Demographic summary of attendees:

Table 1. Summary of invitees (n = 737) and attendees (n = 135) of the RCN workshop on existing bee monitoring efforts by location in USDA Farm Production Regions. There were 31 people who were forwarded invites and RSVP'd; 22 of these invitees attended the workshop. Regions do not include Alaska, Hawaii, U.S. Territories, Canada, or International invitees/attendees.

	Invited	Attended
Mountain West (MT, ID, WY, CO, NV, UT, AZ, NM)	168	31
Northeast (MD, DE, DC, NJ, PA, NY, RI, CT, MA, VT, NH, ME)	150	24
Pacific West (WA, OR, CA)	101	22
Corn Belt (IA, MO, IK, IN, OH)	66	8
Lake States (MN, WI, MI)	64	9
Appalachia (KY, TN, WV, VA, NC)	41	6
Northern Plains (ND, SD, NE, KS)	34	8
Canada	27	8
Southeast (AL, GA, SC, FL)	22	4
Southern Plains (TX, OK)	20	6
International	17	3
Delta (AR, LA, MS)	11	2
Alaska	10	4
Hawaii	4	0
U.S. Territories (Guam)	1	0
N/A	1	0

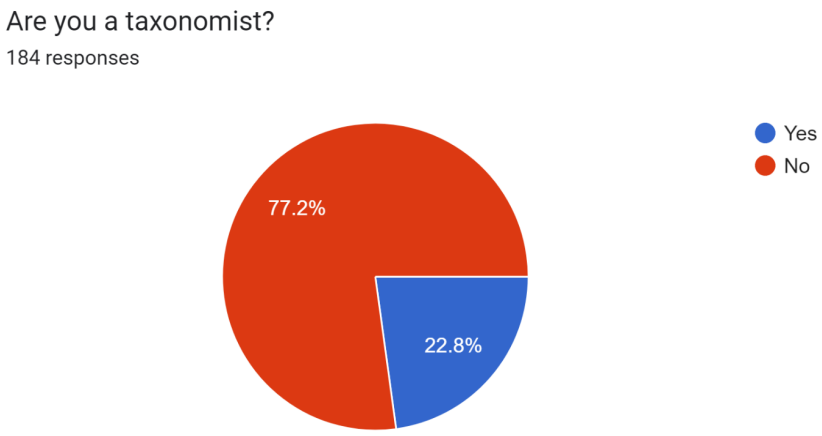
Table 2. Summary of invitees (n = 737) and attendees (n = 135) of the RCN workshop on existing bee monitoring efforts by employment sector. There were 31 people who were forwarded invites and RSVP'd; 22 of these invitees attended the workshop.

	Invited	Attended
Academic	276	55
Federal	244	40
State	67	15
Extension	45	6
Nonprofit	45	10
Tribal	18	1
Consultant	20	6
Industry	12	0
County	5	1
Local	3	0
Community	2	1
N/A	1	0

Pre-workshop survey summary:

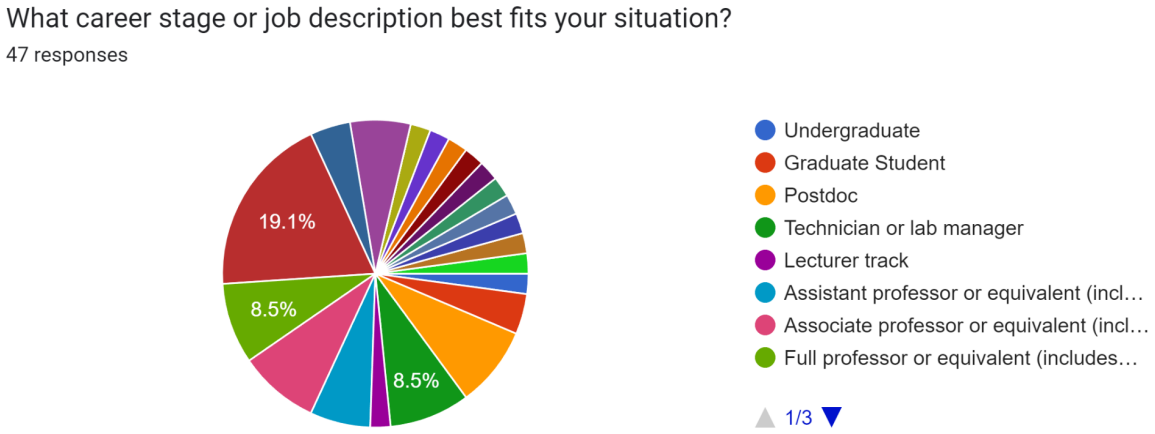
Workshop organizers compiled a detailed survey for prospective attendees to complete along with their response for attending the event. The survey was optional; no questions were required to submit an RSVP. We received 189 responses to the workshop invitation, and all of those responses included one or more answers to the survey questions.

Q1: Are you a taxonomist? (184 responses)



The following set of questions was directed to those who answered “Yes” to question 1, “Are you a taxonomist?”

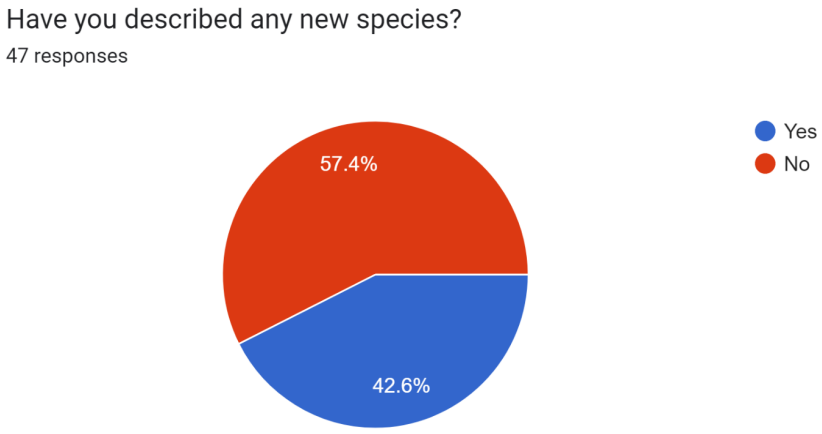
Q2: What career stage best describes you currently? (47 responses)



The most frequent response to this question was permanent government scientist; 9 taxonomists chose this answer (19.1%). The full list of responses is as follows:

1. Undergraduate: 1 response, 2.1%
2. Graduate Student: 2 responses, 4.3%
3. Postdoc: 4 responses, 8.5%
4. Technician or lab manager: 4 responses, 8.5%
5. Lecturer track: 1 response, 2.1%
6. Assistant professor or equivalent: 3 responses, 6.4%
7. Associate professor or equivalent: 4 responses, 8.5%
8. Full professor or equivalent: 4 responses, 8.5%
9. Government scientist (permanent): 9 responses, 19.1%
10. Government scientist (not permanent): 2 responses, 4.3%
11. Independent, self-employed: 3 responses, 6.4%
12. Hobbyist: 0
13. Other answers:
    - two nonprofit employees
    - three museum curators
    - four “faculty”
    - one near retirement professor

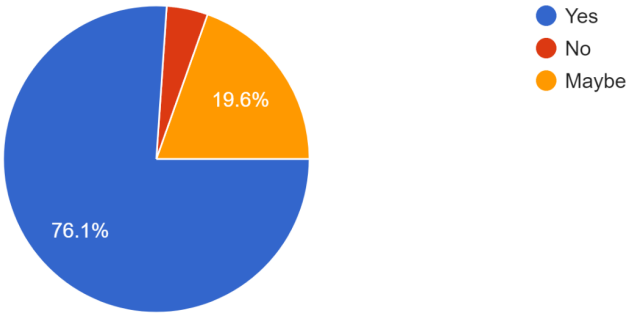
Q3: Have you described any new species? (47 responses)



Q4: Would you describe new species if this were an explicit part of your job description? (46 responses)

Would you describe new species if this were an explicit part of your job description? In other words, is this something you'd be interested in doing if it was a stated part of your job?

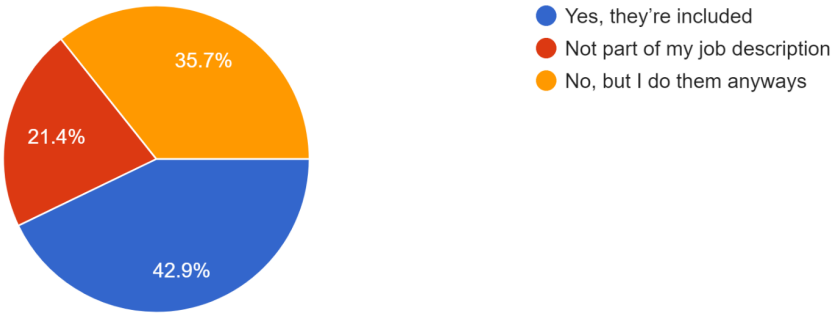
46 responses



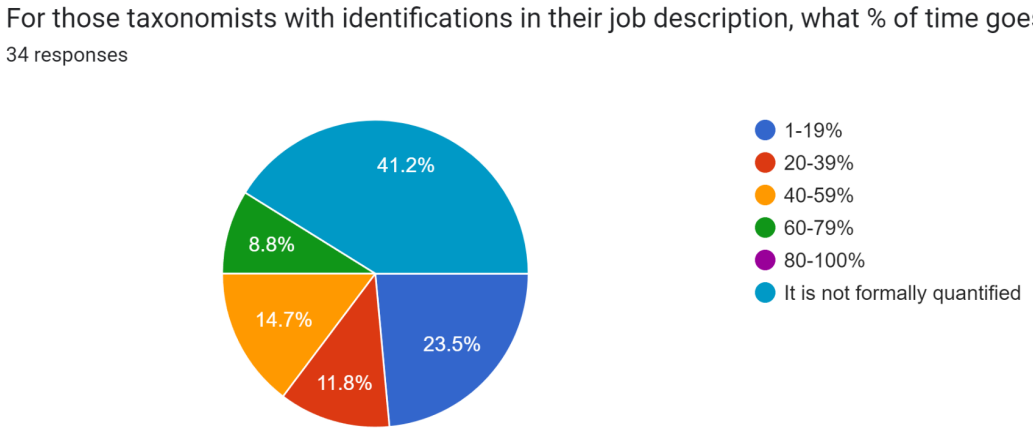
Q5: For those taxonomists with permanent jobs, are your identification duties part of your job description? (42 responses)

For those taxonomists with permanent jobs, are your identification duties part of your job description?

42 responses



Q6: For those taxonomists with identifications in their job description, what percent of time goes to this? (34 responses)



Q7: What type of compensation do you or would you request for your identification work? (45 responses)

Type of compensation	Number of responses	Percent of responses
None expected	6	13.3%
Acknowledgements section is fine no matter the volume	11	24.4%
Coauthorship under any circumstances	4	8.9%
Coauthorship if sufficient volume	25	55.6%
Money	13	28.9%
Money and coauthorship	11	24.4%

Other answers to this question included varied compensation on a case-by-case basis based on the amount of specimens, difficulty of specimens, and the entity requesting verifications, acknowledging verifiers for small volumes or verifiers with limited experience, and requiring museum deposition of verified specimens.

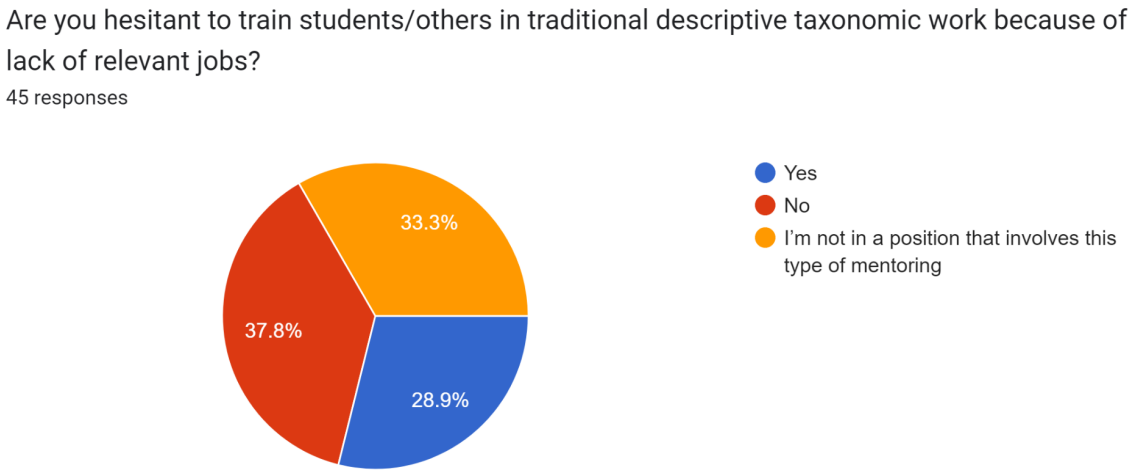
Q8: If you have a fee structure for specimen identification, how much do you charge per specimen for PHYSICAL SPECIMENS? (20 responses)

Responses to this question varied widely, with no real consensus suggesting a “typical” fee structure. Verifiers charge $1-$5 per specimen or a range per specimen based on difficulty; ranges specified were $2-$5 and $1-$7. Other verifiers charge per hour. Two respondents said they charge $75 per hour, and one indicated that with their per hour fee, the cost per specimen averages out to be between $1.50 and $2.50. Lastly, one verifier indicated they do not charge for specimen identification.

Q9: If you have a fee structure for specimen identification, how much do you charge per specimen for PHOTO OBSERVATIONS? (12 responses)

Most respondents to this question do not charge for photo observations. Those that do charge indicated a fee structure of $1 per specimen or $50 per hour.

Q10: Are you hesitant to train students/others in traditional descriptive taxonomic work because of the lack of relevant jobs? (45 responses)

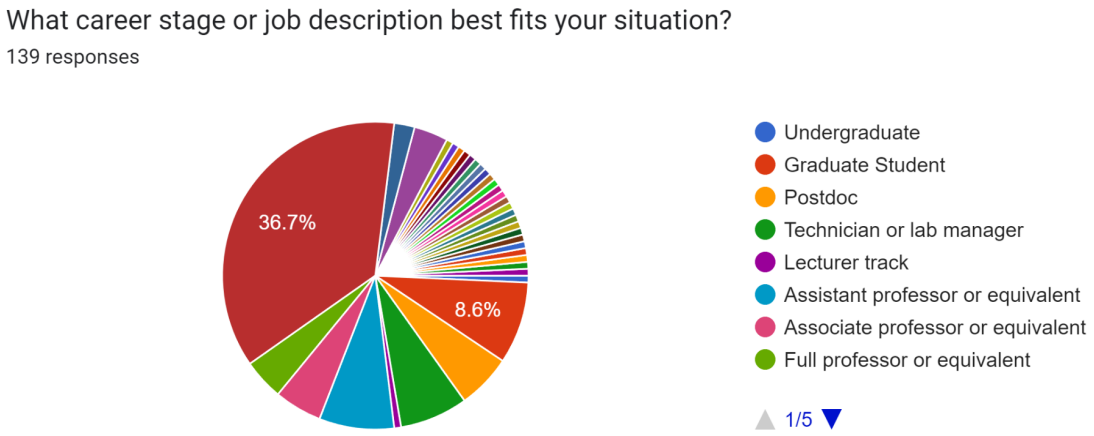


Q11: What are the most pressing issues faced by bee taxonomists or those needing identifications? (33 responses)

The most pressing issue provided was the constant backlog of specimens to identify and the limited time available to dedicate to identifications. This prolongs and grows the backlog of specimens to identify and should be addressed. Other issues presented included lack of jobs, lack of keys for western US bees, lack of reference specimens or detailed images to support identification work, lack of funding and large scale institutional work, lack of value of taxonomic work, poor specimen preparation, and collection of specimens without forethought about how to manage the collection and identify the specimens.

The following set of questions was directed to those who answered “No” to question 1, “Are you a taxonomist?”

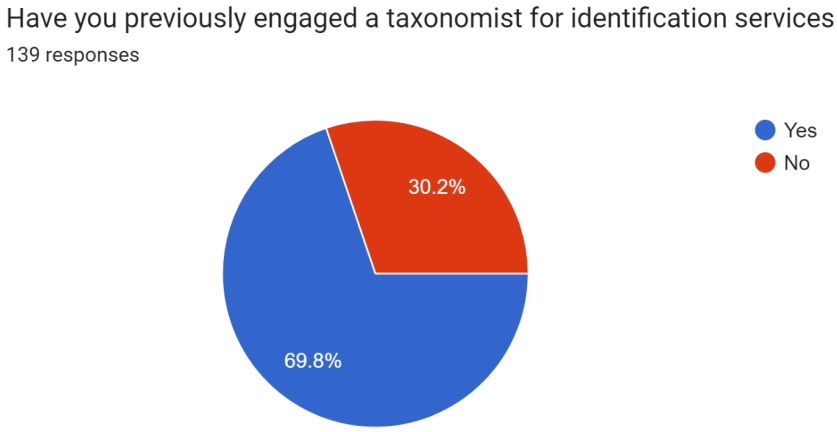
Q12: What career stage best describes you currently? (139 responses)



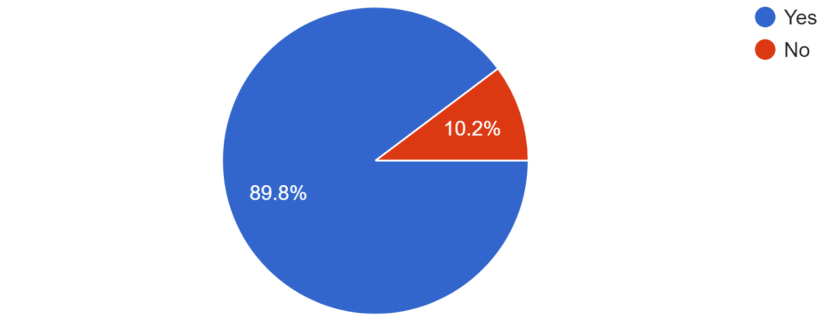
The most frequent response to this question was permanent government scientist; 51 attendees chose this answer (36.7%). The full list of responses is as follows:

1. Undergraduate: 1 response, 0.7%
2. Graduate Student: 12 responses, 8.6%
3. Postdoc: 8 responses, 5.8%
4. Technician or lab manager: 10 responses, 7.2%
5. Lecturer track: 1 response, 0.7%
6. Assistant professor or equivalent: 11 responses, 7.9%
7. Associate professor or equivalent: 7 responses, 5%
8. Full professor or equivalent: 6 responses, 4.3%
9. Government scientist (permanent): 51 responses, 36.7%
10. Government scientist (not permanent): 3 responses, 2.2%
11. Independent, self-employed: 5 responses, 3.6%
12. Hobbyist: 0
13. Other answers:
    - 10 nonprofit/NGO scientists
    - three Extension employees (educator or scientist)
    - One apiculturalist
    - One Ag inspector
    - One biodiversity informatician
    - three government positions
    - four other research/science roles

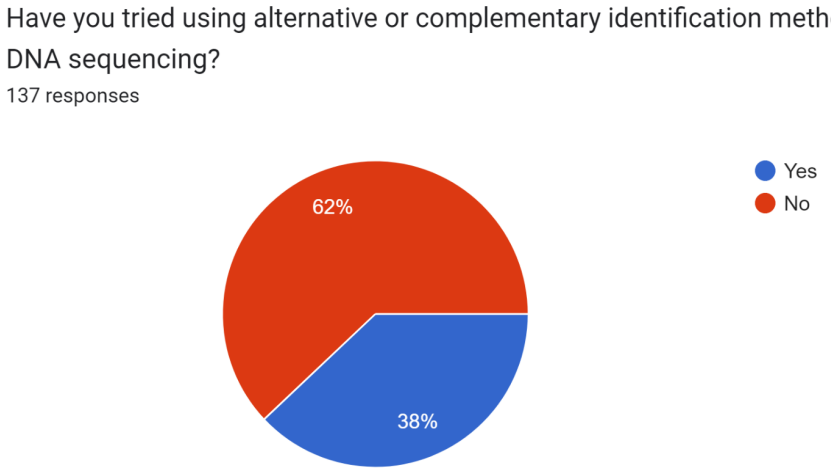
Q13: Have you previously engaged a taxonomist for identification services for your research? (139 responses)



Q14: For your projects, do you foresee a future need for identification services from taxonomists? (137 responses)

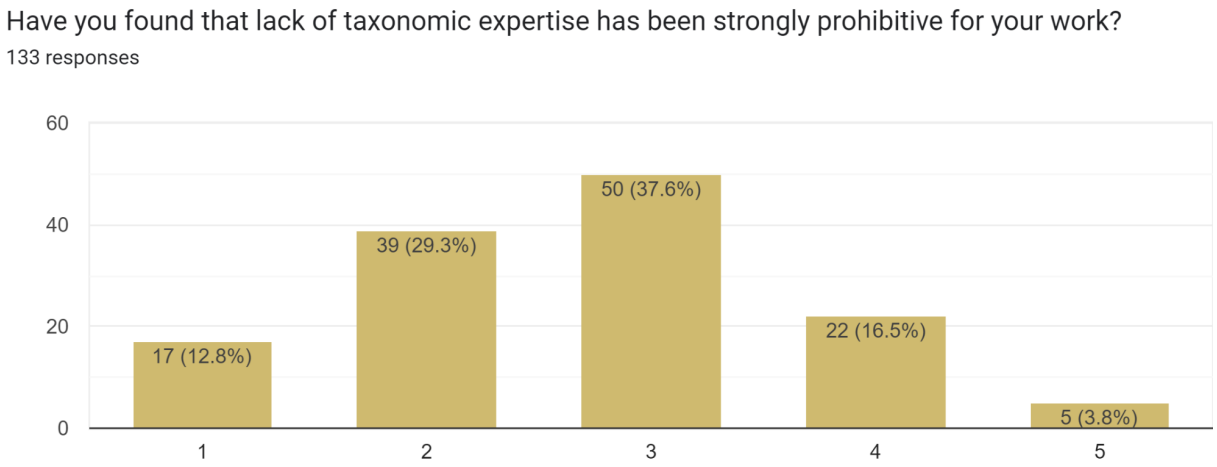


Q15: Have you tried using alternative or complementary identification methods like image recognition or DNA sequencing? (133 responses)



Q16: Have you found that lack of taxonomic expertise has been strongly prohibitive for your work? (133 responses)

Most respondents were neutral in response to this question, and the remaining responses skewed toward more prohibitive than not.



Q17: What recognition are you most able to/prefer to give in return for identifications? (122 responses)

Type of compensation	Number of responses	Percent of responses
Should not be compensated	2	1.6%
Acknowledgements section is fine no matter the volume	25	20.5%
Coauthorship under any circumstances	23	18.9%
Coauthorship if sufficient volume	47	38.5%
Money	48	39.3%
Money and coauthorship	57	46.7%

Other answers to this question included coauthorship contingent on additional contribution, mentioning verifiers in the body of the paper, compensation on a case by case basis, and using unique identifiers including ORCID or Bionomia to create credit online.

Q18: Please name the taxonomists you have engaged for their identification services? (83 responses)

Name of taxonomist	Frequency of consultation
Sam Droege	13
Terry Griswold	13
Jason Gibbs	12
John Ascher	10
Karen Wright	7
Mike Arduser	7
Linc Best	6
Zach Portman	6

Rich Hatfield	5
Robbin Thorp	5
Doug Yanega	4
Skyler Burrows	4
Casey Delphia	3
Jack Neff	3
Jaime Pawelek	3
Joe Engler	3
Joel Gardner	3
Michael Orr	3
Olivia Carril	3
Rob Jean	3
Amy Dolan	2
Citizen science taxonomists	2
Coleman Little	2
Cory Sheffield	2
Elaine Evans	2
Harold Ikerd	2
Jon Koch	2
Michael Ivie	2
Mike Slater	2
Molly Rightmyer	2
Paul Williams	2
Sandra Rehan	2
Sarah Gardner	2

Victor Gonzalez	2
Alex Morphew	1
Allan Smith-Pardo	1
Amélie Gervais	1
August Jackson	1
Charles Michener	1
Charles Ray	1
David Biddinger	1
Derek Sikes	1
Don Harvey	1
Ebner	1
Frank Parker	1
Ivan Milosavljevic	1
James Hung	1
Jamie Strange	1
Jessica Rykken	1
Jim Cane	1
Joan Milam	1
Jonathan Mawdsley	1
Josh Campbell	1
Karl Magnacca	1
Laura Rericha	1
Laurence Packer	1
Leif Richardson	1
Mace Vaughan	1

Matt Carlson	1
Michael Engel	1
Michigan Natural Features Inventory (ca. 2011)	1
Mohammad Al Mousa	1
Paige Muñiz	1
Rob Brooks	1
Sara Bushmann	1
Silas Bossart	1
Spencer Hardy	1
Tabitha Graves	1
Thomas Onuferko	1
York U	1
Zach Rystrom	1

Q19: What are the most pressing issues faced by bee taxonomists or those needing identifications? (90 responses)

Four areas of consensus emerged in response to this question. First, respondents identified a lack of funding and support for bee taxonomy and specimen identifications. Second, respondents described a lack of taxonomy jobs and the limited number of working taxonomists and bee identifiers. Third, respondents highlighted the backlog of specimens waiting for identification and the lack of time available to identify them. Lastly, respondents detailed the lack of accessible information on bee taxonomy and identification and the lack of support and equipment to develop and maintain more accessible information on these topics. Specifically, respondents asked for updated, detailed, easy to understand keys and species descriptions, more opportunities for taxonomic training, a clearer pathway for taxonomic training, and access to reference collections.

Large group discussion summary

During the workshop, we asked attendees seven questions using Mentimeter live polling:

Q1: For taxonomists: are you generally brought in at the proposal stage of a project?

With 27 responses to this question, 20 taxonomists said no, they were not typically brought in at the proposal stage of projects, while seven taxonomists indicated that they are often brought in at that point.

Q2: Non-taxonomists: do you allocate funding for taxonomists in your project proposals?

With 48 responses to this question, 23 respondents said they do allocate funding for taxonomists in project proposals, 10 said they did not allocate this funding, and 15 attendees said they sometimes allocate funding for taxonomists.

Q3: Non-taxonomists: if you have bee ID skills, where or how did you train for those skills?

There were 60 responses to this question, with many respondents indicating they taught themselves their bee ID skills, primarily using online resources including Discover Life, iNaturalist, Bumble Bee Watch, and the weekly bee ID series run by the FWS/USGS Wild Bee Lab. Multiple respondents were alumni of The Bee Course at the Southwestern Research Station in Portal Arizona. Other respondents received in-person training at workshops led by Mike Arduser, Rob Jean, Jason Gibbs, and Sam Droege, and some received training at the USDA ARS Pollinating Insects Research Unit in Logan, Utah. Other resources mentioned that led to bee ID skills include reviewing verified specimens, mentorship from an undergraduate or graduate advisor, on the job training from colleagues, consulting with experts, transferring taxonomic knowledge of other insect families, reading taxonomic literature, and the Master Mellitologist program at Oregon State University.

Q4: Non-taxonomists: would you further develop your bee ID skills if dedicated funding and opportunities to do so were available?

With 58 responses to this question, 49 respondents said yes, they would further their bee ID skills with funding and opportunities were available, three respondents would not, and nine would consider it.

Q5: Which group(s) of bees needs the most work on their taxonomic key(s)?

There were 58 responses to this question, and the most common groups chosen were Nomada, Lasioglossum, Sphecodes, Mellisodes, and Andrena (Fig. 1)

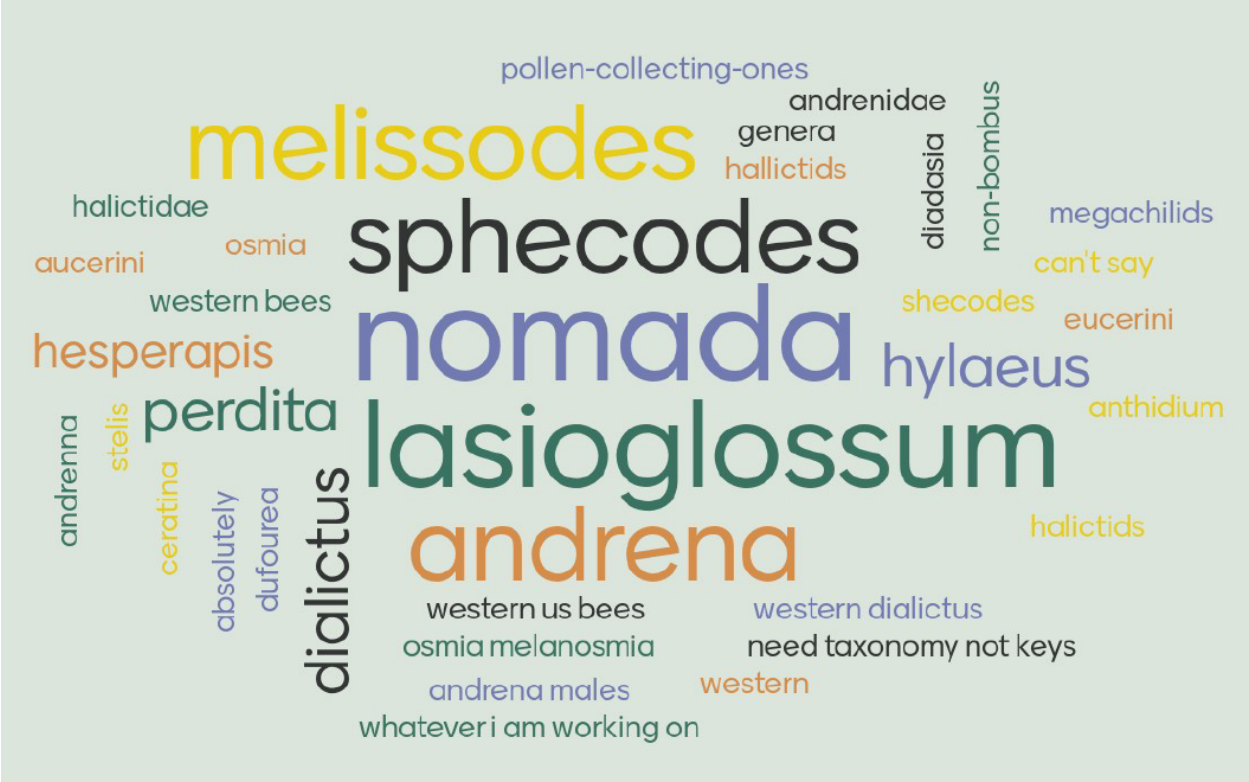


Figure 1. Word cloud depicting the groups of bees attendees listed as needing the most work on their taxonomic keys.

Q6: Would you use a taxonomic service directory if one were developed?

With 64 responses to this question, 58 respondents supported a taxonomic service directory, two respondents did not, and four would consider it.

Q7: What information would you like to see in a taxonomic service directory?

We received 53 responses to this question. Information requested in a taxonomic service directory includes taxonomic area of expertise, geographic area of expertise, compensation structure, including base fees and expectations for additional recognition (co-authorship, acknowledgements, etc), availability and wait time, a short CV or list of projects worked on, preferences for specimen preparation, and institutional affiliation.

Synthesis of breakout group discussions

This workshop had two breakout sessions; each focused on a central theme.

Breakout 1: How to improve support for bee taxonomists

What funding sources/opportunities are available for bee taxonomy, either explicitly focused on taxonomy or otherwise?

Many attendees noted the overall lack of reliable funding sources for taxonomic work, particularly with respect to pure research taxonomy. Attendees asked what could be done to change this and offered a potential solution: advocate for sustained permanent taxonomist positions, ideally with federal or state government agencies. Support for these positions could be pooled from federal, state, nonprofit, and private resources. A stronger taxonomic infrastructure is sorely needed to support the amount of native bee research currently underway in the US and to reduce or ideally eliminate the taxonomic bottleneck. Those that do find funding for taxonomic work are typically supported by soft money; again, attendees repeatedly indicated that soft money support is not sustainable over time and called for more sustained funding.

A dichotomy between two types of taxonomic work emerged in this discussion: taxonomic work can be either 1) verifying identifications of collected specimens or 2) revising existing taxonomy as more is learned about native bee species. Attendees describing this dichotomy in response to this question implied that it is easier to get funding for verifying identifications than for revisionary work.

The primary means through which funding for taxonomic work is obtained is through grants. A couple of tips were offered on how to secure taxonomic funding. First, write identification work as a line item in any bee-related grant. Many attendees suggested this be made a standard or at least more widespread practice in grant-writing. The second suggestion was to try writing graduate student or post-doctoral grants to support revisionary work. Beyond grants, federal and state government agencies have access to agency base funds, which can provide direct support for various projects.

Attendees listed entities awarding grants to support taxonomic work at the federal (Table 3), regional, state, and local levels; further, they described a number of nonprofit grant sources.

Table 3. Federal agency sources for grant funding to support bee taxonomy

Agency	Program
NSF	ARTS (Advancing Revisionary Taxonomy and Systematics)
	Systematics and Biodiversity Science (SBS) Cluster

	SBS Poorly Sampled and Unknown Taxa (PurSUiT)
	Biological Collections
	DEB Division of Experimental Biology
NSERC (Canada)	Discovery Grants
USDA	Farm Bill
USDA NIFA	Hatch grants
	Cooperative Extension
	AFRI Pollinator Health
	Specialty Crop Research Initiative
USDA SARE	Multiple grant types support pollinator work
USFWS	State Wildlife Grants
BLM	Contracts out for collections and identifications
NPS	Contracts out for collections and identifications
USFS	Contracts out for collections and identifications
USGS	Cooperative Fish and Wildlife Research Unit Program
Multiple agencies	Discretionary funds
Multiple agencies	Cooperative agreements
Smithsonian Institution	Fellowships

Regional sources suggested were the Northeast Regional Conservation Needs program, which pools State Wildlife Grant funding to support inter-state conservation work, and the Great Lakes Restoration Initiative. Both of these entities are currently conducting pollinator conservation work. State granters included departments of natural resources, fish and wildlife, conservation, environmental protection, and agriculture. Natural Heritage programs operate in each state and could potentially fund bee taxonomy work. Some states have targeted or general purpose funds that disperse grants, including state lottery funds. Lastly, state legislatures can budget funding for taxonomist positions, as was recently done in the state of Washington. Local granters mentioned were typically nonprofit groups and included local land trusts, garden clubs, native plant societies, and other groups that support conservation or restoration.

Four types of nonprofit organizations were mentioned. Academic or professional societies may support taxonomic work, including the Society of Systematic Biologists, the Linnean Society,

and the Association of Fish and Wildlife Agencies. Private foundations could support bee taxonomy, including the National Fish and Wildlife Foundation, the National Parks and Recreation Association, the Illinois Clean Energy Community Foundation, and National Geographic, though National Geographic likely has limited opportunity for taxonomic funding. Corporations or industry groups supporting bees or agriculture were mentioned, including the Walmart Foundation, General Mills, and crop associations. Lastly, museums were suggested as a source for taxonomic funding or support. Museums rely on public funding, which they complement with private donations, and grants, therefore their capacity to support additional bee taxonomy work may be limited. However, some museums, including the American Natural History Museum, offer graduate or postdoctoral fellowships or internships to train taxonomists; these could be opportunities to support bee taxonomy.

How can we integrate taxonomists more equitably into bee projects?

There was very strong consensus in response to this question that taxonomists be involved with bee projects from the conception and development stage. For projects that involve collecting hundreds or thousands of specimens, hiring a taxonomist to verify those identifications cannot be an afterthought; that hire should be done early and communication with the desired taxonomist should begin as the project is in its earliest stages. Having input from a taxonomist while writing a project proposal can improve proposal quality related to taxonomic needs; only a taxonomist can clearly describe the time, effort, and money required to verify specimen identifications. Taxonomists can also provide guidance on specimen preparation, curation, and collection in the field. If that level of input is not feasible to achieve, multiple attendees suggested to, at a minimum, establish contact with a taxonomist and request identification services while a proposal is being prepared. Ideally, at this stage, a formal agreement or contract on specimen identification work could be completed, including number and type(s) of specimens, pay, supplies, and time to completion. A template of these contracts could be created to standardize this process. When contacting a taxonomist to request identification services, most attendees indicated they always offer to pay them, though some taxonomists are unable to accept contract pay owing to employer regulations. Attendees suggested writing taxonomist pay into grants as a line item as with any other service or equipment needed to complete a research project. Attendees also largely supported making this a standard practice for grants involving native bee specimen collection. Taxonomists can also be brought in more often as co-PIs or formal project collaborators. Once brought in as a co-PI/collaborator or identification services are agreed upon, many attendees stressed the importance of maintaining a clear line of communication with taxonomists throughout a project.

Attendees suggested other ways to support taxonomic work. Acknowledging the contribution of a contracted taxonomist in all project outputs promotes the importance of taxonomy and the legitimacy of taxonomic work. At a minimum, attendees suggested citing the taxonomist(s) name(s) in the main body of any manuscripts using their identifications; the main body (typically the methods section) was specifically preferred for this citation over the acknowledgements section. Citing any relevant taxonomic literature used in the identifications, such as keys, checklists, revisions, etc., also promotes taxonomy in the broader literature. Some taxonomists

may request to be co-authors on publications using their identification work; co-authorship can be offered along with payment when making contracts or agreements. Attendees suggested that peer-reviewers should look out for these practices when reviewing papers and request clarification when taxonomists or taxonomic work is not clearly cited or acknowledged. However, citing identification work is not always straightforward; for example, when using data gathered from data aggregators, the identifiers of those specimens or photos may be unclear. Attendees suggested more broad support for taxonomists at all skill levels, including trainees, interns, and apprentices. This could be done by sending easier to identify specimens to early career taxonomists, providing them with critical experience and reducing workload on top taxonomic experts. Supporting early career taxonomists can also be done by advocating for the creation of more taxonomy jobs, particularly permanent jobs at the federal and state government level. Academic labs can also hire taxonomists as staff. More broadly, attendees suggested supporting taxonomic infrastructure, including museums, collection space, and digitization efforts. When collecting specimens, attendees encouraged scientists to commit to vouchering specimens and keeping clear records of where specimens are vouchered. More broadly still, attendees suggested creating a broader awareness of the value of taxonomy. Without taxonomists to verify identifications and revise existing nomenclature, our knowledge of native bee diversity would be limited. Communicating this to the public could encourage more widespread support for the science of taxonomy.

What alternative career metrics should be used to evaluate taxonomic work and how can we make them better appreciated?

The greatest consensus in response to this question emerged around a shift away from peer-reviewed publications as the primary career metric for taxonomic work. Peer-reviewed publications in taxonomy are often revisions to existing nomenclature. There is limited financial support for this kind of work, so it occurs less often than other kinds of science, and a single revision can take years of work to complete. Revisions are long papers; they can reach monograph length or longer. Additionally, revisions are often published in low impact journals, as higher impact journals do not prioritize taxonomic work for publication. The pace and frequency of academic taxonomy makes relying on peer-reviewed publications difficult for career evaluation or advancement. However, when published, revisions have very high value to pollination biology and ecology, though they are rarely cited by papers that use that information. One alternative career metric to evaluate taxonomists by could be the number of citations on their papers or the length of time their papers are consistently cited. If continuing to emphasize peer-reviewed publications, including taxonomists as co-authors on papers using their identifications is a way to support their work and promote their career advancement. If that is not possible, citing revisions and keys, both peer-reviewed and online, gets their names and their work in the literature and supports taxonomy. Another category of published taxonomic is species checklists. Contributing to the creation or revision of checklists supports taxonomic work, and if part of creating a checklist, citing all taxonomic sources used provides additional support. Taxonomists also contribute to non-academic publications, including websites, interviews, or other public media. Referring to these, sharing these, and promoting them is a way to support taxonomic work.

Service is an alternative career metric that could be used to evaluate taxonomic work. Taxonomists that do outreach work for iNaturalist or citizen science projects can be recognized for those efforts; that outreach includes verifying identifications or providing instruction or seminars on bee taxonomy or species identification. Metrics for verifying identifications could include the number of verifications or types of specimens verified. These metrics could also be applied to verifications completed in contract or other collaborative work. The number of contracts or collaborations could also be a metric of service; this could be an alternative to co-authorship on peer-reviewed publications. Other possible identification-related metrics include the diversity of specimens identified or the breadth of geographic expertise. One suggestion was the number of database entries generated through specimen verification; this would need to be tracked with a unique identifier for the taxonomist. However, a counter-argument to specimen-related service metrics was presented: the number of specimens identified or the number of species that can be identified could be poor incentives and encourage bad actors artificially inflating these numbers. Another type of service is mentorship, including training students or staff directly or teaching workshops that benefit a group of people. Curation is another form of service, including managing specimens, databasing, digitizing, or contributing to museum operation in some way.

Other ways to support taxonomists beyond traditional academic metrics include nominating taxonomists for professional awards. Encourage taxonomists to create and actively contribute to portfolios to showcase their skills and experience. Standardizing what these portfolios include or creating a space to link to them would promote taxonomists and their work. Part of these portfolios could include creating a consistent identifier such as an OrcID iD to use across the web in publications, databases, and sites such as Bionomia, which tracks the personnel who identify preserved specimens. Lastly, creating some sort of certification based on these alternative metrics could help reduce emphasis on number and impact on peer-reviewed publications.

In addition to the current positions taxonomists function in, are there other jobs you could envision where taxonomists are employed to explicitly do taxonomy? What would those look like?

This question led to more discussion of the dichotomy in taxonomic work between verifying identifications and revising existing nomenclature. Taxonomists with extensive academic training in the science of taxonomy write revisions and work to maintain the most accurate nomenclature of native bees. Bee identifiers have training in bee anatomy and physically distinguishable characteristics. Taxonomists can serve as bee identifiers, but bee identifiers do not necessarily need to be highly trained taxonomists. Having jobs where employees can focus more on identifying bees would ease the taxonomic bottleneck by allowing more specimen verification to be completed. This in turn would promote more pure taxonomic research, as having more bee identifiers would allow academically-trained taxonomists to focus more on maintaining nomenclature. Both types of work need more positions made available; consensus emerged that these jobs would be most beneficial as permanently funded state or federal government

positions. In government positions, however, attendees advocated for distinguishing bee specialists from pest specialists, as these two positions are often lumped, but they do very different things. This combination also occurs in Cooperative Extension positions; Extension is another potential source for bee taxonomy positions. New taxonomist positions with sustained funding are preferred over soft money work; while some experts have chosen to be a self-supporting independent contractor or consultant, that work is not feasible for many people. A non-governmental option for taxonomic employment could be non-faculty university scientist work. These positions would not be on the tenure-track and would have reduced teaching and service loads, allowing the scientists to focus on bee identification or nomenclature revisions. These positions could incorporate outreach into the work responsibilities, including leading public-facing taxonomy activities such as digitization drives, identification workshops, and educational seminars.

Government agencies are a good choice for permanent taxonomist positions; many attendees implied that there are not enough current government positions for bee taxonomists. The Animal Plant Health Inspection Service (APHIS), a USDA agency, has a number of insect taxonomists, but none that specialize in bees. Federal government positions could operate across agencies or throughout departments. State agencies are beginning to hire bee taxonomists; some are soft money, but the state of Washington has just hired a new permanent bee taxonomist funded by legislative mandate. Pennsylvania hires taxonomists on a contract basis during the field collection season. NatureServe and the Natural Heritage program are hiring entomologists; some of these positions could support native bees. Attendees suggested some organizations with existing infrastructure to emulate when creating new taxonomic positions including the botanical personnel of many federal agencies, such as USDA, BLM, and the Plant Protection Quarantine program of APHIS, state or regional water quality monitoring centers, and the American Ornithological Society, which manages regional species checklists and presents professional awards that promote career advancement.

Distinguishing and defining taxonomic tasks could lead to the development of a clearer career path for bee taxonomists; this was a frequent topic of discussion among workshop attendees. Establishing a clear career path could clarify how to support early-career taxonomists while reducing the workload of later-career taxonomists. Beyond specimen verification and nomenclature revision, taxonomic tasks include specimen management, curation, digitization, community outreach, teaching, and mentoring. Specimen management includes tasks such as cleaning specimens, pinning them, and creating and applying labels. Curation involves sorting, storing, and database management of specimens. Digitization involves photographing specimens and entering label data into computers. These tasks can be delegated to entry-level technician positions, allowing taxonomists with more training and experience to focus on specimen verification and nomenclature revision. When creating new jobs, attendees suggested those jobs to be established across different levels of experience to create a long-term career pipeline. One suggestion emphasized postdoctoral work to get PhD trained taxonomists more chances to establish themselves for long-term careers in bee taxonomy. For those trained taxonomists or bee identifiers that choose to become independent contractors or consultants, attendees suggested supporting them by promoting their services, locations, and capabilities

through a central location, possibly an online taxonomic directory that would include any bee taxonomist regardless of skill or sustained support.

One idea that came up frequently was creating a national center for bee taxonomy and identification. This center would create more bee taxonomy positions at the federal level and distinguish taxonomic research work from specimen identification services. It would serve the entire nation and collaborate across agencies and sectors. The center could have a central location for training taxonomists and bee identifiers through workshops, seminars, internships, and fellowships. The center could house a national bee collection for reference, loan, and study; further, it could create a robust online database of these specimens and manage identification keys and species checklists. Employees of the center could be dispersed across the country to increase access to quality taxonomic knowledge and infrastructure.

Lastly, attendees suggested a number of potential jobs for taxonomists or bee identifiers. Field taxonomists that can identify bees in the field could reduce specimen collection; similarly, taxonomists that specialize in photo identification as all or part of their salaried work ("eTaxonomists") would further reduce reliance on pinned specimens. There could be taxonomists whose sole or primary responsibility is to teach and train other bee identifiers or taxonomists. Taxonomists could contribute to a number of computer-based or highly technical areas of work, including AI development, database management, standards development (emphasizing taxonomic details and identifier acknowledgment), and molecular tool development. Collection management was also suggested. Support for specimen storage is limited, but robust voucher collections are critical for the future of bee taxonomy and native bee monitoring. Working in museum collections to create loaner reference collections for other identifiers supports taxonomic infrastructure, though maintaining the location and status of those loaned collections is important for their perpetuity. Agencies, labs, or other non-museum entities with collections should engage with curation experts to ensure their specimens are managed properly, supporting taxonomy. Further, it was suggested to create collections for federal agencies in the same way these agencies have and manage herbaria. There are multiple means through which a national native bee monitoring strategy can support taxonomic infrastructure.

Breakout 2: Establishing strategic taxonomy positions or resources in the US

What are the critical missing non-personnel resources (keys, verified material, etc.) for bee taxonomic work in North America?

There were many resources listed by workshop attendees in response to this question, and discussions were connected through themes of accessibility, clarity, transparency, simplicity, and equity. Overall consensus emerged around ensuring equal access to taxonomic resources for people of all skill levels and working to make these resources easier to understand. Some attendees suggested creating incentives for contributing to these resources to encourage their use and development.

The most frequently mentioned resource needed for native bee taxonomy in North America was taxonomic keys. Many keys currently in use have not been updated in decades; further, the language and terminology used in those keys is vague and full of jargon. There were many calls for updating taxonomic keys to reflect modern nomenclature and improve readability and interpretation for a broader audience. Modern keys would also benefit from the addition of detailed imagery of identifying characteristics. Illustrated couplets were mentioned in workshop talks and breakout discussions; these can make keys easier to use and improve identification accuracy. Many keys currently in use are text only or feature line drawings that can be difficult to interpret. Keys should be more broadly accessible; online keys could be created to meet all these needs. Attendees agreed that most bee taxa need updated keys, but there were different ideas on how to prioritize these updates. Some thought that the oldest, most outdated keys should be updated first, while others thought that more difficult taxa groups should be addressed right away. Taxa containing a high number of species, in particular Andrena spp., meet both criteria; attendees suggested that large groups like these could be split geographically for more detailed development of their updated keys. Lastly, attendees suggested that keys be curated online somewhere, making it easier for taxonomists and bee identifiers to know which keys are most relevant or best to use.

Reference collections were another frequently mentioned resource needed for North American native bee taxonomy. These collections provide type or study specimens for bee identifiers to compare for verification and for research taxonomists to assess when revising nomenclature. Type specimens for most bee species should be determined and this information should be transparently shared online; additionally, images for each type specimen should be readily available to avoid a backlog in loan requests for physical type specimens. Attendees suggested that the lack of designated reference collections for many bee taxa should be addressed. Improving accessibility of reference collections and specimens was frequently discussed. Digitization of bee collections generally is a topic of concern, but perhaps prioritizing type specimens and reference collections for digitizing would provide a quick benefit to taxonomists, bee identifiers, and other learning about bees. Creating multiple reference collections across the US that are regionally-based would improve access to physical specimens, but multiple attendees thought that state-based collections would be ideal. Attendees requested that supporting information for these collections, particularly related to the identifier(s) or determiner(s) of the specimen, be created or updated following some sort of data standard. Who has determined type specimens is important information, as well as contact information for the most recent determiner and/or the curator responsible for the specimen. Existing reference collections could use support for updated and continuing curation, through salaried curator positions, upgraded or additional storage space, database management software, and equipment. Equipment for curation and specimen management is extensive, including storage cabinets, cupboards, drawers, and boxes, microscopes, freezers, pins, printers, high-capacity computer hard drives or servers for databases and digitization, cameras, and more. One last point made when discussing reference collections was revisiting undescribed specimens. These could be added to a possible morphospecies database or receive some designation of their undescribed status to prevent their use in diversity analyses while still retaining their potential taxonomic value.

High-resolution images were mentioned in discussions for both updated keys and digitized reference collections, but attendees suggested multiple use cases for such imagery beyond these. Images have value for bee identification and improve access to high-quality taxonomic information. There were multiple requests for an easily accessible and searchable database of numerous clear and detailed images for every bee species. Ideally, each specimen would have images of all angles to show details of multiple body parts, and multiple specimens could have imagery taken to display variability within species. There were also requests for SEM images to show the details necessary for a positive species identification. AntWeb.org is an online database of detailed, high-resolution images of ant specimens that can be used for identification; there were calls to replicate this resource for bees and this and multiple previous RCN workshops. Some attendees mentioned linking images to bee life history habits or traits; this work is currently undergoing through the BigBee project based at the University of California Santa Barbara. The Bee Library of BigBee is uploading high-resolution specimen imagery for native bees and linking those images to trait information, including body size, sociality, nesting, biotic associations, thermal tolerance, and more. In concert with BigBee and other digitization efforts, some attendees suggested providing custom specimen images from insect collections. Technicians associated with collections could be emailed for imagery requests, then take the custom photos and send them to the requesting scientist. Lastly, high-resolution imagery could support machine learning for AI species identification tools.

Species checklists were another requested resource; while many state or regional checklists have been completed, revised, or are soon to be published, there is no comprehensive bee species checklist for the United States. Species checklists should have few taxonomic or geographic gaps. These species lists could be hosted on an reputable, verifiable, and accessible online clearinghouse of some sort that would feature resources for taxonomy, identification, monitoring, conservation, and more. An additional resource on this clearinghouse could be a dictionary or glossary for taxonomic terms found in keys and other taxonomic literature. Another ant resource mentioned by attendees in this context is AntWiki.org. AntWiki has pages of detailed information and imagery for thousands of ant species, and any ant expert can contribute that information. The accessibility and transparency of AntWiki, along with its moderation by a dedicated team of experts, contributes to its legitimacy as a resource for ant scientists.

Supporting taxonomists through training, development, and career support was mentioned. Taxonomy is a crucial component of native bee monitoring, collections, biology, ecology, and more; showing that those contributions are valued through support of professional development could increase and improve access to taxonomic knowledge. Hosting discussion groups for taxonomists or bee identifiers to gather facilitates knowledge exchange and could improve morale. Creating a listserv to focus on species identification, verification, and questions related to taxonomic keys and other literature is another option. Ideally, bee identification training would be more accessible online; improving access to resources like the Bee Course was frequently requested. Additionally, there were requests to expand in-person identification training through more intensive, taxa-focused workshops. Support for travel to these workshops would help taxonomists and bee identifiers participate and grow their skill sets.

A taxonomic resource that is growing in importance and needs additional support is DNA reference libraries. DNA can be used to both verify species identifications and revise existing nomenclature. DNA adds certainty to taxonomy by eliminating human error in species identification. These libraries can be accessible online and share information on native bee genomes and DNA barcodes. They can also feature information on metabarcoding and eDNA method development and clarify how this information affects taxonomic keys and species concepts. Specimens that have genomes or barcodes should have their location shared, as they may not come from a museum specimen or other digitized records.

Multiple other resources were suggested in response to this question. Printed, historical resources were requested, including old, out of print, but potentially the most recent taxonomic keys. Printed material could make study material more accessible for beginning taxonomists and bee identifiers. Related to this, more entry-level public facing identification material similar to The Bees in Your Backyard by Joe Wilson and Olivia Messinger Carril would connect the public to native bees. These texts could be study material to support the expansion of Master Melittologist programs held by Cooperative Extension. For professional taxonomists or bee identifiers, clarifying species concepts, or providing clearer guidance on what makes a species, was requested. More information on bee species, including range maps, floral associations, and sound or acoustic habits could support bee identification and nomenclature revision.

What are some geographic gaps for taxonomic knowledge on bees that can be filled with additional positions? What about taxonomic gaps, for specific bee groups?

Every geographic region of the US except the Northeast was mentioned as lacking some level of taxonomic knowledge. There is major interest in exploring the native bee species of the Mountain West region of the US including Utah, Arizona, New Mexico, Nevada, Idaho, and Montana. Other regions mentioned in order of frequency were: the Southeast (GA, SC, FL, AL, MS, LA), Plains Interior (ND, SD, IA, KS, MO, NE, OK, AR, TX), Appalachia (NC, KY, TN), and the Desert West (including parts of CA, AZ, NM, NV, UT). General areas of concern mentioned with limited taxonomic knowledge were conserved lands, whether they be federal, state, or private, along the Mexican border, and rural or less populated areas. Two habitat types were mentioned for more monitoring: forests and wetlands; further, seasonal gaps were mentioned, in that there is little sampling or monitoring in the earliest and latest parts of the growing season. Gathering this information would close gaps in taxonomic knowledge.

There were some options presented to fill these gaps with new positions. Federal agencies that work with native bees could have multiple taxonomists on staff like they do for plants and pest insects; these taxonomists could specialize in the geographic regions of the country with limited taxonomic knowledge. An alternative would be a federally coordinated program with regional centers. Ideally, each state would have a dedicated native bee taxonomist; though dedicated bee identification services would also ease the taxonomic bottleneck. These professionals may not be government employees; they could be museum employees, academic staff, or independent consultants. Their primary job function should be taxonomic research and bee

specimen identification. Strategic locations for these positions suggested were the American Museum of Natural History in New York City, the California Academy of Sciences in San Francisco, or the USDA ARS Pollinating Insects Research Unit in Logan, Utah. More locations in the Plains Interior, Southeast, and Appalachia could be identified. Lastly, it was suggested that more projects to create regional, state, or local level native bee species checklists could be conducted; support staff could verify identifications on collected or observed specimens.

There were multiple taxa listed where gaps in knowledge exist. Kleptoparasitic species were most frequently mentioned, including Nomada, Sphecodes, and Stelis. The next most mentioned taxa was the genus Andrena, followed by small Lasioglossum (Dialictus) and Perdita. The genera Mellisodes and Hylaeus were mentioned as taxa whose identification keys need updating. Lastly, some Osmia species and the genera Dufourea and Hesperapis were mentioned as needing more taxonomic background.

What role(s) can alternative and complementary methods, like DNA barcoding and machine learning, play in addressing the taxonomic bottleneck?

Attendees had multiple perspectives in response to this question. The most common perspective embraced these technologies as potentially transforming the way bee specimens are identified and nomenclature is confirmed or revised. Expanding the practice of DNA barcoding could lead to the creation of robust DNA barcode libraries that could confirm species identifications; similarly, improving machine learning algorithms with more high-resolution imagery could improve the performance of AI-based bee identification tools. Prior to identifications or verifications, barcoding and machine learning could be used to speed up specimen sorting. These technologies could lead to reduced reliance on specimens, as barcoding can be used to ID bees from leg sections or machine learning can ID bees from images. Reducing lethal collections is important for monitoring threatened or endangered bee species. However, it was suggested that while non-lethal collections could reduce the taxonomic bottleneck through barcoding and AI identifications, more specimens could be collected over the long term owing to the ease of identification. With a robust DNA barcode library, eDNA methods could become more commonplace. eDNA can summarize bee communities and floral visitors over large scales quickly and is an effective way to assess bee occupancy of a site without physically observing an individual. Additionally, barcodes could be useful for fecal sampling methods for pathogens or relatedness. Attendees suggested the

Another perspective was that other priorities should be pursued before expanding access to barcoding and machine learning methods. First, a stronger taxonomic backbone is needed before moving into new technologies. Barcode libraries and machine learning models would be more accurate with better taxonomic information going into them; attendees with this perspective argued that focusing on the current backlog, updating keys, and improving access to literature would be better uses of limited resources. Second, the infrastructure to support barcoding and machine learning is very limited and creating more infrastructure is prohibitively expensive. Access to barcoding labs and imagery equipment is limited. These methods may not be very transparent or reproducible. Countering this, though, the MinION DNA sequencer is

inexpensive and accessible. Last, some attendees were concerned about the lack of use cases for barcoding and machine learning to ease the taxonomic bottleneck and suggested that what infrastructure currently exists could be used for testing and refinement of identification protocols before being expanded.

Two other perspectives were presented regarding barcoding and machine learning. The first was that DNA barcoding may be better suited to easing the taxonomic bottleneck than machine learning. DNA is unique for every species and difficult to refute, whereas very high-resolution imagery may have trouble distinguishing between some very morphologically similar bee species. Andrena and Dialictus were specifically mentioned as bee genera that may benefit more from barcoding for positive identification than machine learning algorithms. The last perspective presented is that both barcoding and machine learning are good supplements to existing taxonomic methods, though neither should be relied on to replace the work done by taxonomists and bee identifiers. Improving the capabilities of barcoding and machine learning methods would require significant investment of taxonomists' time to confirm nomenclature and verify identifications before protocols could be expanded to use by non-taxonomists. These methods could be worked on with current infrastructure and ultimately support traditional taxonomic methods, as better genetic and morphological information could inform species concepts and aid in improving identification or verification accuracy.