the number that Gunn and his colleagues found is uncomfortably large for a universe with an omega as high as 1.0. The survey found 42 clusters per square degree and, because the process of finding clusters "isn't 100% foolproof," says Postman, "we know at the distant end, we're missing 20%." These numbers imply that omega is low, the best theories are wrong, and the universe will keep blowing up fast and forever.

Of course, the observers have caveats about their observations. The distances estimated for the clusters are one possible source of error. Inaccurate distances might mean the clusters are not clusters at all, only galaxies at different distances superimposed on the sky in a way that makes them look like clusters: "[We're] looking back in two dimensions," said Dressler. "Things are piled against the sky." Because of such errors, theories are malleable. With the same data, said Evrard, "I've written papers that work with a low omega and with a high omega. It doesn't take even a very clever theorist."

So the plans for the future are to make more observations. The sky is divided into 41,000 square degrees, and Gunn's optical survey covered only six of them. Those six, says Postman, took 3 years; with newer detectors, "you could map this in 4 nights." Another optical survey team—Postman, Hoessel, William Oegerle from STScI, and Tod Lauer from the National Optical Astronomy Observatories—is now using the telescope at Kitt Peak National Observatory with new detectors to map distant clusters to a red shift of 1.0. They are focusing on a region covering 16 square degrees, about the size of, and roughly in the same place as, the bowl of the Big Dipper. The Deep Extragalactic Evolutionary Probe, or DEEP, will use an instrument built by the University of California and others for the Keck telescope to map 12 1-degree patches to red shifts of 0.6. Still another survey, the Sloan Digital Sky Survey (a collaboration between Princeton University, the Institute for Advanced Study, Fermilab, the University of Chicago, Japan National University, and Johns Hopkins University), will take a much broader view of the sky, mapping nearly 4000 degrees to a red shift of 0.2. And x-ray astronomers in Italy and the United States have proposed a new satellite telescope, the Wide Field X-Ray Telescope, to map clusters over 100 square degrees, to a red shift of 2.0. Richard Burg of Johns Hopkins University, principal investigator on the x-ray telescope, says the proposal is in NASA's hands and—if all goes well—launch is 5 years off. If their plans work out, these researchers may be able to tell us how the universe will end.

–Ann Finkbeiner

Ann Finkbeiner is a science writer based in Baltimore, Maryland.

PRIMATE BEHAVIOR

Nocturnal Researchers Tune Their Ears to Our Ancestors

DURHAM, NORTH CAROLINA—Primate behavior has become a favorite topic in the past few years, as researchers explore how biology influences behavior, and the public laps up books and movies on primatologists like Jane Goodall and Dian Fossey. Not surprisingly, gorillas and chimpanzees—humans' closest kin—have been the stars of the show. Like us, these big apes are active while the sun is up, so researchers seeking to understand their behavior can adopt a simple, if time-consuming strategy: They watch.

The ears have it. The endangered aye-aye relies on hearing to find food and scent to communicate.

But there's also a whole group of primitive primates who feed and mate in the dark, including exotic creatures such as galagos, lorises, lemurs, and tarsiers. Because of their secretive and hard-to-study lifestyle, these "nocturnal prosimians" have been left in shadow compared to their sun-loving cousins. Nevertheless, an intrepid band of researchers, who gathered recently at Duke University,* insists that these primitive primates are well worth the extra effort it takes to study them. Since the first primates were probably nocturnal, today's prosimians are a unique scientific resource, a window into the evolution of primates at least 50 million years ago, says Ken Glander of Duke. And since many of these species are dwindling in number, behavioral research has taken on a new urgency.

At the Duke meeting, scientists demonstrated that although they labor in the dark, they've found the key to understanding their subjects. The trick, says Simon Bearder of Oxford Brookes University in Oxford, England, is to think like a nocturnal primate: Focus on sound and scent, instead of sight. "We're finally beginning to get inside the minds of these creatures—who after all are descended from our own ancestors—to see what it's like to be a creature of scent and hearing. Just because they don't see each other much doesn't mean they don't know whose home range overlaps with whose," says Alison Jolly of Princeton University.

By analyzing calls and scent marking behavior, scientists are finding unexpected diversity among the nocturnal prosimians, in terms of both numbers of species and behavior. Once thought to have relatively simple social structures, these prosimians are now known to have a complex repertoire of behaviors and communications, as do their cousins on the day shift.

Take the aye-aye, *Daubentonia madagascariensis.* One of the many prosimians found only on the island of Madagascar, the aye-aye is considered the world's most endangered primate because it's the only member of its family left. And the aye-aye is definitely a solitary creature. Adults spend more than 80% of their time alone and rarely if ever sleep together, says Eleanor Sterling, who presented the first long-term study of aye-ayes in the wild, done for her Ph.D. thesis at Yale University.

Despite this lust for solitude, there is a distinct social dimension to the aye-aye world. Different individuals occupy the same nest on subsequent nights, and they are well aware of the foraging areas of others. Females, for example, apparently stake out distinct home ranges and were never observed straying into another female's range. The invisible boundaries are apparently drawn by scent marks, left by streaking urine along a branch. "They communicate on a level that we do not," says Sterling, who spent 2 years trailing aye-ayes through the dark, aided by radio collars, dim flashlights, and two Malagasy guides. "If you're leaving scent marks all over, you're telling the others a lot, although we can't necessarily read those marks."

Smell isn't the only sense that helps nocturnal creatures navigate in the dark: They're keen listeners as well, and their calls

*"Creatures of the Dark: The Nocturnal Prosimians," 9-12 June 1993.

are crucial to the delicate task of choosing mates. Those choices—which daylight simians usually make on the basis of what they see—may well be responsible for the development of new species, concludes Bearder, who has spent two decades studying the genus *Galago* in Africa.

Galagos—called bushbabies because the cry of the largest species sounds like the bawl of an unhappy infant—call to advertise their presence, alert each other to danger, and find mates. Once the calls of two groups diverge sufficiently—whether by chance or selection—their members no longer find each other attractive, and so they may rapidly separate into two species, says Bearder.

This idea is supported by the fact that each known species of galago has a different repertoire of calls, although several species look nearly identical. To bushbabies and other nocturnal primates, says Bearder, "Sight is not that important, and so they may look almost identical and yet be different species, or they may look very different and be members of the same species. You have to know how the animals divide themselves up."

The result of all this nocturnal hooting is that the more scientists look—or in this case, listen—the more species they find. Back in the 1970s, most researchers thought all the world's primates were already recognized, remembers R.D. Martin of the University of Zurich, but since then, a number of cryptic, new nocturnal species have emerged. For example, Madagascar's sportive lemur, *Lepilemur mustelinus*, was once thought to be a single species. Now seven distinct species of *Lepilemur* are recognized in different parts of the island. Bushbabies were once divided into six species; today Bearder argues for at least 13. And many of these newly identified species are confined to small regions and are thus relatively vulnerable to extinction, says Martin.

Since humans rely primarily on vision, nocturnal species are perhaps the least understood of all primates, say Bearder and Martin. And while gorillas and chimps will probably always get top billing, the nocturnal prosimians put on a nighttime concert that is clearly worth attending. Unfortunately, as several speakers noted, if the audience doesn't pay attention, the music may eventually stop: Many prosimians, like their larger cousins, are endangered by human encroachment on their habitats. Thus behavioral research is needed now, in order to learn as much as possible before wild populations vanish, and also to improve the success of captive breeding programs. If prosimian partisans have their way, a growing number of animal behaviorists will prick up their ears and follow their noses into the darkness of the rain forest at night.

–Elizabeth Culotta

EPIDEMIOLOGY

Satellite Data Rocket Disease Control Efforts Into Orbit

Last fall in Kenya, several dozen inhabitants of the rural and wooded southern Kerio Valley began suffering the symptoms of yellow fever: elevated temperature, vomiting, jaundice, and internal bleeding. That was a surprise, since these were the first cases of the disease ever recorded in Kenya. The virus seems to have swept into the valley's monkey population from neighboring countries, and then forest-dwelling mosquitoes passed it from the monkeys to people who ventured into the forest. Things calmed down this spring—new cases have subsided, and the valley's 750,000 inhabitants have been immunized.

But yellow fever is still lurking in the forest, and it may be moving toward not-too-distant cities. All it would require is a continuous forest corridor through which the virus could travel from one monkey population to another. The snag is that no one knows whether such forest links exist, and available maps don't show enough detail to deduce the answer. "It's very important that as quickly as possible we identify areas at risk, so we can protect the population by vaccination," says Paul Reiter, a medical entomologist with the U.S. Centers for Disease Control and Prevention who was part of a team called in to investigate the outbreak.

So once the Kerio Valley situation was under control this spring, Reiter headed not into the forest with a surveying team but to the National Aeronautics and Space Administration's (NASA) Ames Research Center in Mountain View, California, in search of a satellite photo. He will soon receive a high-resolution weather-satellite image of Kenya, which he will analyze for signs of forest corridors through which the disease could spread.

Reiter is one of a small, but growing, band of entomologists and epidemiologists who believe high-tech images from space can help combat disease—especially in some of the world's lowest-tech places where even simple questions like "where does this forest end?" can't be answered from the ground. "It's difficult for us in the North or the West to appreciate the problems of scale in Africa," says Oxford epidemiologist David Rogers, who studies the African tsetse flies that carry sleeping sickness. "You simply can't visit all the places you'd like to visit, because you can't get there."

That inaccessibility often spells disaster. "When someone finally comes out of the area saying, 'My people are dying, come help us,' it's too late," says entomologist Robert Gwadz, assistant chief of the laboratory of malaria research at the National Institutes of Health. At a recent meeting in California,* Gwadz and Rogers joined other researchers and representatives of aid and funding agencies to discuss ways that satellite surveillance can provide a new avenue of attack against diseases such as malaria, sleeping sickness, and yellow fever that are spread among humans by insects. Although the satellite approach is still under development, the epidemiologists envision someday being able to predict disease trouble spots—and get to them—before the disease has broken out.

BYRON WOOD/NASA

Vector vision. This Landsat image of California rice fields *(bright green)* shows that most mosquitoes live in fields near pastures and orchards, to the right.

To achieve that goal, researchers have launched a handful of pilot projects around the world to see just what satellite images can do. Rogers and his colleague Sarah Randolph at Oxford, for instance, are using a vegetation index based on satellite images to analyze the distribution of tsetse flies in eastern Africa. Tsetse flies carry trypanosomiasis, a disease that infects and kills cattle as well as humans, in which it is known as sleeping sickness. Cattle are far more susceptible to the disease, and as a result, the flies

*NASA Workshop on Remote Sensing of Vector-borne Disease Associated with Environmental and Cultural Change, 2-6 May, Marconi Conference Center, Marshall, California.