Tracking wildlife

High-tech devices help biologists trace the movements of animals through sky and sea

Bill Seegar sits at the computer in his office at the US Army's Aberdeen Proving Ground near Baltimore and uses his modem to dial a toll-free telephone number. The call goes to Argos, a French company that provides satellite-based location and data collection services. After supplying his identification number and password, Seegar quickly accesses a file. A few more keystrokes call up a software program that converts the data in the file into the location and other biological information on a peregrine falcon some 2500 miles away in Greenland. Not only can Seegar locate the radiotagged falcon, but also he can follow its annual migration to South America and back. And he can do so without leaving the comfort of his office.

This is no ordinary radio telemetry project. "Our work represents a revolution in wildlife biology," enthuses Seegar, a senior research scientist at the Army's Edgewood Research, Development and Engineering Center at Aberdeen. "Satellite telemetry allows us to follow migratory birds [in a] way no one has been able to before. We are taking biology into the next century."

Seegar and other scientists are using new technologies—or making new uses of older ones—to understand animal movements and behavior in ways not previously available. By doing so, the scientists are not just adding to biological knowledge but are helping to advance wildlife conservation.

Beyond locating radiocollared animals, the technologies let scientists record body temperature, speed, altitude, humidity, acoustic, and other data via satellites. Biologists are also using new radar systems to locate and follow migrating birds. They can even use underwater microphones once tuned to Soviet submarines to monitor and track the movements of whales.

Most scientists involved in using advanced technologies to track wildlife work for the Department of Defense (DOD) or have DOD funding. Their research is aimed at providing information that lets the military train troops, conduct maneuvers, or test weapons, while protecting endangered species and other wildlife.

Satellite telemetry for the birds

Working with wildlife biologists at the University of Maryland Baltimore County and with physicists and engineers at the Johns Hopkins University Applied Physics Laboratory, Seegar has developed miniature radio transmitters as small as a disposable cigarette lighter and light enough to be carried on a bird's back. The transmitters send data to Argos receivers aboard one of three National Oceanic and Atmospheric Administration (NOAA) weather satellites that orbit the North Pole 700–800 miles above the earth's surface. The satellite then beams the data to a land-based receiving station, which Seegar and others can access via computer.

Since starting this work in 1981, Seegar has gradually cut the size of the transmitters from 180 grams to 20. Over the years, in addition to tagging peregrine falcons, he and his colleagues have put the transmitters on white pelicans, trumpeter and tundra swans, bald and golden eagles, and prairie and Swainson's hawks, among other birds.

The results of the peregrine falcon studies have been especially rewarding. Peregrines are among the avian world's great wanderers. Some migrate up to 18,000 miles from the Arctic Circle to South America and back. But no one knew the precise routes that individual falcons follow or whether they always return each spring to the area where they hatched.

Seegar and his colleagues tracked 57 peregrine falcons by satellite. One female in particular provided a wealth of information. Seegar followed her as she flew from her nesting ground near Hudson Bay in Canada down the Atlantic Coast to Cuba and across the Caribbean Sea to southern Brazil. The following spring, he tracked the same bird returning north to Hudson Bay via Padre Island off the Texas Gulf Coast—a previously unknown staging area for migrating peregrines.

But Hudson Bay was not the end of the line for this bird. Instead of staying near her native Rankin Inlet on the bay's west coast, this peregrine falcon flew another 1000 miles northeast to Baffin Island in the Arctic Ocean. As an adult who had not yet bred, she may have been less tied to a particular nesting area, Seegar speculates about this bird's unusual extra jaunt.

In following more than 50 peregrine falcons since 1992, Seegar and his colleagues have learned that the birds migrate to widely separated wintering areas. Although most fly to Central and South America, some go no farther south than Cape Henlopen, at the mouth of Delaware Bay.

by Jeffrey P. Cohn

Bird trackers to the rescue

An earlier 5-year, $5 million study of golden eagles and other raptors at the National Guard's Orchard Training Area in southwestern Idaho paid practical dividends for the military and for conservation biology. In the late 1980s, the National Guard was being criticized for disturbing golden eagles. Seegar and Mark Fuller, a wildlife biologist with the US Geological Survey's Biological Resources Division at Boise State University, quickly found that field biologists could not effectively track eagles by conventional means with troops, tanks, and unexploded shells all around.

Instead, the scientists switched to Seegar's satellite tracking system to study the situation. They learned that the golden eagles were not affected by military activities. "They would just move a bit," Seegar says of the birds' response when artillery and tanks began firing. And although Orchard's military planners and land managers had assumed the eagles were year-round residents, Seegar and Fuller learned that the birds winter in southern Idaho, but breed farther north. "We removed the eagles as a concern for the military," Seegar says.

More recently, Seegar's satellite tracking tool helped save an entire species. Swainson's hawks summer in western North America, then migrate to South America in the fall. For years, wildlife biologists knew that the number of these dark-breasted hawks was dropping precipitously. They noted fewer hawks returning north each spring. Some speculated that pesticide use in South America might be affecting the birds' survival.

One scientist who wanted to know the hawks' fate was Brian Woodbridge, a US Forest Service wildlife biologist who had studied Swainson's hawks in Northern California since the early 1980s. Woodbridge collaborated on a study with Fuller, Seegar, and other scientists to put satellite transmitters on approximately 50 Swainson's hawks, including two hawks in Northern California in 1994.

The results of the study confirmed previous observations by field biologists and bird watchers showing that Swainson's hawks converge as they migrate through Veracruz, Mexico. The birds remain together as they continue down Central America to the pampas of southern Argentina.

Martell found that male and female ospreys migrate at different times and winter in different areas

When Woodbridge visited Argentina to study the tagged birds, he saw thousands of Swainson's hawks feasting in a field on grasshoppers stirred up by a farmer's tractor. A few days later, he found 700 dead hawks in a nearby woodland where the night before he had estimated that 7000 birds were roosting. Among the dead birds was one that Woodbridge had tagged in California. All told, Woodbridge and other scientists found an estimated 20,000–40,000 dead hawks in Argentina that year.

Subsequent studies by Michael Hooper, now of Texas Tech University, found that monocrotophos, an organophosphate used until recently by South American farmers to control insects, had killed the Swainson's hawks. The Argentine government has since banned the pesticide, and no further mass hawk die-offs have been recorded. "The satellite technology highlighted an important conservation issue and allowed [researchers] to solve the problem," Woodbridge says.

In another study using satellite telemetry, Mark Martell, conservation coordinator at the University of Minnesota's Raptor Center in St. Paul, found that ospreys differ from Swainson's hawks in their migratory patterns. Like peregrine falcons, ospreys follow individual routes to widely dispersed winter sites from northern Mexico to the Caribbean and southern Brazil.

But Martell made a more surprising discovery. He found that male and female ospreys migrate at different times and winter in very different areas. In fact, female ospreys leave the nesting ground before their young are fully independent. Male and female pairs "may be tied to a particular nesting site, not to an individual mate," Martell notes. "We would not have known this without satellite telemetry."

Future prospects for telemetry

Seegar is working on ways to improve satellite telemetry and is now adding global positioning systems (GPS) to the transmitters. GPS can locate and track animals more accurately than current technology and can also record locations for later transmission, when a satellite is overhead. Transmitters now beam data at regular intervals whether or not a satellite is overhead to receive the information.

Seegar began testing GPS transmitters in 1997 on oryx—exotic African antelopes introduced in New Mexico for hunting in the 1950s. Transmitters have since been put on radiocollared mountain lions in Colorado and Idaho, and on wolves in northwestern Canada. So far, the GPS transmitters have been too heavy for birds, but Seegar hopes to begin testing a 100-gram model in 1999.

As an alternative to conventional transmitters, which are too heavy to place on songbirds, Seegar hopes to substitute diodes for battery-powered transmitters. Weighing less than 1 gram, diodes act as transponders that return a signal from a land-based radar beam. The project is still in the design stage, but a similar diode and radar system has been used to track butterflies and bees over short distances (less than 300 meters).

Tracking birds with Doppler radar

In a technology a little closer to Earth, Sidney Gauthreaux is using the new Doppler radar systems known as NEXRAD (for next generation radars) to track bird movements. Doppler radar systems operate at 164 airports, weather stations, and military bases around the United States.

"Oftentimes, what is seen on radar screens as interference is really migrating birds," says Gauthreaux, a professor of biological sciences at Clemson University in South Carolina. Doppler radar measures increments in frequency shifts and location, thus giving information on speed and direction. And because Doppler uses a narrower, more powerful beam, it gives a finer resolution. Furthermore, Doppler radar uses high-powered computers to process more data more quickly than could be done using older radar systems and older computers. As a result, data from Doppler radar is available from the Internet in half-hour updates.

Nevertheless, distinguishing birds from rain and other weather patterns, as well as from insects, smoke, and dust particles, is not easy, Gauthreaux says. "It takes years to learn," he says. But there are ways to make distinctions. For one thing, even the slowest birds fly faster than the fastest insects. For another, unlike weather systems, birds move at different speeds than the wind. And, because large flocks tend to be evenly distributed when they fly, they appear symmetrical on radar screens, whereas other radar images often appear irregular.

Like conventional telemetry, Doppler radar can be used to tell where a flock of birds is, what altitude it is flying, and how fast it is going. Doppler can be used to relate the birds' flight to weather patterns. It can also be used to track flight patterns and migration routes over the entire country.

Gauthreaux's use of Doppler radar, like Seegar's use of satellites, has provided new insights into bird migration. Gauthreaux has found, for example, that birds migrating from Central and South America do not all leave from the Yucatan Peninsula in Mexico and then fly north across the Gulf of Mexico, as most biologists had thought. Rather, the birds leave from many points throughout Mexico and, if the prevailing winds are from the west, fly east over the Gulf and then turn north. "It gives them a faster route than flying over land," he says.

Migrating birds often wait for tailwinds and other favorable weather patterns to help them in their travels

Gauthreaux has also found that migrating birds often wait for tailwinds and other favorable weather patterns to help them in their travels. Birds migrating along the Atlantic Coast fly out over the water near North Carolina's Outer Banks at night, then return to land over southern Florida by late morning. "We knew they [flew out over water] in New England, but not further south," Gauthreaux says. "Radar is telling us [that] thousands of birds use routes over water as a shortcut to Miami."

The reason may be twofold, he speculates. Air masses over water tend to be more stable than those over land, thus providing easier flying. Also, air over water is usually cooler than air over land, with few of the thermals that hawks and other raptors use to gain altitude for dive attacks on small migratory birds.

Despite providing such insights, Doppler radar has its limitations. It can distinguish among shorebirds, raptors, waterfowl, and songbirds but cannot tell one species from another. Gauthreaux hopes to adapt vertical radar beams, rather than the horizontal ones now used, to measure wing beat frequency. Different patterns can be used to identify bird species. "That's the next step," he says. "But we're not there yet."

For now, however, one of Gauthreaux's graduate students is using Doppler radar combined with field observations to follow one bird species. Since 1995, Kevin Russell has been studying the huge flocks of purple martins that roost near Lake Murray in Columbia, South Carolina. The martins congregate around the lake in June and July when their young have fledged, then leave in late July and August. Russell wanted to know where the martins went and how far they flew each day. "You can only see so far and track so many" by conventional observations, he says. "Radar lets you look at much wider distances."

By comparing field observations with radar images, Russell found that purple martins leave their roost sites before dawn at the same time each day relative to sunrise. They split up and fly in roughly equal numbers in all directions, forming a distinctive expanding ring on the radar screen. The martins also go 10 times farther (up to 100 km) in their daily search for flying insects than biologists had thought.

An acoustic window on life in the ocean

Whereas some wildlife biologists are using new technologies to expand our knowledge of life in the skies, others are using an older system to study and track animals under water in ways that were impossible before. This system is the Navy's sound surveillance system, or SOSUS, the once super-secret arrays of underwater microphones used to track Soviet and other submarines.

Built between the 1950s and the

1970s at a total cost of $16 billion, SOSUS takes advantage of water's ability to transmit sounds, especially low-frequency ones, over long distances. An underwater explosion generated by researchers in Perth, Australia, for example, was detected halfway around the world in Bermuda.

From the beginning, SOSUS confirmed what scientists already suspected—the world's oceans are noisy places. In addition to submarines, SOSUS microphones detect sounds made by surface ships, airplanes, fish and shrimp, whales, and even raindrops hitting the ocean's surface.

Most SOSUS microphones, which feed data to land-based computer banks via cables, are located in the northern Pacific and Atlantic oceans. Their precise number, spacing, and location remain secret, says Bob Gisiner, a marine biologist and program manager in the Navy's Office of Naval Research.

Navy officials began looking for nonmilitary uses for SOSUS in the late 1980s, as the Cold War ended and the Soviet threat eased amidst political and economic chaos. By the early 1990s, civilian and military scientists were using SOSUS to monitor underwater earthquakes and volcanoes, record nuclear explosions, detect illegal drift-net fishing, and listen in on whales.

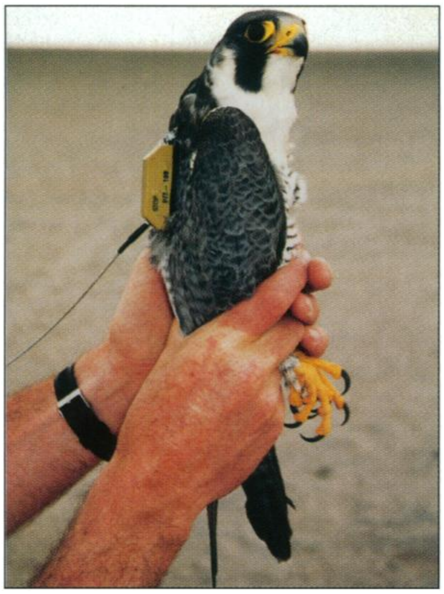
"We can follow whales 24 hours a day, 7 days a week, 365 days a year," says Kurt Fristrup, assistant director of the bioacoustics program at Cornell University's Laboratory of Ornithology in Ithaca. "We have a window on the ocean that operates full-time."

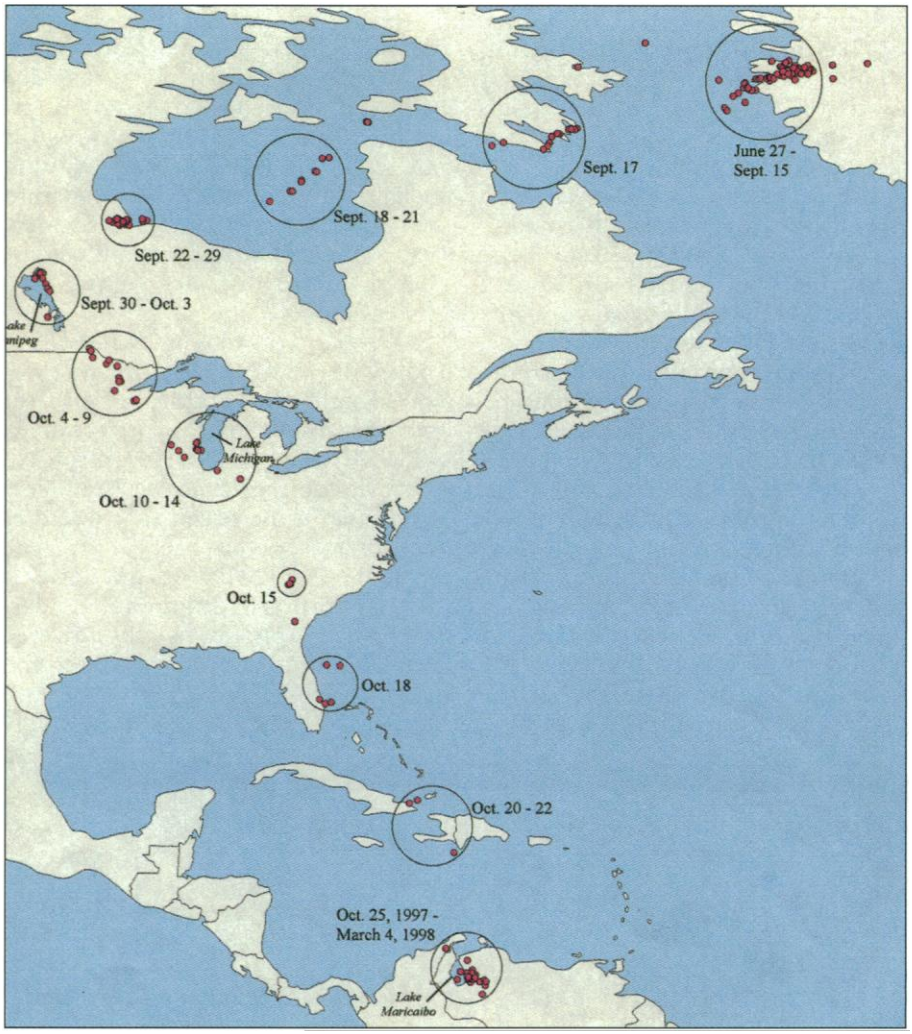
Listening to whales is not new. "It is easy to put hydrophones [underwater microphones usually lowered from a ship's side] in the water and pick up whale calls," Fristrup says. However, "it is hard to know where the sound is coming from or what species is making it unless the whale is really close."

Additionally, scientists could only view or listen to whales for short periods, when the whales were in shallow coastal waters. "Now we can look at the whole ocean in real time," Gisiner says. "We can chart where whales are when. That tells researchers where to go to find a particular species."

Early use of SOSUS focused on identifying which whales make what sounds. So far, only the calls of blue, fin, and humpback whales can be identified with certainty, although some scientists think minke calls can be identified too. All are large whales that emit low-frequency calls.

Distinguishing among calls lets scientists better plot a species' range during breeding and winter seasons, but following individual whales is still difficult. "We can track indi-





Researchers are using satellite telemetry to study the behavior and movements of birds such as this peregrine falcon. The bird shown above was about to be released after researchers secured a satellite transmitter to its back. At right is a map showing the migration path of a mature female peregrine falcon—one of 57 birds that were tagged and tracked by Bill Seegar and his colleagues. Photo: Michael Yates, Boise State University. Map: Courtesy of Blake Henke, Center for Conservation Research and Technology.

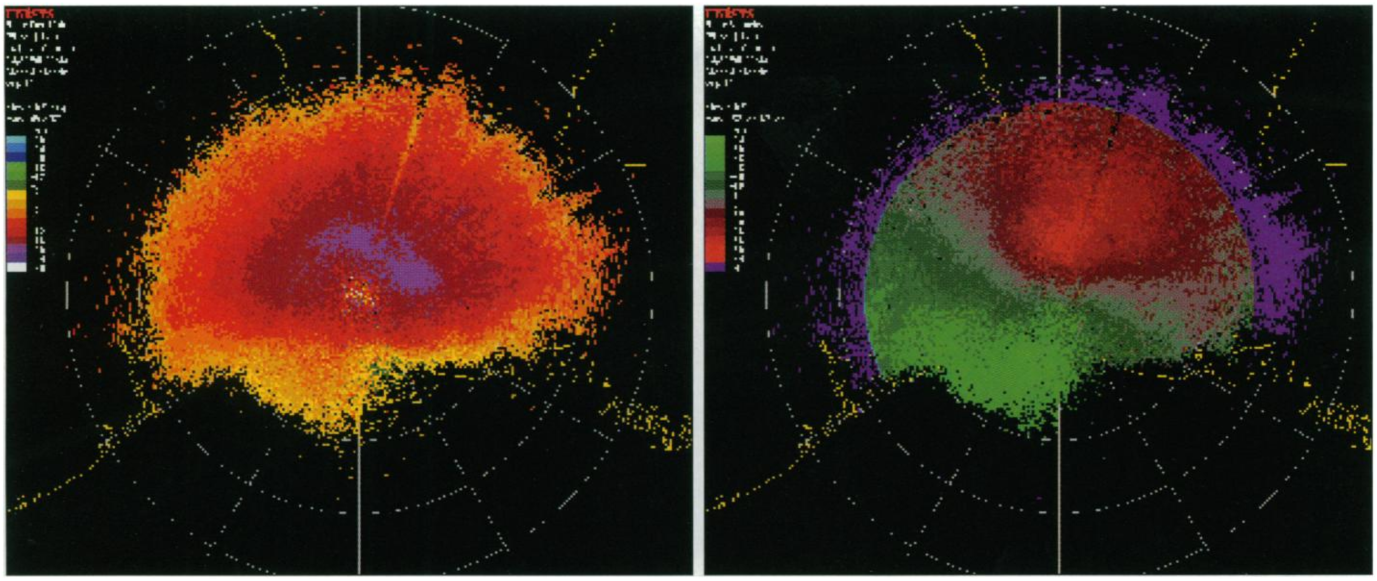
vidual whales," Gisiner says, "but not any individual we want." In general, whales that emit unusual calls can be identified. Christopher Clark, at Cornell, and Charles Gagnon, of the Dam Neck naval facility, in Dam Neck, Virginia, followed one such individual, nicknamed "Old Blue," in the Atlantic for 21 days as it swam 2000 miles from Bermuda to South Florida and back.

Fristrup and other scientists using SOSUS learned that blue whales stop calling when feeding, then resume after they have moved to another feeding area. Perhaps they are letting other whales know where they are. Or, perhaps like dolphins using echolocation, they call to navigate or find food. What does seem certain is that blue, humpback, fin, and minke whales start calling in the fall, continue through winter, and then gradually taper off in spring, Fristrup says.

Other scientists are tracking ocean wildlife using the same satellite telemetry and Argos receivers and transmitters that Seegar and others use to track birds. Bruce Mate, professor of fisheries and wildlife at Oregon State University, in Corvallis, has developed transmitters that can be attached to whales. Because satellites cannot receive signals from a whale that is under water, the transmitters send data only when the animal surfaces to breathe.

Mate found that right whales often move rapidly to sites far offshore to feed at great depths. Previously, he says, scientists thought right whales were slow-moving surface feeders that stay near shore. Mate's findings can be used to help right whales, which are sometimes injured or killed in collisions with ships. This is particularly important in the Atlantic, where right whales still only number around 300.

In another study using satellite telemetry, Mate tracked a blue whale in the Pacific that swam 1200 miles from the Baja Peninsula, where blue whales usually winter, to a region of intense upwelling off the Costa Rica coast. Such areas are often important food sources for whales. Scientists had assumed that blue whales, like humpbacks and gray whales, do not eat during winter. Mate's findings, however, suggest that this as-



Sidney Gauthreaux and his colleagues are using NEXRAD Doppler radar systems to track bird movements. The image at left (base reflectivity) shows the pattern of radar echoes from migrant birds departing from the upper Texas and western Louisiana coasts and from some migrants continuing to arrive from the Gulf of Mexico. The different colors represent different amounts of reflectivity per unit area, and the values are directly related to concentrations of birds. The image at right (base velocity) shows the direction and speed of the same echoes. Birds flying away from the radar station appear red, and birds moving toward the radar station appear green. Images: Sidney Gauthreaux.

sumption may be wrong.

In ongoing research, Daniel Costa, professor of biology at the University of California–Santa Cruz, is using radio transmitters and NOAA weather satellites to study elephant seals. Costa hopes to learn more about the temperature in the water that elephant seals dive through, the seals' dive depths, and the sounds they hear around them.

Costs and benefits

The insights provided by the new technologies often come with a high price tag. The transmitters that Seegar uses cost about $3000 each. And tracking just one animal via Argos receivers costs $1500 a year, Seegar says, although the cost can be cut by transmitting data only one day out of every three.

Another limitation, Gisiner says, is the Navy's need to carefully control SOSUS data to preserve the system's defense use. The Navy has also closed some land-based receiving stations as part of post–Cold War cutbacks. As a result, "some of [SOSUS'] promise has not been fulfilled," Fristrup says.

Still, researchers using new technology to track wild animals have barely scratched the surface. "We're still tumbling around trying to find what we're doing," Mate says, but already "the technology has forced us to rethink what animals do and where they go. It gives us insights we can't get from conventional telemetry."

Nevertheless, there is still room for conventional wildlife biology. "It is hard to interpret behavioral data from satellites alone," Mate says. "We need biologists in the field to confirm our findings." ❑

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