Scientists unravel the secret world of elephant communication

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It's a cloudless July afternoon in Etosha National Park in northern Namibia, and ecologist Caitlin O'Connell-Rodwell is scanning the horizon for elephants. "It's so fantastic here," she says. "We're constantly seeing elephants, rhinos, zebras, ostriches - it's the Garden of Eden."
A research associate in the Stanford University School of Medicine, O'Connell-Rodwell has come to one of Africa's premiere wildlife sanctuaries to explore the mysterious and complex world of elephant communication. She and her colleagues are part of a scientific revolution that began nearly two decades ago with the stunning revelation that elephants communicate over long distances using low-pitched sounds that are barely audible to humans.

In 1997, O'Connell-Rodwell took this discovery in a bold, new direction by proposing that low-frequency calls also generate powerful vibrations in the ground - seismic signals that elephants can feel, and even interpret, via their sensitive trunks and feet.

Scientists have long known that seismic communication is common in small animals, including spiders, scorpions, insects and a few vertebrate species, such as white-lipped frogs, kangaroo rats and golden moles. Seismic sensitivity also has been observed in elephant seals - huge marine mammals not related to elephants.

But O'Connell-Rodwell was the first to suggest that a large land animal is capable of sending and receiving vibrational messages. "A lot of research has been done showing that small animals use seismic signals to find mates, locate prey and establish territories," she notes. "But there have only been a few studies focusing on the ability of large mammals to communicate through the ground."

Her insights generated international media attention after the Dec. 26, 2004, tsunami disaster in Asia, following reports that trained elephants in Thailand had become agitated and fled to higher ground before the devastating wave struck, thus saving their own lives and those of the tourists riding on their backs. Because earthquakes and tsunamis generate low-frequency waves, O'Connell-Rodwell and other elephant experts have begun to explore the possibility that the Thai elephants were responding to these powerful events.

"Elephants may be able to sense the environment better than we realize," she says, pointing to earlier studies showing that elephants will sometimes move toward distant thunderstorms. "When it rains in Angola, elephants 100 miles away in Etosha National Park start to move north in search of water. It could be that they are sensing underground vibrations generated by thunder."

Frozen trunks

O'Connell-Rodwell began studying elephants at Etosha more than a decade ago. In July 2004, she returned with husband Tim Rodwell, a Stanfordeducated physician, to oversee the most sophisticated seismic experiment to date—an elaborate field study funded by Stanford's interdisciplinary Bio-X program.

Joining them in Namibia were four colleagues with a wide range of expertise: Colleen Kinzley, general curator at the Oakland Zoo; Jason Wood, a Stanford geoscientist; Katie Eckert, a University of California-Davis veterinary student; and Dave Shriver, a University of Iowa law student ("I deal with animal harassment issues," he jokes).

Equipped with amplifiers, speakers, geophones and video cameras, the research team spent a full month performing round-the-clock tests designed to see how elephant herds respond when specific calls are played back through the ground.

The researchers set up camp at Mushara waterhole - a freshwater spring where elephants, giraffes, lions and many other species gather day and night to drink or bathe during the dry Namibian summer.

To avoid disturbing this remarkable parade of wildlife, and to prevent one of these large creatures from invading tents or destroying delicate electronic gear, the research team erected a 7-foot-tall cloth barrier around the perimeter of the campsite. Though no thicker than a washcloth, the light-brown tarp proved an effective deterrent against wandering herbivores and curious lions.

"Large animals could easily jump over the tarp or go right through it, but I think they perceive it as a solid object," says Tim Rodwell, an epidemiologist who served the dual role of camp doctor and electronics guru.

Rodwell and O'Connell-Rodwell supervised construction of the campsite, which included four elevated tents, a cooking/dining area and a 20-foot-tall, two-story observation tower with a commanding view of the waterhole and surrounding scrubland.

Sitting in the upper level of the tower, O'Connell-Rodwell and Katie Eckert pay close attention to the wildlife below. "I try to get a good count of the elephants as they come in and a good view with the video camera," Eckert says.

The upper level served as command central for the four-week experiment—a high-tech headquarters crammed with laptops, cameras, cables and recorders and powered by solar energy.

"Elephants have generally been coming to the waterhole between noon and midnight, so all the cooking and major noise in the camp has to be done by 2 p.m.," O'Connell-Rodwell notes.

Peering through binoculars, she and Eckert finally spot four male elephants on the horizon. The bulls head straight for the waterhole and begin splashing, spraying and performing a variety of other aquatic antics.

Suddenly, and for no apparent reason, the four males step away from the water and freeze in unison, as if posing for a group action shot. O'Connell-Rodwell is particularly intrigued by one bull known as Billy Idol, easily recognizable by the extra holes in his large ears. "He's got a lot of ear piercings, hence his name," she explains.

Unlike the other males, whose trunks are frozen in midair, Billy Idol has placed his flat on the ground, the tip pointing inward toward his front feet. Billy and the others remain still like statues for several seconds. Finally, the spell is broken, and the quartet of bulls ambles back to the waterhole to resume drinking and socializing.

Synchronized freezing is a common behavior in the wild, even among large herds of 20 or more. Remaining motionless seems to enable elephants to focus their keen senses of smell and hearing on unfamiliar noises and odors in the air. But O'Connell-Rodwell believes they could be responding to tactile sensations as well.

"Bulls often lay their trunk on the ground when freezing," she observes. "We think they may be using it as a tool to detect vibrations in the earth."

Good vibrations

Elephants don't just feel the vibes, O'Connell-Rodwell says, they also transmit vibrational signals through the ground—long-distance seismic messages that could play a crucial role in their survival and reproductive success. "Perhaps they're sending out signals to potential mates far away," she says. "Or maybe they can tell if a predator is in the vicinity by picking up seismic cues from a distressed herd."

These underground messages may not be deliberate transmissions, but rather the byproducts of intense low-frequency sounds produced when elephants run, charge and vocalize. In the mid-1980s, scientists Katy Payne, Joyce Poole and their colleagues discovered that elephants emit a variety of infrasounds—calls too low in pitch to be heard by most humans. In 1989, Payne and her colleagues conducted a landmark experiment at a waterhole in Etosha demonstrating that these powerful infrasonic rumbles contain specific messages that can be heard and understood by other elephants more than 2 miles away.

Several years later, environmental scientist David Larom and his co-workers proposed that, under ideal atmospheric conditions, low-frequency calls could travel 6 miles or more through the air. Now in private industry, Larom has long been intrigued by O'Connell-Rodwell's work.

"This is important basic research," he says. "Like all creatures, humans perceive with limited spectra and sensory modes. We bias research with the unconscious and incorrect assumption that other animals 'see' the world as we do. Every time we discover otherwise, it expands the horizons of scientific knowledge and sends us the humbling and vital message that we are not, after all, 'the measure of all things.'"

Planthoppers and pachyderms

Larom met O'Connell-Rodwell in Etosha in 1992, the year she began her work at Mushara. "I started doing research on elephants for the Namibian Ministry of Wildlife and Tourism," she recalls. "I was looking for ways to help farmers keep elephants away from their crops. I wanted to see if there was something about elephant behavior, particularly their vocalizations, that we could use as a deterrent."

Having just earned a graduate degree in entomology at the University of Hawaii-Manoa, O'Connell-Rodwell noticed something about the freezing behavior of Etosha's 6-ton bulls that reminded her of the tiny insects back in the lab.

"I did my master's thesis on seismic communication in planthoppers," she says. "I'd put a male planthopper on a stem and play back a female call, and the male would do the same thing the elephants were doing: He would freeze, then press down on his legs, go forward a little bit, then freeze again. It was just so fascinating to me, and it's what got me to think maybe there's something else going on other than acoustic communication."

In 1995 she was accepted to the doctoral program in ecology at UC-Davis and began working with Professor Lynette Hart, an authority on the social behavior of large mammals. Their first goal was to prove to themselves, and to the scientific community, that elephants actually have the physical capability to send and receive low-frequency vibrations. To do that, they had to convince skeptical geophysicists, like Hart's brother, Byron Aranson.

"It was a unique collaboration," Hart says. "We started with the physics of it, then moved to behavior and how the animals would respond."

Getting geophysical

Over the next five years, Hart, Aranson and O'Connell-Rodwell conducted experiments with captive elephants in the United States, Zimbabwe and India. Using geophones buried in the soil, the scientists were able to confirm that low-frequency rumbles and mock charges do, indeed, generate measurable seismic waves that travel along the surface of the ground. In 1999, the UC-Davis team developed a mathematical model predicting that low-frequency vibrations have the potential of traveling up to 20 miles in the ground—potentially three times farther than airborne calls.

A year later, after earning a doctorate at UC-Davis, O'Connell-Rodwell moved to Stanford, where she designed a series of studies to test the model. In 2003, while working in the laboratory of Stanford geophysics Professor Simon Klemperer, she and her colleagues conducted a rigorous experiment with a trained male elephant held in captivity in Salinas, Calif. Several dozen geophones were installed in the ground to monitor the seismic waves generated each time the bull vocalized. The results indicated that elephant vibrations are unlikely to travel more than 2 miles in the soil, not 20 miles as previously estimated.

Why the discrepancy? Geology may be one reason. Seismic waves move at different speeds in different soils. In Salinas, vibrations race through the ground at 1,300 feet a second—twice as fast as in Etosha National Park. Because slower seismic waves maintain their integrity longer, it is possible that elephant vibrations in Etosha would travel farther than in Salinas.

"After we did the Salinas study, we realized that there were other things, like noise and wind, that we hadn't taken into account," O'Connell-Rodwell says. "Salinas is a farming area with a lot of tractor and generator noise in the background. But Etosha is a very quiet seismic environment, so we're hoping to get a more realistic assessment of how far elephant vibrations propagate in Namibia."

Breeding and warning

Scientists believe that an elephant's ability to converse over long distances is essential for its survival, particularly in a place like Etosha, where more than 2,400 savanna elephants range over an area larger than New Jersey.

"Elephants live in matriarchal breeding herds made up of mothers, aunts and their offspring," O'Connell-Rodwell notes. "Once males reach puberty, around age 12, they get kicked out and start traveling alone or forming small bachelor herds."

The search for a mate in this vast wilderness is further complicated by the elephant's reproductive biology. Females breed when they are in estrus—a brief period of ovulation that only occurs every two years and lasts just a few days.

"Females in estrus make these very low, long calls that bulls home in on because it's such a rare event," O'Connell-Rodwell says. These powerful estrus calls carry more than 2 miles in the air and may be accompanied by long-distance seismic signals, she adds.

Breeding herds also use low-frequency vocalizations to warn of predators. Adult bulls and cows have no enemies, except for humans, but young elephants are susceptible to attacks by lions and hyenas. When a predator appears, older members of the herd emit intense warning calls that prompt the rest of the herd to clump together for protection and then flee the scene.

In 1994, O'Connell-Rodwell recorded the dramatic cries of a breeding herd threatened by lions at Mushara waterhole. "The elephants got really scared, and the matriarch made these very powerful warning calls, and then the herd took off screaming and trumpeting," she recalls. "Since then, every time we've played that particular call at the waterhole, we get the same response—the elephants take off."

Reacting to a warning call played in the air is one thing, but what if the elephant could only feel the call through the ground?

To find out, the research team devised an experiment using an electronic shaker that converts acoustic sounds into vibrations. The device was brought to Mushara in 2002 and buried near the waterhole. Using long wires, the researchers connected the shaker to a tape deck installed in the upper level of the observation tower 100 yards away.

Every time a herd showed up at the waterhole, O'Connell-Rodwell would pop a tape of the '94 warning call into the deck, and the underground shaker would play it back as a seismic vibration. To make sure the elephants were feeling the calls and not hearing them, microphones were installed above ground so researchers could monitor all low frequency sounds in the air.

"The results of our 2002 study showed us that elephants do indeed detect warning calls played through the ground," O'Connell-Rodwell observes. "We expected them to clump up into tight groups and leave the area, and that's in fact what they did. But since we only played back one type of call, we can't really say whether they were interpreting it correctly. Maybe they thought it was a vehicle or something strange instead of a predator warning."

(To hear actual elephant vocalizations, visit the website [www.elephantvoices.org/index.php?topic=resources)](www.elephantvoices.org/index.php?topic=resources)

Mushara 2004

The 2004 Mushara experiment was designed to solve that problem by using three different recordings—the '94 warning call from Mushara; an anti-predator call recorded by scientist Joyce Poole in Kenya; and an artificial warble tone. A shaker was once again buried near the waterhole and wired to a tape deck in the tower. All three sounds were randomly played through the shaker at different times to see if the elephants could recognize them as distinct vibrations. "We wanted to determine if they can discriminate between familiar and unfamiliar calls that are played back as seismic signals," O'Connell-Rodwell explains.

To record the elephants' reactions, she and her colleagues buried an array of 22 geophones along a straight line extending 1,000 feet from the waterhole. The array gave them the opportunity to record hundreds of seismic rumbles from elephants and other visitors—the most comprehensive study of large animal seismicity ever attempted in the wild.

Breeding herds came to the waterhole five or six times a day during the experiment, sometimes as late as 2:30 a.m. Whenever a herd was spotted, the researchers scrambled up the observation tower and took their places. O'Connell-Rodwell operated the playback system in the upper level, while Jason Wood monitored the geophone array and Katie Eckert—using a special night lens after sunset—videotaped the elephants' reactions.

Directly below them in the lower level, Dave Shriver and Colleen Kinzley acted as "blind observers," monitoring the herds but never knowing which recordings, if any, were being played back through the shaker. Their observations would provide an unbiased assessment of the elephants' behavior.

Although still analyzing data from the 2004 experiment, O'Connell-Rodwell is able to make a few preliminary observations: "The data I've seen so far suggest that the elephants were responding like I had expected. When the '94 warning call was played back, they tended to clump together and leave the water hole sooner. But what's really interesting is that the unfamiliar anti-predator call from Kenya also caused them to clump up, get nervous and aggressively rumble—but they didn't necessarily leave. I didn't think it was going to be that clear cut."

Conservation goals

Although still in its infancy, seismic research may ultimately have important applications for elephant conservation. One goal of the 2004 Mushara experiment was to develop a remote census technique using geophone arrays to count elephants and other animals. The research team discovered that the footfall of a large animal produces a unique signature that's visible on a spectrogram, making it easy to tell if an elephant, rhino or giraffe has walked by.

"We think we can tell the difference between elephants and other species based on the spectral content of their footstep as they pass by a geophone array," says Jason Wood, who is leading the seismic censusing study. "The idea is to have geophone arrays that could be left in the ground for a month at a time, recording data without anybody having to be there. We're hoping they could be deployed at remote waterholes or ideally in central Africa, where it's hard to conduct an aerial census because of the dense forest canopy."

Human-generated noise is another concern for conservationists. Researchers have found that rotating helicopter blades generate low-pitched noises, and possibly seismic vibrations, that can disrupt and frighten wild herds located far away. David Larom and others argue, therefore, that the use of helicopters in areas inhabited by elephants should be carefully monitored and controlled.

Seismic research also may prove useful as a *deterrent against poachers. "There is military technology to detect and track tanks seismically," Larom explains. "This could potentially be used to track poacher vehicles as well."*

Eventually, O'Connell-Rodwell hopes to broaden her research to include other large animals that produce low-frequency vocalizations, such as rhinos, lions and giraffes. "Caitlin and others have already established that small creatures use seismic communication," Larom observes. "The elephant studies, if they prove out the seismic hypothesis, should be extended to other megafauna—hippos, perhaps—then on down the size scale."

O'Connell-Rodwell is writing a book on seismic communication in elephants that is scheduled to be published in 2006. Meanwhile, she and her colleagues continue to analyze the results of the 2004 experiment and plan to gather new data when they return to Mushara waterhole in May 2005. That experiment will include a new study on the impact of acoustic and seismic estrus calls on the dominance hierarchy among bulls.

"Our work is really at the interface of geophysics, neurophysiology and ecology," she says. "We're asking questions that no one has really dealt with before."

SIDEBAR: Anatomy of the trunk and feet offers new clues to elephant seismic sensitivity

In addition to her fieldwork, Caitlin O'Connell-Rodwell also is conducting laboratory studies on elephant physiology to determine why they are so seismically sensitive. As a research associate in the Stanford Department of Otolaryngology, O'Connell-Rodwell has begun collaborating with department chair Robert Jackler; Sunil Puria, an associate professor (consulting) of otolaryngology and of mechanical engineering, who studies the biomechanics of the middle ear; and Robert Sapolsky, a professor of biological sciences.

O'Connell-Rodwell is particularly interested in the elephant's feet and the trunk, believed to be the primary receptors of low-frequency vibrations. The trunk may be the most versatile appendage in nature. Its many uses include drinking, bathing, smelling, feeding and scratching. It turns out that the tip of the trunk contains two kinds pressure-sensitive nerve endings—Meissner's corpuscles that detect infrasonic vibrations, and Pacinian corpuscles that respond to vibrations with slightly higher frequencies.

Little is known about how these nerve endings are distributed in the elephant's skin. To solve part of the puzzle, veterinarian Donna Bouley, an associate professor of comparative medicine at Stanford, and undergraduate Christina Alarcon are dissecting the foot of an Asian elephant that recently died at a zoo. Preliminary results reveal a high density of Pacinian corpuscles in the front of the foot and along the edges—a finding consistent with the notion that elephants are sensing seismic signals when they press their feet on the ground.

O'Connell-Rodwell also is applying her insights in animal seismicity to the problem of hearing loss in humans. It turns out that people with hearing impairments develop a much greater tactile sensitivity in the auditory cortex of their brain than people with normal hearing. Working in the laboratory of Christopher Contag, an associate professor of pediatrics at Stanford, O'Connell-Rodwell has been investigating the possibility that newborns with severe hearing loss could have their hearing improved by exposure to vibrational stimulation shortly after birth.

A companion article appears in the May issue of National Wildlife magazine.

Source: Stanford University