Eavesdroppers:
How scientists are learning to listen in on the animal kingdom.
Four stories on wildlife and sound.

by

Elizabeth H. Quill

B.A. Journalism
Ithaca College, 2006

Submitted to the Program in Writing and Humanistic Studies
in partial fulfillment of the requirements for the degree of

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Abstract

Typically, if scientists want to study animals in the wild they rely on field observations by eye. If they want to track those species to know where they are, where they are going, and how they behave, then researchers may capture and tag them. These methods, however, are difficult if not impossible for rare and hard-to-see species like whales in the ocean, elephants under a forest canopy, or birds at night. Sound gives scientists a new way of knowing what is swimming, roaming, and flying where. And some scientists are using these sounds for conservation, to identify the habitats animals need to survive and to protect the animals from human activity. Of course, as with any new science, there are unanswered questions. The uncertainties are especially profound in the ocean, where researchers know little about how marine creatures hear. Scientists are still searching for answers, but now they have a new way to find them.

Thesis Adviser: Boyce Rensberger
Title: Director, Knight Science Journalism Fellowships

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Prologue: Listen

Few people pay attention to sound, mainly because they are not taught to listen. As the eyes adjust to a bright light or nerves in the wrist soon ignore the weight of a watch, when sound becomes constant, the brain begins to ignore it. The trill of the crickets cutting through thick summer heat softens to a lull, and even the barking of a neighborhood dog fades from earshot. Whipping wind, rustling leaves, and pounding rain fall into the background, swallowing nature's other noises as they retreat. Some sounds are filtered. Others, like the chickadee's "fee be de" and the cardinal's "choo," may never register.

But humans have the capacity to hear much more. Many can follow a stranger's call to locate a speaker, they can identify a song from the first few chords, and they can recognize their mother's voice, even over the telephone. Some birders, for example, train their ears, and tend to be better-than-average listeners. The late Ted Parker, often called "the finest field birder in the world" is said to have known the calls and songs of more than 3,000 species. His tradition lives on. Linda Macaulay, an amateur ornithologist, travels the world recording the rarest avian voices. She says there is something about sound she can't explain. "You listen all the time," she says. "You have an incredible ability. You just don't realize it."

Though birds are especially vocal, they are not alone in life's natural uproar. Every species bigger than a microbe communicates with bustling chords and vibrations. Even a single flap of a bee's wing sends a wave through the air. The composition of sounds, the soundscape, can carry information. Just as crashing waves or rustling trees can help a blind observer picture her environment, the voices of birds, elephants, whales, and all creatures great and small can help scientists study that environment. Sound opens a new window on the world. In his forward to Listening to the Land, David Brower, former director of the Sierra

Club, writes: "We should listen eloquently. More than that, we should learn to see the land – to look at the Earth as if we had never seen it before." Sound can give scientists new eyes. And this story, one of many, begins with birds.

Inspiration from above: Can scientists use sound to track migrating birds?

On a balmy night in late May 1985, thousands of migratory sparrows and hundreds of cuckoos called out of the Minnesota sky. Their staccato "tweeps" and repetitive "woops" emanated in all directions as they communicated among themselves. The sound also moved downward, toward the ground. Bill Evans, an amateur birder turned ornithologist, had just returned to his campsite on a bluff by the St. Croix River when he noticed the chorus. "I enjoyed just hearing it," Evans says years later. "I thought, 'There is an enormous amount of information up there, and there has to be a way of extracting it.'"

Determined to document the voices, Evans purchased a VCR. A two- or three-dollar VHS tape would last all night in extended play mode, and the audio quality, though admittedly not perfect, was OK. He rented a Sennheiser microphone, the top-of-the-line kind, and ran a power cord into the field. This is when Evans's obsession began. He wanted to know what creatures were passing in the darkness out of sight, above the trees. Since then, he has never missed a migration. He set up monitoring sites across the country, committing himself to identify every night migrating land bird in eastern North America. Excluding shore birds like plovers and sandpipers, most birds land in this group. For Evans, night flight calls were like the pieces of a giant, dynamic puzzle. If he could identify the birds, then he could understand the patterns of their movement and he could educate others. "Once you have the recordings, you can hand them down," Evans says, like a packrat with a mission. "The sounds are changing all the time."

If scientists want to study animals in the wild they rely on field observations. If they want to track those species to know where they are and where they are going, then researchers typically capture and tag them. These methods, however, are difficult if not impossible for rare and hard-to-see species like whales in the oceans, elephants under a forest canopy, or birds at night. Sound gives scientists a new way of knowing what is swimming, roaming, and flying where. And if scientists understand these things, the habitats animals need to survive can be located and protected. The nocturnal flight calls, according to Evans, provide a simple and straightforward first cut of the information conservationists need.

Evans thought nothing of flyway protection 25 years ago. A student at Oberlin College, he did not know where his life would lead. "I was floundering," he says. When he heard the migrating birds in 1985, he began thinking about John James Audubon's accounts of hoards of migrating passenger pigeons darkening the skies of southern Ohio.

"The air was literally filled with pigeons; the light of noon-day was obscured by an eclipse, the dung fell in spots, not unlike melting flakes of snow, and the continued buzz of wings had a tendency to lull my senses to repose," Audubon wrote about an autumn day in 1813. The birds were hunted for food and shot for pleasure. They sold for two cents a pair in New York City. The last passenger pigeon died in the Cincinnati Zoo in 1914.

"I was sad I would never see it," Evans says. "But I realized change is happening all the time."

Ornithologists have been counting the calls of migratory birds since the 1890s, and *Audubon*, the magazine of the National Audubon Society, first published tallies of calls in the

1950s. Late in the same decade, Richard Graber and Bill Cochran, leading ornithologists working at the Illinois Natural History Survey, began a nocturnal flight call study in the state. Graber and Cochran lugged around 15-pound reel-to-reel decks and pulled wagons loaded with amplifiers. Only in the past two decades have better and cheaper microphones, computers, and software provided a way for researchers to acquire, sort, store, and analyze thousands of hours of sound, turning curiosity into science and descriptive detail into data. "Now you can just stick your laptop out in the field for an entire season," Evans says. "Technology has opened the sky."

In the beginning, Evans saw himself as a historian, archiving bird flight. He imagined lines of recording stations stretching from the Rockies, west of which the night flight phenomenon is not as pronounced, to the East Coast. But he knew he could not collect the data alone. He began reading Graber and Cochran's old papers, he attended an American Birding Association conference with his father, and he landed a job at Cornell's Library of Natural Sounds, now named the Macaulay Library after Linda Macaulay, an amateur bird recorder.

"At the time, I was working as an assistant librarian in a history of electricity library," Evans says. "That was after I stopped delivering pizza."

Evans did not stay at Cornell long. He says he needed to be in the field. He worked at Cornell again in the mid-'90s, but left for similar reasons. Cornell connected him with leading ornithologists, amateur birders, and graduate students. He also earned a reputation thanks to the public relations office. But Evans worked better outside of academia. Without a college degree, he could never be a leader at the lab. Instead, he made his own path. Evans says Cornell had a minor impact on his career. Instead, he attributes his success to the Grateful Dead.

In 1988, after spending a night in the recording pit at a Grateful Dead concert, Evans came up with a simple microphone set up. He saw a fan using a square 18 inch by 18 inch piece of Plexiglas to double the sound pressure of the received music. He thought he could produce something similar. He made his microphone by drilling a hole through the center of a plastic plate and sticking in a recording device, like the ones found in tape recorders or cell phones. For waterproofing, he covered the setup in plastic wrap. Evans set the plate in a big flowerpot to keep nearby insects' chirps and rustling grass out, and to hear only a cone of sound reaching high, sometimes 2,000 feet, into the air. The whole thing cost about $35 and could capture thousands of sounds each night. "The sounds are not crisp and clean, but they are good enough to make the identification," Evans says. His cheap microphone, compared to $1,000 Sennheisers, meant he could afford to litter the country with recording sites. Evans focused on simplicity. "It has to be simple so others can tune in," Evans says.

Though Evans considers himself a solo operation, working alone from his office in Ithaca, New York, he often reaches out to others. In 2002, he set up Old Bird, a nonprofit corporation aimed at developing and distributing the tools people need to monitor night flight calls. He organized a Web site at www.oldbird.org where amateur birders can go to learn how to record, identify, and analyze sound on their own. Birders from Canada to Central America have turned to his site for these purposes. He is working with the Audubon Society in New Hampshire to set up 11 sites in the fall. And he even set up a series of recording sites on the roofs of high schools with the help of teachers in Texas. "They have these great flat roofs," Evans says. "Clean acoustic environments." He has inspired students in Maryland, Pennsylvania, Tennessee, and, of course, New York. And he recruits 20 to 30 new people each year. Though he is not familiar with all their work, they are all familiar with his. Some call him a pioneer, but Evans says that is not the right word. "I had a unique vision," he says. "And I followed it."

Andrew Farnsworth met Evans during a visit to Cornell University, where Farnsworth now works at the Lab of Ornithology. He spent the first of many nights on the top of Mount Pleasant in Ithaca, New York, when he arrived in the fall, listening to the sounds of cuckoos, grosbeaks, warblers, buntings, and bitterns. Farnsworth remembers Evans well. "He had this vision, and he knew it could only be a good idea to have more people working on it," Farnsworth says. Evans spent 12 years recording flight calls of North American birds with a fellow-birder Michael O'Brien for a CD, and Farnsworth, as part of his Ph.D. thesis, added western warblers to the collection.

Collecting and identifying the sounds took time. "The trouble is you have to know them all in order to know one," Evans says. To identify birds at night, Evans and O'Brien, who works as a nature tour guide in Texas, first recorded sounds of birds during the day. They had to match those sounds to the birds through visual identification. Only then could they use the day sounds to identify night calls. Species like the Canada and Wilson's warblers proved particularly difficult because daytime sightings are rare. Evans says it was a matter of matching things up. The process was more cumulative than punctuated. This seems to be true for acoustic research in general; it takes a lot of sound samples to make sense of the results, to see a clear picture.

The sound CD, like most of Evans's endeavors, is not ordinary. It includes spectrograms of calls, which aid listening by giving people a way to picture the sounds. A machine, or now a computer, graphs pitch, which is called frequency, along a timeline. The resulting picture looks like a seismograph from an earthquake. A single line on the spectrogram holds more information than can be caught by just listening to a short, high call. And scientists can look at the frequency and the duration of the sound. As in Morse code, a long dash is different from a short one. The fuzziness of the line represents the hoarseness of the call. The shape or curve, the way it rises and falls over time, gives scientists clues about what made the sound.

The CD gave Evans another way to reach out to an interested scientific community and a curious public. He sold more than 1,500 copies. Jeff Wells used the CD to prepare for the World Series of Birding, an annual competition for bird-finders, and now he uses the calls to identify birds flying over his home in Maine. Wells, a bird consultant, says he wanted to do more than just listen, so he started a blog and shares recordings with the public. "[Night flight] happens everywhere, and it is hidden away," Wells says. "But there is a river of birds going over your head every spring and fall." Evans's mission spread through Wells and others. By the time Evans left Cornell for the second time in 1999, he had a following of believers. He has been running his nonprofit organization out of a small office at Snow Lion Publications in Ithaca ever since.

After talking with Evans on the phone, I expected VHS tapes to clutter his office – stacked on the desks, thrown on the floor, knocked across tables. He had been recording at an average of 10 sites east of the Rockies for nine hours each night for 100 nights a year for almost 15 years before digital recording technology became available. That comes to 135,000 hours of birdcalls. When I went to his office, I did see VHS tapes, but they were stacked neatly from floor to ceiling on two-by-four shelves, organized according to year and season.

"I cleaned up," confessed Evans, a tall man with prematurely white hair and a charming smile. Computer monitors lined the far wall, and input-output VCR cables hung from the sprinkler system. There was something peculiar though, coolers on the floor – metal iceboxes, green '50s coolers, "Drink Coca-Cola" coolers. Evans reached down and pulled off a lid – more VHS tapes.

Evans thought he would have listened to and analyzed more tapes by now, but the tapes have to be played back in real time and he became sidetracked. In the early 1990s, the Nebraska Public Power District asked him to study the species flying above a proposed wind power site. He does not remember how the power administrators knew him, but he expects they read about his work in the newspaper. The Power District was interested particularly in the Baird's sparrow, a threatened species. "I did not want to just monitor birds when there are communications and wind towers going up in migration paths and no one is doing anything about it," Evans says.

Bird collisions with lighted television and radio towers have been documented for more than 50 years. For example, a television transmitter in Eau Clair, Wisconsin caused 1,000 bird deaths each night for 24 nights during one migration season. Total estimates of bird deaths range from 40 to 50 million birds per year. In a study conducted in his backyard and submitted to the Federal Communications Commission this year, Evans used acoustic techniques to study the way birds congregate around a light. He found they are attracted to blue, green, and white light, but not red light. Therefore red light, he says, could be a simple solution to deaths at communications towers. But deaths from wind towers are not well studied and seem to be more variable.

Since his first study in Nebraska, Evans has been called on to conduct surveys, gathering abundance data and species identifications for both power companies and environmental activists. "We need clean energy, but we should know what its impact is," he says. He did not expect his work to go in this direction, but it has opened a lot of possibilities. If his techniques can be used at proposed wind turbine sites, they can be used elsewhere. He can monitor bird populations in degraded habitats. He can determine species presence and abundance in forested areas or wetlands. And comparing data from year to year can give him an idea of changes in population. Evans does not consider himself an activist, but an independent – brought in to answer scientific questions.

Evans has already shown that his techniques can be useful in environmental regulatory efforts. For example, as part of one power study in New York, Evans heard a least bittern, American bitterns, and grasshopper sparrows flying overhead. These species appear on the state's threatened and species-of-concern lists. Brianna Gary, avian ecologist with the New York State Department of Environmental Conservation, says wind power developers do not legally have to conduct these types of studies. "We can't tell them to do anything," she says. But, she adds, developers tend to participate in recommended studies like radar and acoustic monitoring because they are good for public relations. Radar gives researchers a sense of the density of birds flying overhead, but it is expensive and does not provide information about species composition. Gary says sound works well in combination with other methods.

Recordings like Evans's have also led to new scientific understanding of bird behavior. For example, scientists used to think migrating birds moved in one broad front, so it did not matter where towers were built because the same number of birds would be affected. But Evans challenged these assumptions and found that birds flow like rivers, often following geographical cues. "This is not an unwieldy phenomenon," Evans says. "I am seeing incredible correlations in countings. There are fascinating patterns."

Jo Anna Leachman, a graduate student at the University of Maryland and disciple of Evans, is recording nighttime calls in the Appalachian Mountains. She is asking whether birds fly in valleys or along ridges. Leachman collected mostly the soft "shee-ahs" of the thrush and the musical trills of the warbler, which both fly at altitudes between 500 and 1,000 feet. Birds flew over all five of her sites in the spring, but only two in the fall. This suggests something is affecting the way the birds fly and where they fly. "I don't know exactly what it means," Leachman says. "I am hoping to get a better idea of what is going on."

Evans has some ideas. He found in his own studies that birds appear to avoid clouds, so he thinks weather patterns could affect flight. On nights with low cloud ceilings, the birds fly along valleys. "The birds are channeled, sort of like water, through a mountain terrain," he says. "You get these dense, complex corridor phenomena." As part of a study for the power company Ecogen, which included data from nine sites across Central New York, Evans found similar channeling behavior. Densities of flight calls vary predictably from one site to another and one year to the next. In coastal or dense migration areas, small changes in the placement of wind turbines could affect bird mortality. When the Ecogen power site is constructed next year, Evans plans to conduct mortality studies by collecting dead birds. He wants to prove without a doubt that if more birds are flying overhead then more birds will be killed by the wind turbines.

Evans still has more work to do, but he has created a baseline. John Confer, a conservation director for the New York State Ornithological Association, says currently the data Evans collects is analyzed in a relative way. Evans compares one site to other sites, and he predicts good spots over bad spots. Confer says this is the first step. "His work is really valuable," Confer says. "Evans can say, 'It would be terrible to put a tower here, let's try something else.'"

Evans believes anybody with a roof can help him. He wants microphones everywhere. "I don't necessarily need to be doing the studies," he adds. Evans envisions people across the country collecting recordings, using their computers to classify the sounds, and funneling species abundance information to one central Web site or database. Then, anyone can turn to the Web site to track these birds the same way they turn on the TV to watch the weather forecast.

Now that information can be stored on a flash drive, like those found in digital cameras, it is easier for citizens to join the effort. Evans uses simple setups so others can get involved. CDs, hardware, and software are available to everyone. Programs like Tseep and Glassofire, for example, can pick out recorded sounds that resemble birdcalls. Evans says he is still holding his breath for one more technology – an automatic classifier that can recognize species and sort birdcalls based on species. This is the last hurdle to universal monitoring. And Evans is not alone in his dream. Researchers at Cornell University have made classifiers a priority. During their search for the ivory-billed woodpecker, once thought to be extinct, they collected 26,000 hours of recordings. So, they programmed the computer to run through the recordings and sort the sounds based on frequency, duration, and shape of the call. It saved researchers time. A similar design could be used for night flight calls.

Evans is optimistic. Behind his desk, made from cinder blocks and plywood, among old glass jars filled with pens and markers, he points to a picture of the legendary Ted Parker in Peru with a microphone. "I met him at Archbold Biological Station, [in Florida,] and we played basketball together," Evans says, with a mix of nostalgia and loss. Parker specialized in birdcalls from the New World tropics. "When I started in the lab in 1988, everyone was talking about him as a legend," Evans says. Parker stood out because he had a passion for learning the sounds, but he was not much into academia. Parker became Evans inspiration. Evans inspired others. "He died in 1993," Evans says. "And now all his knowledge could be lost." Evans attachment to the photo reveals something about his early work. He simply wanted to collect disappearing data. Now, as Confer says, Evans is the world's expert in night flight calls.

In an adjacent room at Snow Lion Publications, there are no signs of birds, no VHS tapes or external hard drives. No computers and no coolers. Dried wild flowers hang upside-down from the sprinklers. A lamp in the corner brightens a map of the United States. Pencil-drawn circles scatter the map. "This is where I have been," Evans says, referring to sites where he had collected recordings. One circle in North Dakota, two in Minnesota, two in Arizona, two in New Mexico, three in Florida, and one in North Carolina. A line slashed through half a dozen dots in New York and another one slicing the southernmost tip of Texas. "And where I want to be," he adds. Three lines stretch from Nebraska to the Atlantic Ocean.

Evans says the past five years have been critical to his research. He has gained a reputation, and showed that his work has an applied value. He sees how monitoring can help humans understand their impact on their environment. He says sometimes he becomes frustrated because environmental regulation and legislation that depends on his data are so slow. The study he conducted in Nebraska nine years ago is just now being used to site the tower. He is working against the system, but he is doing what he can. "No matter how things change, they will change more," Evans says. "We have to understand our impact. We have to be honest."

Rumble in the Jungle: Can deep notes help biologists understand giant beasts?

A mother elephant calls to her calf from a forest clearing in the Central African Republic. The calf has gone missing, swept up in a herd of panicked elephants and forced to scamper into the trees half a mile away. But the calf calls back. He sounds like a Model T horn. The mother calls, purring like a giant cat, and the calf calls again. "Aooga, aooga." They continue the conversation, and each time the two move closer. After about 10 minutes, they reunite. The calf rubs against his mother's side, partially shaded by her large, flapping ear.

"It's like a game of Marco Polo," says Mya Thompson, a doctoral student at Cornell University. "The elephants are sending relevant messages."

Thompson has been working in the Dzanga forest clearing in the Central African Republic since 2000. "It is one of the wonders of the world," she says. "You walk through the forest and all of a sudden see a clearing with 100 elephants, water buffalo, and monkeys in the trees. It is hot and the bugs are biting constantly, but you feel this elephant society unfolding before you." Thompson has two goals. First she wants to assess elephant population size, and then she wants to understand how vocal communication helps them maintain social ties. She says if scientists can hear and give meaning to calls, they could not only determine the size of the elephant population, but also its health.

"We are going beyond the numbers to see if we can assess anything more interesting about the population," she says.

Scientists have always been interested in animal behavior and the biology behind it. Part of the fascination with the field, called ethology, comes from the fact that the actions of animals provide the only easily available clues about their intelligence, learning ability, communicative ability, and emotions. Ethologists who study higher mammals hold particular power over the public's imagination. But not all animals are easy to observe. Though scientists know a lot about savannah elephants, for example, they know much less about forest elephants, which remain hidden beneath a canopy of leaves. Following in the footsteps of birders, biologists have learned to listen. They've become eavesdroppers. Some, like marine biologists at Scripps Institute of Oceanography, for example, are trying to determine the number of Pacific north right whales in the Bering Sea by lowering microphones into the water. Others, however, are going further. A graduate student at Ohio State University, for example, studies the structure of coyote families based on their howls. And participants in a project at Marquette University, called the Dr. Dolittle Project, are using acoustic technology to collect vocalizations from all animal species. They want to tie sound to behavior in an effort to improve species survival programs. In the book Animal Talk: Science and the Voices of Nature, Eugene Morton and Jake Page write that we need to "learn to think about these newly and more accurately perceived sounds from the standpoint of what the animals themselves might be hearing."

There's a lot about elephant behavior that scientists do not understand. These giant mammals live in family groups, consisting of a matriarch and other females who cooperatively care for the young. Members of a group may scatter and rejoin after hours or even months of separation, and they react as one despite the miles between them. They recognize each other and seem to mourn the death of family members. Researchers believe calls help them coordinate movement, identify each other, and summon or warn others in case of danger even when the group is scattered over long distances. Elephants' abilities to do this baffled scientists because there seemed to be no obvious method of communication. In the tradition of ethology, researchers took a natural history approach. They observed elephants, writing notes about what they heard and saw. Still, the mechanism behind the elephants' talents eluded them.

A clue emerged in 1984 when Katy Payne visited Washington Park Zoo in Portland, Oregon, to see the elephants. Her then-husband, Roger Payne, was studying whale sounds along the West Coast. "I expected nothing," Katy Payne says. "When you don't have a hypothesis or an axe to grind, you are just open." While at the zoo, she felt a strange throbbing in the air. It reminded her of the lowest notes rumbling from a pipe organ. "There were pressure changes," Payne says. "I hardly noticed I was noticing." A few months later, Payne returned to the zoo with colleagues to capture the throbbing and take detailed notes of what she heard and felt. She used a recorder that picked up infrasonic sound, sound below the level of human hearing. Among animals, the great fin and blue whales, species her husband studied, were known to make calls in this frequency range.

Elephants produce sound in the same way humans do; they push air over their vocal chords. The vocal chords vibrate at a particular frequency, and the elephant can adjust the frequency by lengthening or shortening the chords. An elephant's vocal chords are 3 inches long while human vocal chords average around half an inch. Once the air passes over the chords, the sound is shaped as it travels through airways in the elephant's head, including the nasal cavities and trunk. The chambers resonate, making each elephant voice unique. Since these chambers are big, the noise is low. And the elephant can use its trunk, mouth, and tongue position to modify or amplify different components of the sound.

When Payne left the zoo for the second time, she did not know what was on her tapes. She flew back to Ithaca with a scientific breakthrough in her briefcase. When she finally listened to the tapes at 10 times the recorded speed and three octaves higher than the recorded frequency, she heard mooing. Elephants were communicating with energy below the range of human hearing, which begins at a frequency of 20 Hertz. Within a few days Judith Berk, a researcher at the San Diego Zoo, reported infrasonic frequency calls in African elephants. These mammals trumpet, cry, roar, shriek, and rumble. The rumbles range from 5 to 30 Hertz, and can travel through miles of air. Like wind, thunder, or noise at a construction site, if these sounds are powerful enough, then they can shake the ground.

The sound piqued Payne's curiosity, so she began studying the species in the wild. She worked with Joyce Poole in Kenya. "We saw the elephants doing things we didn't understand," Payne says. "We thought they were listening at a distance, but we had no evidence." Then she traveled to Namibia to observe how elephants responded to human-created low-frequency sounds. She went on to Zimbabwe, tracking females with radio collars to find that family members tend stay within two miles of each other. Her fascination grew, and she formed and became director of the Elephant Listening Project at Cornell University. She loved spending time with the elephants. She wrote in her book, Silent Thunder: "What cohesion. What unanimity. What relishing of one another." When Mya Thompson heard about Payne's project, she volunteered to help. Thompson later became a research assistant and is now a doctoral student. Her first task was to figure out how to count elephants using only sound.

While savannah elephants can be counted using aerial surveys, forest elephants are hidden. In order to gather population numbers, researchers have had to go out with machetes and hack through the forest looking for piles of dung. By genetically sampling the dung, which contains cells from the animal that produced it, they can estimate the elephant population. But Jason Wood, a geologist at Stanford University who is studying forest elephants in South Africa, says there are problems with poop. "The dung varies in amount produced," Wood says. "And it breaks down." Sometimes researchers will walk for half of a mile and only find five piles. A recorder left on the forest floor, by contrast can collect thousands of calls. Thompson says sound could be a better tool.

In the Dzanga clearing, Thompson recorded elephants and counted the ones she could see. She compared the number she heard with the number she saw and developed an abundance model. Then she went to Kakum National Park in Ghana to test the model. "We wanted to get our own estimate and then use existing estimates for cross-validation," Thompson says. She concluded that 10 calls in a 20-minute period in a given area indicate roughly 20 elephants. Meanwhile, in Kruger National Park, Wood decided to approach the problem differently. He is listening for footfalls to determine population size. The two methods will compliment each other because both researchers want to know how many elephants are out there.

But just counting elephants does not give researchers a sense of how the elephants are interacting. Thomson and Payne want to do more. During her studies, Payne found elephants could sense each other's sounds up to 2.5 miles away, giving them a listening range of 20 square miles. Later studies increased the possible range to 40 square miles. When an elephant bellows there is a low base frequency, and overtones, as with a strummed guitar. Humans can hear elephant overtones, but not the lowest tones. As sound travels through air and ground, higher frequencies fall off faster. So an elephant a mile away from a source would still hear the low frequency, but a human would hear nothing. It works great for the elephants. Unlike people, they don't need a telephone to communicate with nearby neighbors or friends. And Payne and other researchers believe these calls can provide clues about culture, intelligence, and individuality.

In addition to being a good place to count elephants, the Central African Republic is a good place to sit and watch them. Andrea Turkalo, an American wildlife researcher running a conservation site in that country, has identified and named more than 3,000 elephants that visit the clearing regularly. So when Thompson traveled to the country, she was able to build on Turkalo's observations and experiences. "You sit with her, and it is a soap opera," Thompson says. When Penelope and her sister greet after weeks of separation, a story unfolds. "The two rumble and rumble," Thompson says. "They stick their trunks in each other's mouths, and then they pee." Thompson collects these visual descriptions to go along with calls. There are calls used in greeting ceremonies, calls used to distinguish individuals, "let's go" rumbles and calls used during mating. "If I can figure this out, we can scan through recordings we know nothing about and learn what is going on," Thompson says. "We are documenting the elephant repertoire."

Others have tried to create elephant dictionaries before, identifying the calls and labeling them based on behavior. But the studies were circular because the researchers then used the calls to predict the behavior. Thompson's work is different. She is combining the natural history approach with a quantitative approach. Sound data makes this possible by incorporating numbers. Because sound analysis software can measure frequency, duration, and other properties, Thompson can categorize calls in an objective way. Then, she can use that information to try to understand behavior. Shermin De Silva, a graduate student at the University of Pennsylvania, says the biggest problem in the study of elephants is a lack of quantitative data. She is documenting Asian elephant sounds in Sri Lanka by following females and then using computer software to characterize their calls. "When you have a verbal description, it is hard to know if you are talking about the same thing," she says. "You want to be able to describe vocalizations by themselves, independent of behavior."

Scientists believe that by understanding vocalizations, they can not only identify animals' daily behaviors, but also their cries for help. And our thick-skinned friends seem to be crying for help a lot lately. Recently, there have been increasingly tense relationships between man and elephant and, according to some reports, elephant aggression has escalated. Some scientists believe elephants are stressed because of the way poaching, culling, and habitat loss have disrupted family bonds and destroyed elephant culture.

Thompson and De Silva are both working with national parks and would like to see their techniques used for conservation. They believed from the beginning that the more people knew about these animals, the better they could protect them. For example, no one knows how many forest elephants there are. Counts vary by a factor of 10. "This is scary," Thompson says. "If we have no way of estimating how many elephants there are, we have no way of arguing in an international forum to keep the protections up."

De Silva says it also helps if wildlife managers know what the elephants are doing. "Is the population increasing, decreasing or stable? Is there resource competition? Which animals are associated with each other?" she asked. Calls could help scientists assess the health and welfare of the populations in this way. Reproduction is the biggest indicator of a population's health. And if researchers listen for rumbles made at times of heightened sex hormone levels, musth rumbles for males and estrous calls for females, they might understand how much mating is happening. This information could be used to help managers understand the demographic picture and make decisions about expanding and shrinking parks.

Payne understood these possibilities when she first began studying elephants. She says there are questions conservationists and scientists can ask: "Are they healthy? Are they losing males? Are we recording gun shots from illegal poachers and chain saws and blasts being made for seismic testing for oil?" Sound, she says, is a window on the elephant world. But she also believes sound can help people understand animals, relate to them, and learn to care about them.

One day in the Central African Republic, an infant and her mother and older sister came into the clearing. The infant was dying. "Far too thin," Payne says. She died beside a trail. Over the next few days, more than 100 elephants passed. "They showed signs of recognition that all was not well," Payne says. They stopped and approached. Some tried to lift the baby calf with tusks and trunks. Others sniffed, groaned and rumbled. Some drew away and later returned. Payne says one adolescent male tried to lift the baby 57 times. "It seemed the animals had a sense of responsibility," she says. "It seemed like empathy."

Payne begins her book, Silent Thunder, with the word "tese," which in Shona means "for all of us." She says she has learned a lot from elephants. She believes culling, poaching, and destroying habitat kills the spirits of the survivors. And she believes elephants do not ignore the experiences of their friends and families. Sound allows scientist to ask an old question in a new way. Payne asks, "How do we look at the whole ecosystem and the way it is changing with human exploitation, and inform managers in time so we don't lose these elephants."

Keeping a distance: Can manmade acoustic signals keep whales safe?

"This is a sad story," Mark Johnson begins. "And not the whale's fault."

The ebony beauties with the big heads and patched faces almost disappeared from north Atlantic waters. Their signature triangular flukes with deep notches are still seen rising arched from the ocean, creating a broad waterfall and slipping smoothly back beneath the surface without a splash. And they still migrate every year from their cool summer homes in the Bay of Fundy through shallow coastal waters to breeding and calving sites off Georgia and Florida's shores. But scientists estimate only 300 North Atlantic right whales remain.

"The Atlantic right whales are horribly endangered," says Johnson, a senior engineer at Woods Hole Oceanographic Institute. "They happen to live in one of the most actively shipped and fished areas in the world." While ships move east to west, docking in ports along the coast of the United States, whales move north to south, making them ready targets for boat collisions. And as the whales swim along the coasts of Maine and Massachusetts, they encounter unfamiliar objects, nets that tangle about their flippers and tails. But the whales don't really have a choice. They go where they breed, and they follow their food, regardless of humans.

Scientists don't know exactly how many North Atlantic right whales still exist, but since they can identify individuals based on callosities, rough white patches of skin on their faces, they think their guess is pretty good. Each individual's face has a different pattern, like a fingerprint. But simply being able to identify individuals does not help researchers understand them. And sightings are rare, offering only snapshots when the whales choose to surface. Acoustic research has helped fill in the gaps, giving scientists information about where in the ocean whales and other marine organisms swim, primarily through the deployment of underwater microphones, called hydrophones. These devices can monitor the grunts, moos, moans, sighs, and songs of whales. When it comes to the North Atlantic right whale, the picture has become clear. Scientists know where they swim, and they know what kills them. Now, they are turning the tables, moving from passive observers to active protectors. They are using sound to try to solve the whales' problem.

Whalers gave right whales their name because they were the "right" whales to hunt. They swim slowly, often near the surface along shores, and they are easy to catch. Because their bodies are 40 percent blubber, they float when they die and produce a lot of oil compared to other species, sometimes 200 barrels each. The populations of both North Pacific and North Atlantic right whales were almost wiped out by the whaling industry before the 1900s. Once, 80,000 roamed the oceans, but during the early 1600s, whalers took 300 to 500 animals a year. By the mid-1600s only 1,000 remained. After the hunting of right whales was banned internationally in 1937, populations in the southern hemisphere began to recover because they were left alone. There are around 4,000 individuals in those waters. But northern populations remain threatened by ships.

The northern population does not look good. Michael Moore, a senior research specialist at the Woods Hole Oceanographic Institute, says that of the unnatural deaths in this species, about two-thirds are caused by boat strikes and the other third by entanglements. He says death by boat strike or entanglement is torture. "It is not something that would be tolerated if it was in full sight," he says.

Doug Nowacek, a biological oceanographer at Florida State University, says six North Atlantic right whales were killed last year. "We are barely replacing what is being killed." A study published in *Science* in July 2005 suggested that the population growth rate for right whales has been declining since 1980. Though the birth rate might be increasing slightly, it is still not overcoming the death rate. In the 16 months before the study, eight whales were found dead. Six were adult females, and three were pregnant. Nowacek says because of the large investment in bearing calves, deaths to reproductive females are of particular concern. "That is double jeopardy," he says.

Since 1998, commercial ships entering right whale calving grounds have been required to radio the U.S. Coast Guard to find out current whale locations, determined by reported whale sightings and plane surveys that fly daily. But aerial surveys are dangerous and expensive, and the whales move. To prevent entanglements, scientists are trying to improve gear by using net designs less likely to get caught in flippers and that breaks more easily. But new gear hard to test. Johnson says it is a thorny issue, and there are limited options. "The best solution is to stop fishing," he says. "But this is not on the table."

If the ships can't get out of the whales' way, Johnson suggests, maybe the whales could get out of the ships' way. Whales modify their behavior based on the sounds other whales produce. The song of a male looking for a mate may encourage a female to approach. On the other hand, the clicks of a killer whale looking for its prey might cause the whales to flee. Johnson thought, maybe humans could modify whale behavior in a similar way using artificial sounds. Ultrasonic beeps have been used to drive crows out of cities, and soothing music has been played to keep cows calm before slaughter. In the marine world, pingers that emit high frequency sound pulses have been tried to keep dolphins out of fishing nets and loud noises have been tried to keep seals from invading aquaculture ponds. There is debate about the success of these techniques, and different species respond differently. Johnson, Nowacek, and Peter Tyack, all colleagues at Woods Hole, wanted to look more closely at right-whale responses.

The first step for the trio was to understand how and what right whales hear, and how they react to different sounds. The researchers decided to conduct playback experiments and observe whale behavior. First, they wanted to play ship sounds. In theory, injuries due to boat collisions do not make sense because the ships are big and noisy. The whales should move out of the way, but they don't. Tyack says they could may habituate to the ship sound, or perhaps water distorts the sound. Next, the researchers wanted to try playing alarm calls. "Maybe you need a warning signal," Tyack says. "Maybe you need something the animal would hear only if it was in danger."

The researchers developed a tag to monitor whale behavior and sound production. Johnson designed the device, which could be attached to the whale's skin by a suction cup. "My hope is that this device will eventually help us learn to be better neighbors," Johnson says. The researchers' main goal was to gather information on dives and responses: Where are the whales? What do they hear? How do they move?

The D-tag, as it became known, contains two recording devices that pick up sounds from the whales and other sounds in the water. It has a digital compass, a pressure sensor to measure the depth, an orientation sensor to measure the animal's pitch and roll and the same kind of accelerometers that activate the airbags of a car. This allows scientists to count each beat of the tail as the right whale's body undulates. "You can tell if the whale is pitched up and down, upside down, or rolling over," Nowacek says. "It allows you to put back together the picture of what the animal is doing underwater at any time." The tag records behavioral data in the same flash memory device on which the sound is recorded, using the same memory systems found in cellular phones. "Second by second, the movements are recorded synchronously with the sound," Nowacek says. The electronic component is about the size of a standard computer mouse, but it also has a plastic case and suction cups, making it banana-sized.

The researchers took their tags and a speaker to a spot in the Bay of Fundy, where more than 10 percent of the right whale population feeds during the summer. They worked during the summers of 1999 through 2005, tagging and testing all the whales they could find. Using an underwater speaker pulled slowly behind a boat, they played ship noise and alarm sounds. Nowacek says ship noise is difficult to reproduce, but it was as close as they could get. "They make low, broad frequency sounds," he says. "Like white noise. Wshooooo." The alarm call was produced in the lab, designed to pique the whales' interest but be a bit obnoxious. Johnson says it was a stab in the dark. "We just jammed it together because it sounded bloody annoying," he says. The alarm was composed of a number of parts, including sound like a fire alarm in a high-rise building, the sound of nails on a chalkboard, and a down sweep that went "EEEeeer, EEEeeer, EEEeeer." The researchers ran a total of 48 individual tests.

The results were unexpected. The whales completely ignored the pseudo-ship noise. They kept feeding in their usual and stereotypical U-shaped dive pattern. Tyack says in retrospect, it should not have been surprising that the whales ignored that sound. "If they reacted to a vessel every time they heard it, they would never eat," he says. "They seem to habituate."

Nowacek compared the sound to traffic. He says anyone flying into New York or Boston could count 20 ships waiting to go into the harbor. If all these ships produced sound, the animals might simply get used to it. "It would be like living in the middle of the highway and never getting hit," he says.

The whales reacted to the alarm call in a different way. "Five of the six jumped out of their skin when we played the alarm sound," Johnson says. "They just got the hell out of there." Johnson says they abandoned their feeding and made a shallow-angled high-powered ascent. They spent more time at the surface, 70 percent of their total time rather than 10 percent, and they beat their tails faster. Johnson says a loud or unique sound might "freak out" a whale.

However, Nowacek says the results show alarm calls are not a solution to the boat-strike problem. Once the whales came to the surface, they swam between one and 10 meters below it. "They rocketed to the surface," he says. "They were vulnerable, but not visible." Nowacek says this is a nightmare. If a boat is going 20 knots or so, which is a mile in three minutes, the last place a whale wants to be is just below the surface.

Similar experiments have shown that, in some species, sound deterrent devices on fishing lines and nets may do more harm than good. Ann Bowles, a researcher at Hubbs-Sea World Research Institute in San Diego, found dolphins avoid the sound of pingers, so she thought she could replicate the work in manatees, which live in the shallow waters of Florida and are often tangled in lines and hit by recreational boats. Bowles put pingers on fishing lines in the manatee tank at Sea World. "The first thing they did was to touch it," Bowles says. "The instinct is to find out the details. They swim up, not away."

Michael Moore says this leaves scientists stuck. The whales won't change. "The idea that we can successfully and effectively modify the behavior of the right whales is naïve in the extreme," Moore says. "It all depends on food and sex. If you got to get it, you got to get it."

And John Hildebrand, a researcher at Scripps Institute of Oceanography, who studies North Pacific right whales, sees the experiments as a conservation lesson. Instead of finding ways to make the whales adjust, he wants the humans to adjust. "If you are serious about right whales protection, you'd clear the areas," he says. "Why not address the primary problem."

In the end, Nowacek, Johnson, and Tyack came to the same conclusion. Scaring the whales is probably not the answer. "I am pretty skeptical that you are going to put anything on the bow of a ship and have a measurable success in reducing boat strikes," Nowacek says. But D-tags have the possibility to help scientists learn a lot more about whale behavior and biology, and the experiment was not a waste. Sometimes learning what won't work is almost as important as learning what will.

Tyack plans to move in the opposite direction. "We want to find something that fits into the way the people on the boats operate but makes them aware," he says. Right now, the best idea is an automatic identification system. Each whale would have a tag and ships could locate the whales from onboard, the same way they locate other vessels. They could send out sound waves and wait for them to bounce back. If the ships could see the whales on their plotters, perhaps they could steer around them. Tyack says he is trying to be creative, to come up with new ideas, but the technology still has a ways to go. To him, it feels like a race with death. "You feel like you are trying to salvage a disaster," Tyack says. "You have a feeling of impending doom."

Noise as they hear it: Is an increase in undersea noise driving cetaceans crazy?

On March 15 and 16, 2000, 14 beaked whales, two minke whales and a spotted dolphin stranded themselves on beaches in the Bahamas. Marine biologists dragged 10 of the whales back to sea, but the others died in the sand. Post-mortem exams revealed torn head tissue and internal bleeding around the ears and brains in several whales. The incident served as a "smoking gun" for the scientific community. The culprit was an unexpected crippler – sound.

The U.S. Navy had been using active sonar in the area. Sonar systems, which send out impulses of sound and detect echoes in order to locate objects in the water, were sweeping hundreds of miles of ocean near the Bahamas. Some marine biologists believe that as the sound waves passed through the air- and gas-filled cavities in the bodies of the marine mammals, they created vibrations that rattled and bruised tissue. Sonar sounds have a pure tone, unlike most natural noise, meaning they include only one frequency and they assault a small portion of the ear. Others think the sound made the mammals surface too quickly, giving them the marine mammal equivalent of the bends, or misdirecting them toward the shore.

The Bahamas strandings were anomalous. Usually animals strand because a leader or key member of the population beaches itself. The others just follow. But the strandings of beaked whales attributed to the Navy were different. They included individual incidents across miles of beach and different species were involved. The navy accepted some responsibility in a report released in December 2002, stating that sonar devices aboard the ships "were the most plausible sources of this acoustic and impulse trauma." Since this incident, sonar activity has been linked, justly or unjustly, to strandings off the coasts of Washington, Alaska, Hawaii, North Carolina, the Canary Islands, and Greece.

Sound may provide a useful tool for conservation, but it can cause problems of its own. While some scientists are using sound to assess human impact on the environment, others are turning the idea around and assessing the impact of human sound on the environment. In the same way an airbag deploying in a car can pop a person's eardrum or chronic exposure to machine noise in a factory can lead to permanent hearing damage, loud noises can harm animal hearing. Nowhere is the problem more pronounced than in marine environments. Sound travels farther and faster in water than in air, and scientists know little about how ocean dwellers perceive sound. Strandings are a visible sign of possible damage, but some scientists believe there are other more subtle impacts.

Life in the deep oceans has always had an air of mystery. Scientists have struggled to study the deep, and consequently, know little about the species that survive and thrive there. Jacques Cousteau opened an era of underwater exploration with his invention of SCUBA during World War II, and he opened people's imaginations when he chronicled his adventures in his 1954 bestseller The Silent World. Still, direct observation remains limited because it can be dangerous and expensive, but scientists know for sure, despite Cousteau's title, that the sea is not silent.

Wind whips water into waves, gas bubbles gurgle and storms pound through the ocean's acoustic environment. Dolphins click to navigate and locate food. Spiny lobsters rub that though the impact of human sound now appears obvious, until a few years ago the problem was unknown. "Civilization is drowning out the sounds of whales and other sea creatures," he writes. "The point is we are not listening, or if we are, we're not listening well."

The problem: scientists do not fully understand if and how this noise affects marine dwellers. As early as the 1960s, Roger Payne, the marine biologist who discovered humpbacks' elaborate mating songs, suggested that increasing manmade noise in the oceans could limit baleen whale communication abilities. But scientists are still trying to determine the short-term and long-term impact of blasts and chronic noise on these organisms' behavior and wellbeing. They are still scratching their heads. Ann Bowles, a researcher at the Hubbs-Sea World Research Institute in San Diego, is working with other marine biologists and the Acoustical Society of America to propose recommendations for noise standards. But the task is difficult. "We have a good idea of what humans can tolerate, but we have no idea what these marine mammals are receiving or what they can handle," Bowles says. "People can complain; animals can't."

Whales and dolphins cannot sit still in doctor's offices to have their heads examined, so strandings and deaths give scientists their only opportunities to study whale anatomy. When the whales stranded on the Bahamas in 2000, the National Marine Fisheries Service called in Darlene Ketten, a marine biologist with a joint position at the Woods Hole Oceanographic Institute and the Harvard Medical School. Ketten's job is messy. In an effort to understand how whales die, she conducts necropsies, the autopsies of the animal world. She focuses on hearing. Sometimes ear tissue is frozen and delivered to her lab; other times she is called directly to the beach to saw the tissue out of smelly corpses. "I try to go to the their antennae beneath their eyes like a raspy violin to scare away predators. Toadfish blow like foghorns during spawning, and humpback whales squeak, grunt, and sing songs that evolve from one mating season to another. The lobster sounds can be heard half a football field away, and a blue whale's rumbles can travel from the Bahamas to waters off the coast of Newfoundland. The sounds vary in frequency, or pitch, from those too low for humans to hear to those much too high.

More recently, the shorelines have become underwater urban environments and the deep sea has also been assaulted with sound. Sonar systems, ship engines, dredging activities, and air guns used in offshore oil exploration add to the racket. "You can't study marine mammals without thinking about human impact," says Peter Tyack, a marine biologist at the Woods Hole Oceanographic Institute. "You realize manmade sound is everywhere."

And the ocean is getting noisier. After digging up declassified U.S. Navy documents from the mid-1960s, John Hildebrand, a marine biologist at Scripps Oceanographic Institute in San Diego, found underwater noise levels have increased 10 to 12 decibels off the coast of Southern California in the past 40 years. Since decibels measure loudness on a logarithmic scale, this means sound intensity is 10 to 12 times its 1960s-level. "Things are significantly noisier almost everywhere than they used to be," Hildebrand says. "What is the impact of this?" Hildebrand attributes most of the increase to an increase in shipping trade. According to the paper, which appeared in the *Journal of the Acoustical Society of America*, the world's commercial fleet more than doubled from a little more than 40,000 ships to almost 90,000 between 1965 and 2003. And the ships are getting bigger and louder.

In The Urban Whale, Chris Clark, who works at the Bioacoustics Research Program at the Cornell Lab of Ornithology and is known worldwide for his work with whales, writes animal," she says. "The biggest problem is working on it at the right time." Once, Ketten left a New Year's Eve party in high heels and a velvet dress to fly to Nantucket Island for a dissection. While she does her work though, she wears surgical scrubs and boots. She records every dimension of the whale's head. Then she begins flensing – slicing and removing the whale's fat and blubber so she has room to carve out the middle and inner ear with her butcher-sized knives. The job can take days.

When she is done, Ketten hopes to understand a little more about whale biology. During her doctoral research at Johns Hopkins University in 1980, she developed a technology that could take CT scans of heads of dead whales, allowing scientists to see structure in greater detail. Meghan McKenna, a Ph.D. student at Scripps Institute of Oceanography in La Jolla, California, says the technology is important because in order to understand the impact of sound, scientists need to understand how hearing works.

"Marine mammals have evolved an amazing system in order to capitalize on using sound as their main sensory tool in the marine environment," she says. In humans, sound travels through an air channel in the eardrum. But in whales, sound vibrations move through a fat channel from the lower jaw to the inner ear. When sound crosses from water to air, it loses a lot of energy, but when sounds move from water to fat, it is not as distorted because the properties, such as density, are similar. As part of her masters work at the University of California, at San Diego, McKenna used CT scans to try to model the way sound would travel through the whale head and the effect the sound could have on tissue at different frequencies and intensities, which correspond to pitch and loudness.

Ann Bowles says this work is important because, in the wild, "a deaf whale is a dead whale." But she adds, there are other still more difficult questions. More subtle, but more widespread, than sudden bangs and blasts are the possible effects of persistent and chronic noise. Stress from unfamiliar noise could result in changes in behavior, and elevated background noise levels could result in sound masking, meaning a species can't hear in its usual range. Like humans who refuse to live near airports because of the noise, whales may leave important feeding and breeding grounds if noise levels are too high. Sometimes though, they can't leave. Then, like humans who have to scream to talk to a friend at a rock concert, whales may have trouble communicating with family members or potential mates.

The Endangered Species Act lists 11 species of cetaceans, which include whales, dolphins and porpoises, as endangered, and the World Conservation Union, once known as the IUCN, lists another three as vulnerable. For those species with populations of only a thousand individuals ranging over an entire hemisphere, the lost of just five whales can lower the group's reproductive success. McKenna says, especially for these species, she wants to answer questions like: "Are we impacting their reproductive habits? Are we changing their behavior so they need to use more energy to communicate or to find food? Are they staying out of good habitats because it is too noisy?" Bowles says scientists are still trying to understand how to ask, let alone answer, these types of questions for the animal world. They have studied only a few pieces of the puzzle.

One of the complications is that different whale and marine species react differently to sound, and factors like age, sex, and location could affect responses. Furthermore, different sounds affect species differently; frequency, duration, and volume add to the variables that biologists need to test. "Scientists are a bit overwhelmed by the number of species and variety of responses," Bowles says. They are trying to collect data, but for now, they only have glimpses.

For example, Chris Clark found that fin whales, which sing at low frequencies undetectable to the human ear, could once talk to neighbors 100 miles away but now can be heard only five to 10 miles away.

Sam Ridgeway, a biologist at the Space and Naval Warfare Systems Center in San Diego, found background noise could temporarily affect dolphins' and whales' hearing ability, interrupting their echolocation. In these cases, navigating through a noisy environment is like driving through a thick fog.

Peter Tyack, a senior scientist at WHOI, discovered another difference between species. He found that right whales react to loud alarm sounds when they are feeding, but show no immediate reactions to ship noise. Beluga whales, by contrast, reduce calling rate and shift frequency production when boat noise is in the waters. But Tyack says different experimental set ups and different recordings could also contribute to the reactions. Tyack also found that male humpbacks modify their songs when exposed to sonar. They sing longer songs to compensate for acoustic interference. Sixteen singing whales were followed for a period of several hours, and then exposed to low frequency sonar and followed again. Songs were 29 percent longer during the sonar events. Once the sonar shut off, singing returned to normal. And as part of his thesis, Tyack found gray whales avoided a speaker playing low frequency sonar sounds placed in their migration path. Since their path is so precise, deviation by just a few degrees can be picked up. Miles upstream, the whales begin to swim in a trajectory that will take them around the speaker. "It was only because you had a hundred whales going by that you could define this behavior," he says. But Tyack does not know what these results mean for the species' survival

Of course, just because a species reacts, does not mean it is harmed. Bowles says humans react to loud noises even if the noises are not harmful. For example, she says most whales would respond to a loud noise in the water. "You did something new and different, and he wanted to check it out," she says. When changes impact reproductive rates, that is when they become important, but this is difficult to measure.

Dr. W. John Richardson, owner of LGL Ltd., an environmental research firm in Sidney, British Columbia, works with companies and government agencies to assess the environmental impact of their construction and development projects. "The important thing," he says, "is to try to put these things in perspective and recognize which things have real biological significance."

When Darlene Ketten was called in to study the beached whales in the Bahamas, she found bleeding in the ears of five whales. Some people immediately blamed the Navy, but Ketten wanted more evidence. "Most of the animals we looked at were severely decayed, so there was very little that could be said with authority whatsoever," Ketten says. She was thrust into a controversy she did not want to be a part of, and she refused to immediately blame the Navy for the deaths. She just couldn't tell. "People see blood around the ears and assume it must be noise," Ketten says. "If I say, 'I'm sorry. You are wrong.' I am accused of a cover up." She says this attitude discourages scientists from getting involved. "I am frustrated," she adds.

Hildebrand says when whales beach, everyone wants to point fingers and assign blame. He sits in a corner office at Scripps, and his window looks out over the Pacific's blue waters. By his door, hangs a piece of paper with these words written in crayon: When our Earth was made, it did NOT come with a replacement – Zoe. "That's my daughter," Hildebrand says. It is obvious he cares for the creatures he studies. He wants to help them. He prints peer review articles for journalists, directs them to Web sites, and provides names and contacts. But then he tells them not to write about anthropogenic sound. He shakes his head. It is just too complicated.

Ann Bowles' office also looks over the Pacific. It's smaller and more organized. She talks like an advocate. She has intense grey eyes that stare straight through large-framed glasses, and her gaze does not waver when she is trying to make a point. There is a mix of despair and anger in her voice. "We just don't know," she says. "How much noise is too much?" But Bowles believes there is a way of solving the problem. She says currently only very specific research questions are funded, but in order to tackle the problem, the approach needs to be broad. Most of the studies done in this area are those required by National Environmental Policy Act, which makes federal agencies consider the environmental impacts of their actions. NEPA asks specific questions like: Will the sonic booms from a particular space shuttle launch affect a particular species? Will drilling oil off a particular coast affect a particular species? Bowles says if science is to move forward, before researchers look at individual sounds, they need a greater understanding of what animals hear and how they interpret it. Basic biology and animal behavior studies are critical. "Someone at the government level needs to say, we want to solve this problem," she says.

That has not happened. Instead, the debate continues. In January 2005, 37 whales stranded themselves on the North Carolina coast shortly after the Navy tested sonar in the area. In the first draft of the report on the incident, Teri Rowles, coordinator of the National Marine Fisheries Service's standing response program noted that injuries to seven whales could indicate damage related to loud blasts from active sonar. In an updated report, the reference was removed because the sonar was found to be just one of several possible causes. The truth? No one knows for sure. The short- and long-term impacts? Also unknown.

Epilogue: Understand … Almost

Sound, like art, has an aesthetic quality. Throughout the early 1800s, John James Audubon drew life-sized portraits of birds, determined to capture and describe every species in North America. His passion, born from a love of nature, brought him to science and conservation. He conducted the first known bird-banding experiment in North America, tying strings around the legs of eastern phoebes. His images, particularly those of extinct species like the passenger pigeon, provide a brief look into the past, in the same way artifacts paint a picture of a lost culture. Many birders follow a path similar to Audubon's. After hearing the whistles and tweets, they are moved to want to understand the sounds, and then moved to protect the creatures that make them.

Bioacoustics is still in its infancy. Biologists are running around the world, sticking microphones in the trees, ground, and sea, collecting and digitizing more voices, calls, and songs than they could possibly listen to in their lifetimes. They have a passion for data collection, which has always been a hallmark of science. In the same way the ancients mapped the stars before they knew what their presence meant and geneticists mapped the genome before they knew how to use its building blocks, biologists are recording the world. In the novel Seeing and Believing, a history of telescopes, Richard Panek writes that the designers of the telescopes did not know what they were seeing or looking for, they were just trying to look deeper. He continues, "The truth about science is that it also proceeds in an unruly, unintuitive fashion. That sometimes observation precedes hypothesis ...That sometimes the best answer a scientist could want is more questions."

Some biologists are still in the data collection phase, cataloguing the sounds of species before they disappear. Others have done more. In his hours of recordings, Bill Evans has come to understand the patterns birds follow as they fly in the night. Katy Payne and Mya Thompson have learned how elephants can communicate and coordinate over long distances. And teams of researchers at Woods Hole Oceanographic Institute have found out when whales sing, where they swim, and how they dive. In each of these cases, the researchers have moved from basic research to applied conservation – siting wind towers, informing park managers, and trying to protect species from boat collisions. Collecting data can be slow, but once all the pieces are gathered, researchers hope they will fall into place. If scientists tried to understand the chemical processes in a single star without knowing anything about the formation of the universe as a whole, they would not get far. Ann Bowles and Darlene Ketten wish the study of anthropogenic noise would begin with data and patterns rather than specific applied studies. They want to see the clearer and fuller picture. They may have the answers, and they just need to find the right questions.

Eavesdropping can not only teach us to listen, but also can teach us to wonder. In the book, Animal Talk: Science and the Voices of Nature, Eugene Morton and Jake Page, write: "In the eyes of animals we have always seen a distant mirror of ourselves – so different but clearly with much in common." Similarly, we search for wisdom, warnings, assurances, and sometimes even person-hood in their voices. "Like those patterns we see with our eyes squinched shut, which drift away as we look at them, the meaning of the voices of nature has always seemed to stay beyond our ken." Conservationists are challenging this boundary.

Nature may not speak to them directly, but they are convinced that it tells them its stories. Sometimes, though, it only whispers.

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