bee interact with its nest?
  - f) What nesting material does the focal bee use?
- 3) Change in focal species status
  - a) Is there CHANGE in any of these?

- b) Are there stressors present for the focal bee?

**What response variables should be measured in a protocol focused on gathering information on focal species dynamics of native bees?**

More variables were suggested for a sampling protocol on focal species dynamics than the previously discussed protocols on communities and plant-pollinator interactions. Three categories of variables emerged:

- 1) Bee occurrence
  - a) Species abundance
  - b) Presence/absence (0s important)
  - c) Number of individuals or colonies
  - d) Number of offspring
  - e) Emergence rate
  - f) Sampling effort
- 2) Bee behavior
  - a) Time spent nest searching
  - b) Nesting density
- 3) Bee biology
  - a) Disease prevalence
  - b) Thermal tolerance
  - c) Body size
  - d) Wing wear
  - e) Diploid males
  - f) Inbreeding
  - g) Gyne production
  - h) Male production
  - i) Worker production
  - j) Sex ratio
  - k) Functional and phenological traits

Other variables addressed the habitat of focal species, including general habitat characteristics and the presence of native or exotic bee or plant species.

**What specific data should be collected in a protocol focused on gathering information on focal species dynamics of native bees?**

A sampling protocol on focal species dynamics differs fundamentally from a sampling protocol on community level information; therefore, the data suggested here may not build on the suggestions for the community level protocol. A focal species protocol was discussed as a “more intense version” of the previous protocol tiers discussed. As such, these data to collect are interpreted as a standalone protocol.

Bees	<ul style="list-style-type: none"> <li>● Occupancy</li> <li>● Detectability</li> <li>● Specialists or generalists</li> <li>● At edge of ranges</li> </ul>
Plants	<ul style="list-style-type: none"> <li>● What is blooming <ul style="list-style-type: none"> <li>○ Color(s) of bloom</li> </ul> </li> <li>● How much is blooming</li> <li>● When plants bloom</li> <li>● Amount and types of interactions between bees and plants</li> </ul>
Sites	<ul style="list-style-type: none"> <li>● Time of year</li> <li>● Habitat type</li> <li>● Trap type or other survey method</li> <li>● Soil type</li> <li>● Soil moisture</li> <li>● Temperature</li> <li>● Collector experience</li> </ul>
Sampling effort	<ul style="list-style-type: none"> <li>● Number of site visits</li> <li>● Length of time spent sampling</li> </ul>

### Extra comments from discussion

There were frequent questions on the process of choosing or determining focal species to monitor through a standardized protocol, and no clear criteria to choose focal species was provided. Choosing species may require additional consultation with the professional community for feedback. Names were provided for scientists who have conducted focal species sampling; in addition to workshop speaker Jeff Everett, Tab Graves from USGS and Tam Smith from USFWS were suggested as resources to aid in developing focal species selection criteria and sampling methods.

Questions arose on the range of these focal species—will they be regional or national? Other questions were posed on the knowledge base required for focal species monitoring, implying that there is generally not enough information on potential focal species to begin monitoring them. The logistics involved in locating very rare species were discussed, along with the amount of labor required to accomplish this. The potential role of eDNA was mentioned.

The risk of threatened focal species and the effort required to locate and monitor them necessitates scientific and statistical rigor in any protocol; indeed, policy makers need reliable, quantifiable information to move forward with any legal protection. The US Fish and Wildlife

Service requested measures of statistical certainty with any sampling data; specifically, calculating statistical power. Other agency needs for this level of rigor are unknown.

#### **Topic 4: Sampling methods for other considerations of native bees**

**What questions should a protocol focused on other considerations of native bees be trying to answer?**

Presentations for this section of the workshop were on bee health, including disease, parasites, and other pathogens, and nesting habitat. These topics arose in previous discussions and were only briefly mentioned here. The “other consideration” with the most discussion was general sampling methods; details on this discussion and others are presented below.

- Sampling methods
  - Bowl trapping
    - How is this affected by floral abundance and diversity?
    - Height of traps?
  - Non-lethal method development
  - Heat
  - Radar
  - Dogs
  - Tracking with fluorescent powder
  - Bioacoustic monitoring
    - This was not in the discussion notes, but workshop co-organizers talked with Laura Figueroa at workshop about her work
  - Machine learning
  - Camera traps/videography
    - Video vane trap
  - Proxy or surrogate species
- Genetics
  - Diversity at sites
  - eDNA from flowers to determine visitors
    - Utility of eDNA for doing single species ID
- Pathogens
  - Sample excretions for pathogen presence (poop, vomit)
- Nest associations
  - What soil conditions should be measured?
- Thermal tolerance
- Remote sensing for habitat
  - UAV to detect flowers
- Role of community scientists
- Data sharing



**What response variables should be measured and specific data should be collected in a protocol focused on gathering information on other considerations of native bees?**

Owing to the extensive suite of questions discussed in this section, there were not many response variables or specific data fields suggested. For sampling methods, there was discussion of acoustics, infrared cameras, LiDAR cameras, 3D photos from paired cameras, and AI methods for interpreting camera or sound data. For genetics, tarsal clippings were suggested. For pathogens, disease status of specimens at each life stage was suggested. Broadly, establishing sites and effort necessary to access them was discussed, as well as developing tools that illustrate current spatial gaps in our current understanding of national native bee distributions.