Undergraduate research shows leaderless honeybee organizing

June 11 2007

Honeybee. Credit: James Ward

Undergraduate education generally involves acquiring "received knowledge" – in other words, absorbing the past discoveries of scholars and scientists. But University of North Carolina at Charlotte senior biology major Andrew Pierce went beyond the textbooks and uncovered something previously unknown.

Pierce's discovery has to do with detecting a significant new detail concerning the behavior of the European honeybee – perhaps the most studied and economically important insect on Earth. Beyond agriculture, the finding may also have key implications for understanding the dynamics of all social animals, including man.

Pierce's recently reported his research in an article appearing in the behavioral biology research journal Ethology, with co-authors Lee Lewis and UNC Charlotte biology professor Stanley Schneider, Pierce's mentor. Pierce was first author on the paper – a rare achievement for an undergraduate.

"It was a very good work and an impressive achievement for a student researcher – he got a publication as an undergraduate," Schneider noted. "I really like working with our undergraduate honors students – they are so bright."

Pierce, age 22, has been working as a researcher in Schneider's lab for the past two years through a UNC Charlotte Honors College program that fosters research experiences for undergraduates.

Using an ingeniously designed experiment, Pierce and his co-authors were able to document details of bee social behavior that fundamentally confirm the hypothesis that major colony activities are initiated by the cumulative group actions of the colony's older workers, not by the queen's individual decision.

What Pierce and colleagues found was that older workers gave signals to the queen and to the rest of the colony that it was time to swarm and leave the hive. Later, they were able to observe inside the swarm itself and see workers give the queen a signal, known as "piping" that tells her to fly.

"Researchers have never reported worker piping being done on the queen before, so some of what we found was exciting," Pierce said. "It was generally surprising to see the level of interaction that the older bees have with the queen. This doesn't normally happen in the hive," he noted.

"It's interesting because it shows that though the queen has a tremendous impact on the colony, she's not the decision maker," Schnieder said. "The colony is not a dominance hierarchy and, from a human perspective, this is unusual. Our human society is very dominance hierarchy structured --we have centralized systems of control. But bee colony systems of control are very different – they are totally de-centralized."

Schneider's lab studies the honeybee and its behavioral ecology. Like humans, honeybees are remarkable for living in large organized groups where highly developed social behaviors coordinate the efforts of thousands of individuals to accomplish complex tasks – manufacturing, community defense, environmental control and maintenance, food production, brood-rearing and education. Like human civilizations, bee societies follow organizational principles, such as following social rules (like human customs and laws) and division of labor.

But here the similarity ends. Bees do not have large brains and are not capable of complex thought like humans. Though the bee colony is centered around the queen and her reproductive capabilities, findings by Schneider and others indicates that she does not exactly "rule." Instead, the colony appears to be controlled by the anonymous consensus of the colony's workers.

Though it is of great interest to researchers studying social behavior, a great mystery still remains regarding how bee societies effectively direct and coordinate complex operations without a central controlling intelligence. Pierce's finding is part of an ongoing research effort in Schneider's lab aimed at understanding the mechanisms of leaderless societal management – in particular, the importance of two communication-related behaviors known as the "vibration signal" and "worker piping."

Different from the famous "waggle dance" that foraging worker bees perform to tell other bees where to find a food source, the vibration signal appears to be a more general, multi-purpose form of communication. Schneider has concluded that this signal, which consists of one bee grabbing another bee (worker or queen) and then vibrating its body, does not convey a specific message, but instead is a form of "modulatory communication" that alters existing bee behaviors (making bees perform their jobs more actively, perhaps) or changes bees response to other signals.

Pierce and Schneider have documented in their current paper how workers use the vibration signal to prepare the queen for swarming by making intrusions into her "court" and vibrating her hundreds of times an hour. She responds by changing her behavior -- reducing her food intake, slowing egg laying and becoming more active. At this point, the workers begin to send a second signal that researchers call "worker piping" at a fevered pitch. Piping, which consists of bees making contact and vibrating their wing muscles rapidly, appears to be a general instruction to fly.

The researchers document that the workers stop using the vibration signal when the queen flies and leaves the nest with the swarm. Piping, however, continues in the swarm, as the bees need to make the queen fly again once a new nest site has been selected.

"Drew Pierce did this project last summer," Schneider explained. "We constructed a special observation stand where we could actually see how workers were interacting with queens inside a swarm cluster, where they are hanging in a tree. That was really interesting, because nobody had ever really been able to look at that before," he noted.

"What was interesting was how little attention the workers pay the queen – until it became time to go – to become airborne. Then they started interacting with her at very high rates, and performing the 'worker piping' signal on her. This interaction is a behavior that nobody had described before," Schneider said.

Contrary to the popular conception of a colony controlled by instructions from its breeding queen mother, the research shows a picture of the queen as a passive egg layer whose own behavior is programmed, with changes dictated by signals delivered by older workers.

This does not mean, however, that the colony is controlled by a key group of experienced bees either. The worker bees that deliver the critical signals have short life-spans and tiny brains incapable of managing the colony the way a human village might be managed by a council of elders. Instead, critical strategic choices, such as the assessment that it is time to divide the colony and swarm, appear to be decided by the dynamics of the group itself. Social interactions, environmental pressures or group dynamics in some still-unknown way initiate a string of behaviors that effectively manage complex group activities.

"It is a real challenge to understand how bee colonies work, but it is also fascinating because they are so different. Evolutionarily, they got to the same point as humans – living in these highly organized societies that function with remarkable efficiency -- but they are organized so differently when you start digging into them," Schneider said. "It's interesting that these major differences can result in the same emergent social properties. It may tell us something about ourselves."

Source: University of North Carolina at Charlotte