

# Flight of the Bumblebee: Using Acoustics to Eavesdrop on Bees and Pollination

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## Summary

We all know that bees buzz, right? But did you know that their buzzes can give us clues about the health of the environment? They are important as pollinators, yet many populations of different bee species are declining around the world. We want to help them, but we still have a lot of basic questions about them such as: Where do different species live? How many are there? Which flowers are they visiting? How do they react to changes to the environment and climate? Their buzzes may help us answer these questions. Like all sounds, the buzzes made by bees can be measured by frequency, and we found that different groups of bees buzz with different frequencies. Using microphones and a buzz-detecting computer software, we provide new information about bee activity and pollination. This ‘eavesdropping’ on bees may help us better protect them and the pollination they provide.

## Background

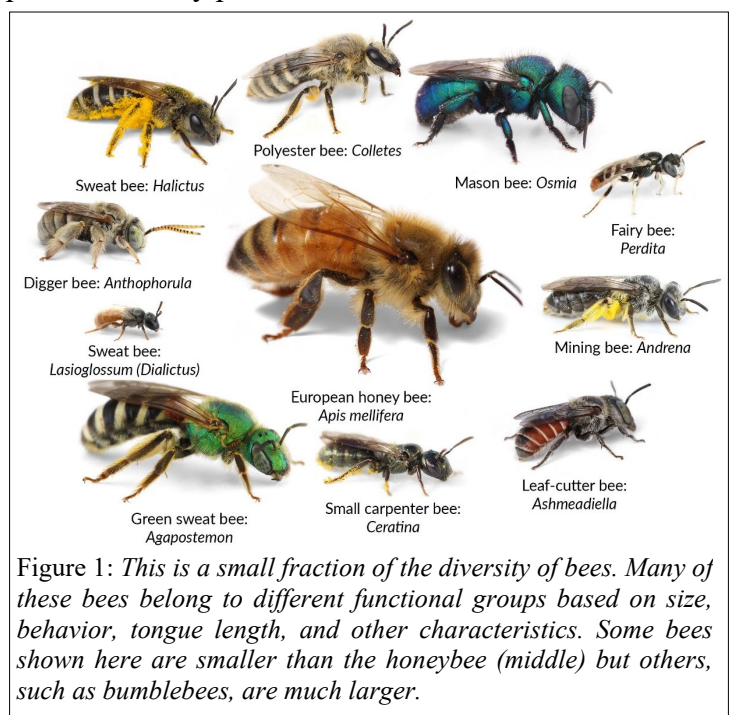
Most of the 350,000 flowering plant species on our planet require pollinators to reproduce. Bees are the most important pollinators for these plants, which include the majority of our food crops such as fruits, nuts, and vegetables. Did you know that there are more types of bees than just honeybees? There are over 4,000 species of bees (Fig. 1) in the United States and more than 20,000 worldwide!

Many of these bee species have different roles, or *functions*, as pollinators within ecosystems. One type of bee cannot pollinate all the flowers of different shapes and sizes. For example, some bees have long tongues for sipping nectar from long-tubed flowers. Other types of bees are large or small enough to access different sized flowers. Scientists have placed these different kinds of bees into **functional groups**.

They have learned that certain flowers may not be pollinated if a functional group of bees is missing. In this way, these groups help maintain biodiversity by pollinating different types of flowers.

Populations of many bee species have been declining over the last several decades. We want to help them, but we don’t know enough about them yet. With so many different kinds of bees in diverse ecosystems, they are difficult to monitor and study. Current monitoring practices require bees to be caught and killed for study, which may harm bee populations even more.

We developed an alternative monitoring approach using the **acoustics** of bee buzzes. Some bees buzz with higher *itches* or **frequencies** than others. We use microphones in the field to ‘eavesdrop’



**Functional groups:** a collection of organisms that performs a particular role in an ecosystem  
**Acoustics:** the study of sound and its properties  
**Frequency:** the property of sound that deals with pitch  
**Eavesdrop:** to secretly listen

on bees then we analyze sound recordings using computer software. When viewed on a **spectrogram**, buzzes create unique patterns that look like ladders (Fig. 2). We used a computer program that is able to find and interpret these patterns. This information may be useful to tell us something about different groups of bees and the pollination they provide.

Now let's take a look at the research we did.

**Spectrogram:** a visual representation of a sound that shows frequency and amplitude in time.

We first describe the methods, or *how* we did it, and the results, or *what* we found. Then, we discuss how this new tool might be used.

### Experimental methods and results

#### 1. Can groups of bees be distinguished by their buzz frequency?

Bees are placed into different functional groups based on their size. For example, some flowers need bigger bees to open and pollinate them. We also know that as the mass of a vibrating material increases, the frequency of the sound waves it produces tends to decrease. This is familiar if you play the guitar; the thicker the string, the deeper the sound and the lower the frequency (pitch). We hypothesized that the frequency of buzzes made by larger bees while in flight would be lower than that of smaller bees.

We studied two bumblebee species that differ in size (Fig. 3): the golden-belted bumblebee (*Bombus balteatus*) and the forest bumblebee (*Bombus sylvicola*). We caught many of each and chilled them in coolers to make them easier to handle. We measured the length of their wings, which can be used as a measurement for body size. The smaller forest bumblebees have shorter wings and the larger golden-belted bumblebees have longer wings.

We then put the bees into cages with microphones to record the flight buzzes. We recorded the sound of the bees for about six minutes and repeated this for a total of 28 bees (15 golden-belted and 13 forest). We put the recordings through our software and found that as wing length increased, the

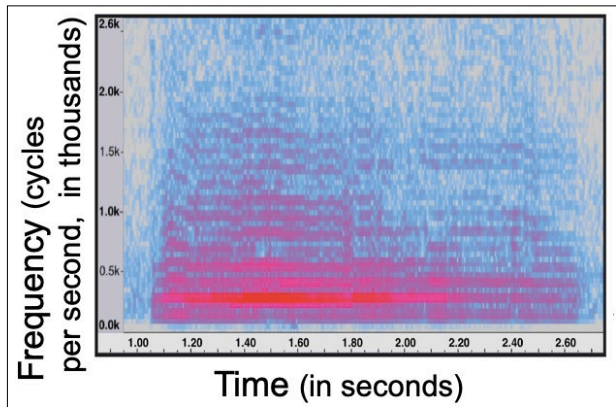


Figure 2: A spectrogram of a typical bee buzz. Frequency is measured by cycles per second and the darker the pink, the louder it is. Notice the stacking pattern of the frequencies.



Figure 3: The golden-belted bumblebee (left) and the forest bumblebee (right).

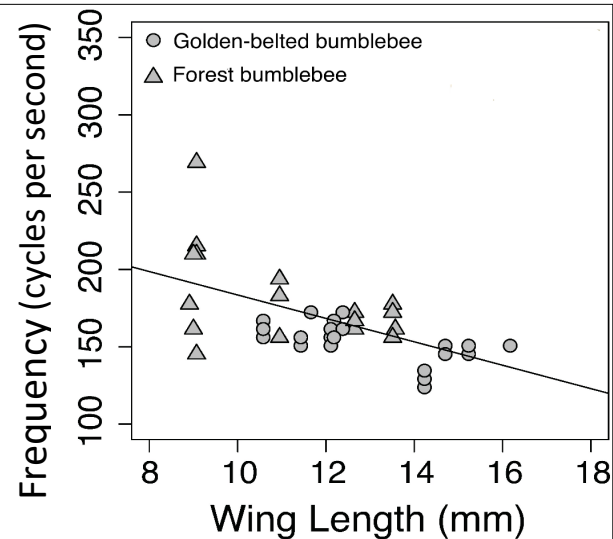


Figure 4: Relationship of frequency of flight buzz to wing length (in millimeters). Each circle represents one golden-belted bumblebee and each triangle one forest bumblebee. Note that there is overlap; not all the forest bumblebees have higher frequencies. However, the average of each species is different. The black line represents the overall trend of these averages.

frequency of flight buzzes decreased. This means that bigger bees generally have deeper sounding buzzes and smaller bees have higher pitched buzzes while flying (Fig. 4).

Functional groups of bees are also categorized by tongue length. Shorter-tongued bees feed on short-tubed flowers while longer-tongued bees tend to feed on long-tubed flowers. We thought these differences might produce a change in how the bees buzz while flying. We hypothesized that bees with different tongue lengths would have different frequencies of their flight buzzes.

To study this, we read science papers published by other researchers. We looked for research that reported bee tongue length and flight buzz frequency for bumblebees. This information was available for the two species we studied plus 17 others. We found that bumblebees with longer tongues typically have a lower frequency than bees with shorter tongues (Fig. 5). That means just by measuring buzzes we can identify different functional groups of bees in an ecosystem!

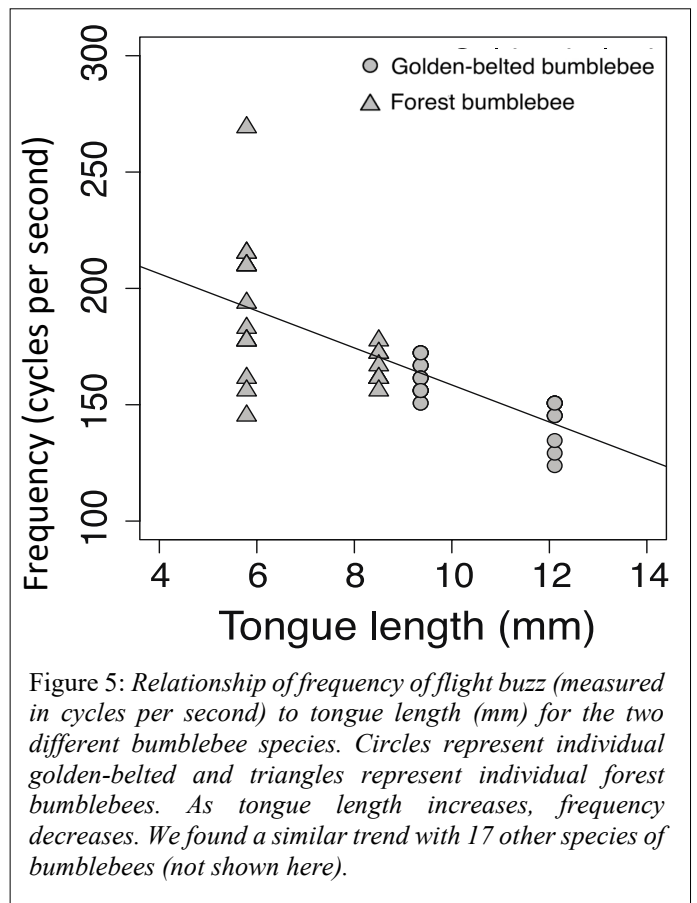


Figure 5: Relationship of frequency of flight buzz (measured in cycles per second) to tongue length (mm) for the two different bumblebee species. Circles represent individual golden-belted and triangles represent individual forest bumblebees. As tongue length increases, frequency decreases. We found a similar trend with 17 other species of bumblebees (not shown here).

## 2. Do observations of bees match the numbers of buzzes measured by acoustics?

We expected our buzz-detecting software to find a lot of buzzes when there were a lot of bees and few buzzes when there were few bees. To test this, we set up microphones in three different flower patches on the mountain. Each patch was about the size of two football fields and had many wildflowers, including Parry’s clover (*Trifolium parryi*) and alpine clover (*Trifolium dasyphyllum*) which are pollinated by bumblebees (Fig. 6).



Figure 6: Parry’s clover (left) and alpine clover (right)

We placed five microphones in each patch and eavesdropped on bees for six hours. We also counted bees during 45-60 minute walks through the patches. This differs from traditional sampling techniques, which require catching and killing bees in order to study them. We found that the more bees that we saw during our walks, the more buzz activity was found by the software. This means that our acoustic monitoring system can accurately measure bee activity in patches of flowering plants (Fig. 7).



3. Can buzzes tell us something about pollination in the landscape?

Lastly, we wanted to know, do more buzzes mean more pollination? We measured pollination by counting the number of seeds produced by plants. We selected 25 clover plants of each of the two species of clover. Then we counted the seeds from each plant after pollination and seed development. We also set up a **control** by counting the seeds of an additional 25 plants of each species that had cages around them to exclude bumblebees. We hypothesized that flight buzzes would be positively **correlated** to the number of seeds counted for the experimental group but that few seeds would be observed in the control group.

We found data to support this: the more buzzes recorded in a patch, the more seeds were produced by plants. This means that we may be able to predict pollination just from buzzes of bees! We found that when bumblebees were excluded from the flowers, the predictions between the number of buzzes found and the number of seeds produced per plant was much less accurate (Fig. 8).

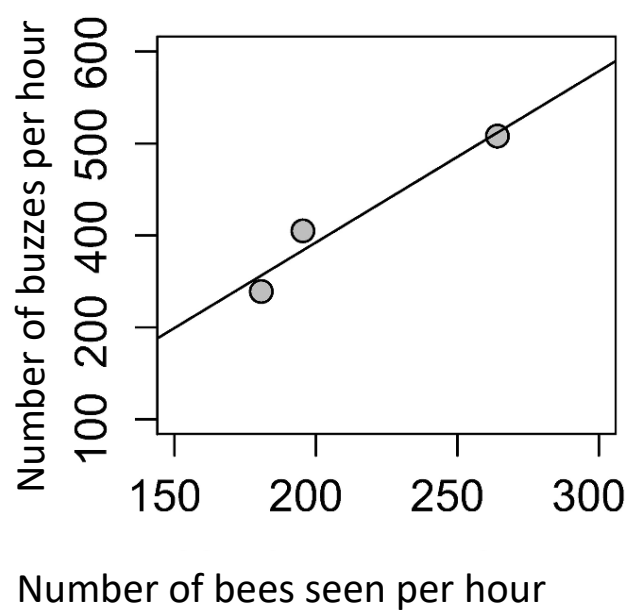


Figure 7: Relationship of visual bee counts and buzzes found with software. Each of the circles represents one of the surveyed flower patches.

**Control:** a part of the experiment used to minimize effects of other variables and allow for comparison  
**Correlation:** a relationship or connection between two or more objects.

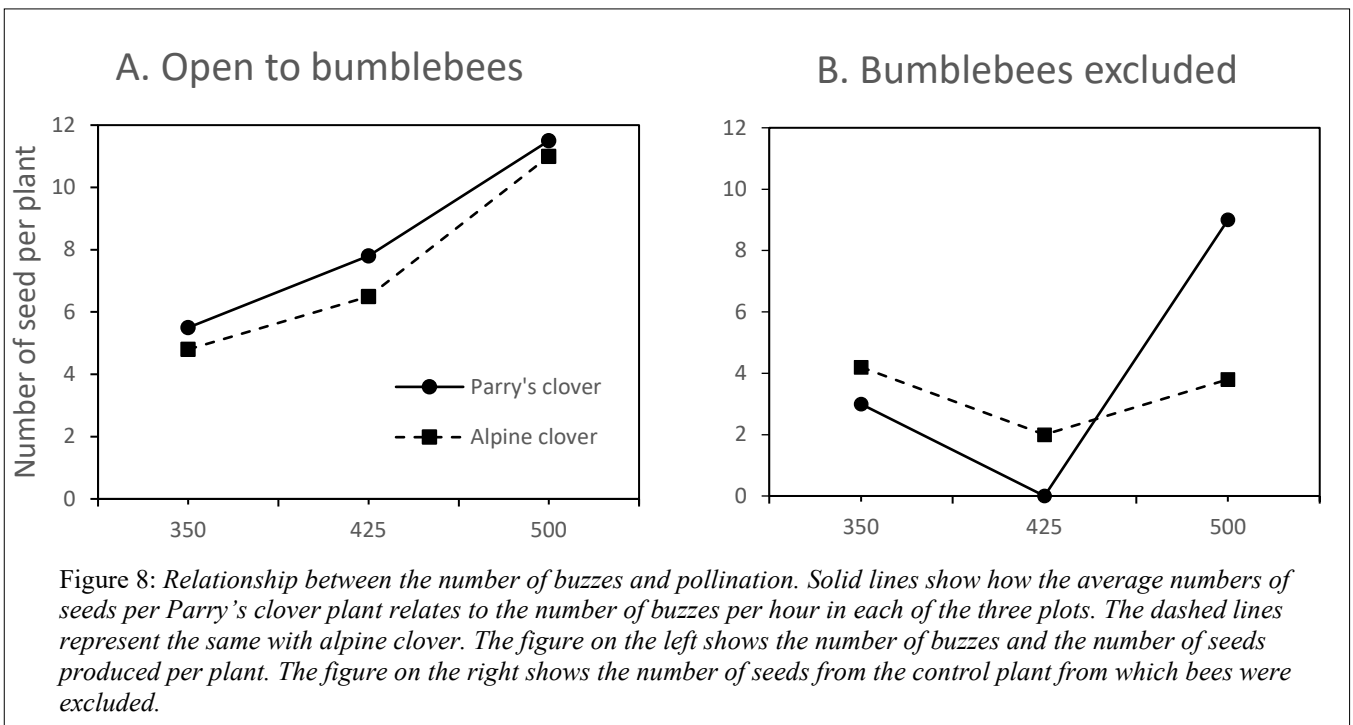


Figure 8: Relationship between the number of buzzes and pollination. Solid lines show how the average numbers of seeds per Parry's clover plant relates to the number of buzzes per hour in each of the three plots. The dashed lines represent the same with alpine clover. The figure on the left shows the number of buzzes and the number of seeds produced per plant. The figure on the right shows the number of seeds from the control plant from which bees were excluded.

## Discussion

Now, let's go over the results. As you recall, the problem at hand is that many species of bees – which are very important for our crops and natural ecosystems – are declining around the world. Better ways to study and monitor them could help sustain them and the pollination they provide.

We have developed a method of acoustic monitoring that is an alternative to traditional monitoring. We show that by ‘eavesdropping’ on bees, we can detect different functional groups, total bee activity, and pollination. This means that we can use acoustics to accurately monitor bees and pollination. Importantly, this method is much easier and cheaper than other techniques. It can help us better understand bees and how pollination changes across seasons or landscapes, or in response to a changing climate. It could also allow us to detect and to respond quickly to areas not receiving adequate pollination.

Acoustic monitoring may be particularly useful for improving agriculture. It could allow farmers to quickly know whether their crops are being sufficiently pollinated when they are in bloom. This would give them the information to decide if they need to supplement their crops with managed pollinators (such as honeybees) that are brought in to pollinate. This could help farmers save money and could benefit the wild bees if they do not have to compete with exotic species for food resources (Fig. 9).

While biologists have long used acoustics to study a diversity of animals – from bellowing orangutans to chirping frogs – they have not been developed for bees. What we have described here is very exciting, but it is only one example of how we can use acoustics to answer ecological questions relating to bees. Knowing what you have learned about ecology and acoustics, do you see any other applications?

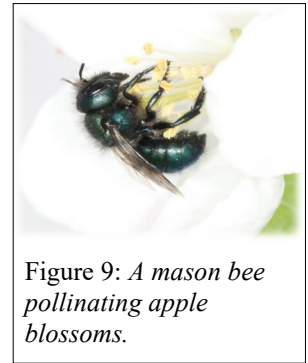


Figure 9: *A mason bee pollinating apple blossoms.*

## Conclusion

The pollination that bees provide for most of the world's plants is vital for the health of humans and nature, and our planet's biodiversity. Despite their importance, however, many bee populations around the world are declining. Better monitoring of bees could help us understand how to better preserve them. We show that acoustics are a viable monitoring technology for bees. This new technology can detect and measure different functional groups, bee activity, and pollination. A better understanding of bees may help preserve pollination, reverse trends of declining populations and maintain a healthy environment.

## Glossary

**Acoustics:** the study of sound, or more specifically, the study of the physical properties of sound.

**Control:** something to which you can compare a variable in your experiment. Controls are used to minimize all of the effects in an experiment except for the variables in which you are interested.

**Correlation:** a relationship or connection between two or more objects. Correlations are typically described as being positive, negative, or absent.

**Eavesdrop:** to secretly listen in on a conversation.

**Frequency (pitch):** the number of sound waves in a given moment, measured in cycles per second.

**Functional group:** a group of different organisms that perform a similar role in an ecosystem.

**Spectrogram:** a visual representation of sound that shows both the frequency (pitch) and amplitude (loudness) of sound waves.

## Supplemental Material

ID number	Bumblebee species	Buzz frequency (cycles per second)	Tongue length (millimeters)	Wing length (millimeters)
1	Golden-belted	172	9	12
2	Golden-belted	156	9	12
3	Golden-belted	151	9	11
4	Golden-belted	167	9	11
5	Golden-belted	172	9	12
6	Golden-belted	167	9	12
7	Golden-belted	172	9	12
8	Golden-belted	151	9	12
9	Golden-belted	156	9	11
10	Golden-belted	156	9	11
11	Golden-belted	172	9	12
12	Golden-belted	167	9	12
13	Golden-belted	172	9	12
14	Golden-belted	162	9	12
15	Forest	183	6	11
16	Forest	215	6	9
17	Forest	162	6	9
18	Forest	178	6	9
19	Forest	215	6	9
20	Forest	156	6	11
21	Forest	269	6	9
22	Forest	210	6	9
23	Forest	178	6	9
24	Forest	145	6	9
25	Forest	194	6	11
26	Forest	210	6	9
27	Forest	210	6	9

*Suggested activity:* This is a table of the data showing buzz frequency, tongue length, and wing length of different golden-belted and forest bumblebees. Notice how there are some overlapping frequencies: bee #24 actually has a lower buzz frequency than all of the golden-belted bees although it is smaller than them (we would expect smaller bees to have higher buzz frequencies). But what about the average of all them?

Try recreating the graph from figure 4. First, plot all of the individual bees following the same format from figure 4. Then find the averages of both buzz frequency and wing length for both of the species to create your trendline (the black line that runs through the middle of the graph). Unlike figure 4, this table only includes worker bees and not queens (which are larger than workers), so it will not match perfectly to the graph from above. (This table also has information for recreating figure 5 from the text – again, with only the workers and not queens. Give it a try to see if you get the same results!)

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Figure 3b courtesy of Zack Miller

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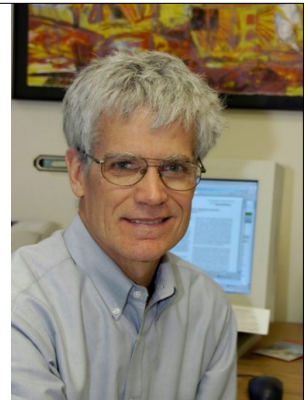


## Contributing Authors:



**Zachary Miller**, left, Graduate Research Assistant, University of Missouri: “I first became interested in bees during my service as a Peace Corps Volunteer in Paraguay, South America. I spent countless hours working with honeybee colonies and was captivated by their behavior and cooperation. I found it incredible that they were able to construct such sophisticated dwellings all from tiny drops of nectar and dabs of pollen collected from flowers. This work blossomed into a deeper awareness and fascination of the diversity of bees in the world and the plants that depend on them for pollination. It also opened my eyes to the dependence of humans on the work of pollinators. Now, I study pollination and bumblebee behavior in hopes to help understand how bees and flowers are reacting to a changing planet and how humans can continue receive the fruits of the labor of these marvelous little creatures.”

**William Folk, PhD.**, right, is a professor of Biochemistry at the University of Missouri. “I first became aware of bees as a child in Alaska, when I stumbled across a nest in the ground and I was stung many times by the angry bees before my mother came to my rescue. As a high school student in Houston Texas, I collected insects and studied fruit fly genetics as science projects. That introduction to how genes determine our shape and behavior fascinated me, and throughout my career as a scientist I’ve studied genes in bacteria, plants, animals and humans. While those studies keep me very busy, I do enjoy getting outside – and help at our daughter’s goat farm where we keep honeybee hives, and I work to improve the habitat for native bees. We are finishing a large barn quilt that will have a representation of bees visiting flowers – and will soon have it up!



**Nicole Miller-Struttman, PhD.**, left, is an evolutionary ecologist at Webster University. As a post-doctoral Fellow at the University of Missouri, Dr. Miller-Struttman co-authored the published research that is the basis of the *Flight of the Bumblebee* anchor text. “I fell in love with the teddy-bears of the insect world, bumble bees, when I was a graduate student. They are intelligent, fascinating, social insects. Many of them are also, unfortunately, declining. They are not alone; insects all over the world are struggling to survive. In collaboration with citizen scientists, we use non-lethal methods, such as acoustic monitoring and photo surveys, to figure out how we can help them. Insects are adaptable creatures. They can evolve relatively quickly, if we provide them the “space” to do so. In addition to my research, I work with teachers, gardeners, libraries, and more to rebuild habitats that will, hopefully, provide that opportunity.”

**Candace Galen, PhD.**, right, led the research team at the University of Missouri that developed an important yet inexpensive acoustic listening system using small microphones in the field to monitor bees in flight, making it possible to monitor bee activity and subsequent pollination of crops. “Causes of pollinator decline are complex and include diminishing flower resources, habitat loss, climate change, increased disease incidence and exposure to pesticides, so pinpointing the driving forces remains a challenge,” said Dr. Galen, professor of Biological Science. “For more than 100 years, scientists have used sonic vibrations to monitor birds, bats, frogs and insects. We wanted to test the potential for remote monitoring programs that use acoustics to track bee flight activities.”

