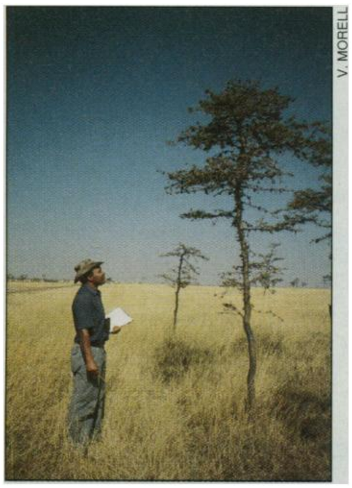
ECOLOGY

Counting Creatures of the Serengeti, Great and Small

SERENGETI NATIONAL PARK, TANZANIA—It's just after dawn, and in the dense woodlands along the Grumeti River the birds are beginning their morning chorus. This is prime data-collecting time for ecologists A.R.E. Sinclair and Simon Mduma of the University of British Columbia (UBC) in Vancouver, and they bend their heads and cup their ears to better hear the bird calls. "That's two gonoleks singing their duet; the cooing is a green pigeon; and that harsh cry is a gray-headed kingfisher," says Sinclair. Mduma and Sinclair's wife, Anne, jot down the species on their data sheets. Crouching low, Sinclair listens again, then creeps forward, following a hippo's trail through the dark stands of fig and African olive trees. Silently, he points to an oval circle of mashed grass and ferns where the hippo had rested, then raises his eyebrows in mock alarm at the bus-length crocodile stretched on a sandy beach across the river. But it's the birds Sinclair is after, and a few moments later when he first hears and then sees an olive-green bulbul, he smiles broadly. "They are rare and hard to see," he whispers, "and so are exactly the kind of bird we're trying to find by creeping around like this. It's the kind of species most likely to vanish if we lose these forests."



V. MORELL

Canopy count. Mduma is exploring the remote Serengeti.

Counting olive-green bulbuls in a forest may seem odd in the Serengeti, an ecosystem best known for vast herds of antelopes and large carnivores racing across wide-open grasslands. Indeed, most scientific research in these famed East African plains has focused on grassland plants and the "glamour" animals—lions, rhinos, buffaloes, and cheetahs. Sinclair himself, who directs UBC's Centre for Biodiversity Research, has done several such studies since he began working in the Serengeti in 1965.

But even the man whom other researchers sometimes refer to as "Mr. Serengeti" says that his past work has not been comprehensive enough, and that it's time to pay attention to the other creatures of the park—the smaller mammals, birds, and insects—and their diverse habitats, such as this little-known riverine forest. With a small grant from the Natural Sciences and Engineering Research Council of Canada, Sinclair has just launched the first systematic biodiversity study of the park. "We need that baseline data: the variety of species, their numbers, habitats, and how all these are interrelated," he says. "Without it, we have no way of knowing what generates the Serengeti's diversity, how the park is changing, or how people are affecting the environment outside the park." For example, riverine forests such as this one along the Grumeti are shrinking, but no one knows why—whether it's part of a natural cycle, or due to human influence.

Armed with new—if meager—funds from government research agencies, scientists worldwide are setting out on similar surveying missions in key areas. "There's still no part of the planet where we know every species," says Joel Martin, program director for the U.S. National Science Foundation's (NSF's) biotic surveys and inventories. "And we're losing species and habitat at an unprecedented rate, which makes these kinds of surveys imperative." But there are no set rules about the best way to tackle this enormous task. Some surveys, such as those funded by Conservation International, are quick-hit projects, with a team of scientists sampling as much as they can in a region in a 4-week period. Others target all the plants of a country, or a specific group of animals in a region and their parasites. A few projects try to identify every organism in a given area, although such all-taxa surveys are costly and difficult to coordinate. (See *Science*, 9 May, p. 893, on the breakup of one such planned survey.)

For Sinclair, a simple approach is best. With two men and two Land-Rovers—plus a lifetime of natural history observations—he hopes to understand, if not count precisely, the densities, habitats, and cycles of the Serengeti's flora and fauna. Although some note that the shoestring approach may miss crucial information about, for example, all the insects, Sinclair and Mduma argue that the Serengeti Biodiversity Project is a more realistic model for the developing world than all-taxa surveys. "It's a tremendously exciting approach and just what we need more of," says Peter Raven, director of the Missouri Botanical Garden in St. Louis, "because he's looking for cycles of change" and "setting this up with Tanzanians."

Money for such work wasn't available even in the Serengeti until recently, say Sinclair and others. "Everybody's idea of the Serengeti is a big acacia tree with a leopard hanging in it," says Peter Arcese, an ecologist at the University of Wisconsin, Madison, who has also worked extensively in the Serengeti. "So that's where the grants went." The emphasis on the big glamour pusses only began to shift around 1990, says Sinclair, when researchers began to hammer home the fact that Earth is now in the grip of a sixth great extinction, following the five recorded by fossils (*Science*, 21 July 1995, p. 347). Suddenly, documenting the remaining species became an urgent task, and funding agencies began putting up money to make it happen. The NSF's inventory program, for example, was launched in 1991; this year's budget is about $2.4 million. Conservation International had begun its Rapid Assessment Program 2 years earlier.

Often, these projects focused on areas that had not been studied at all. But now, researchers are beginning to discover the scientific value of long-studied national parks such as the Serengeti, Kruger Park in South Africa, and Yellowstone, says Sinclair: "They're the places that hold a record of our natural world—and in about as pristine a condition as we can now find." But even though they are protected, they continue to suffer decline—which makes documenting what's in them even more important, adds Keith Langdon, a biogeographer at Great Smoky Mountains National Park in Tennessee, who's coordinating a proposed survey there—the first ever all-taxa inventory of any U.S. park (*Science*, 12 December, p. 1871).

Tackling a project of this size seems at first glance a logistical nightmare—particularly with a staff of two and only $60,000 a year. In the 14,673-square-kilometer Serengeti, habitats range from grasslands to various kinds of acacia forests to stony outcrops, and organisms

V. MORELL

Master surveyors. Sinclair and Mduma count Serengeti birds and small mammals, not just big cats and wildebeest.

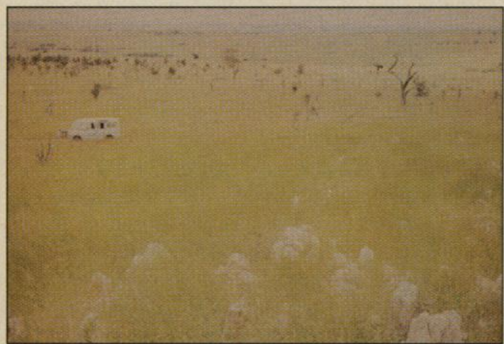
Return of the Forest

SERENGETI NATIONAL PARK, TANZANIA—Back in 1980, when the acacia and bush forests of the Serengeti National Park were shrinking, ecologist A.R.E. Sinclair tried to take notes on the "last tree in the Serengeti." "I remember climbing to the top of that ridge," he says, pointing to a steep hill. "There was then one acacia growing at the very top." The forest decline had been going on since before Sinclair started working in the park in 1965—and elephants were held responsible. "Everyone blamed the elephants, which was easy to do since you could see them eating the trees," he says.

But now, in the late 1990s, Sinclair has a very different perspective on the comings and goings of Serengeti species. His long-term monitoring of the park's ecosystem (see main text) has persuaded him that rather than having a single cause, such changes are driven by complex interactions among such factors as the life-span of acacia trees, the numbers of wildebeest, and the influence of humans. The loss of forest—and its recent return—is a case in point.

By the mid-1970s, some conservationists feared that the Serengeti was doomed to become a desert unless elephants were culled. "People thought the forests and bush were the way 'pristine Africa' was supposed to be," recalls Sinclair. In fact, the "pristine" woodlands of the 1930s and '40s were new, themselves part of a larger trend. They had grown up after cattle belonging to the local people had been devastated by an outbreak of rinderpest disease in the 1890s—leading to mass human starvation.

People burn grasslands, in part to create fresh pasture for cattle, and fewer people meant fewer fires. As a result, the acacia seedlings grew up, ultimately creating forests in the midst of the grasslands. But by the 1920s and '30s, the human population had begun to recover, although the Serengeti's vast wildebeest herds—also devastated by rinderpest—did not. Without the wildebeest munching their way across the plains, the grass grew tall, and people—from Masai herders to park rangers—once again began setting fires. Now, however, they set more and hotter fires to control the grasses.



A.R.E. SINCLAIR/CENTRE FOR BIODIVERSITY RESEARCH

Desert or forest? Although the Serengeti's acacia forests declined in the 1970s, the trees returned, as seen in photographs taken in 1980 *(top)* and 1991 *(above)*.

In the 1960s, several factors came together: A wet climate favored the grasses, so even more fires were lit, scorching new tree seedlings. The older acacias, which live only 60 to 70 years, began to die. And although elephants also fed on the young trees, Sinclair and his then–graduate student Holly Dublin did field experiments in the 1980s showing that fire—not elephants—killed off most of the seedlings. The result was a nearly treeless Serengeti.

By the mid-1970s, the ungulates had at last recovered, following the establishment of a successful rinderpest control program in 1963. Because wildebeest were again cropping the grass, people slowly began setting fewer fires. Today, the park is dramatically different from what Sinclair saw when he first arrived 32 years ago. Numbers of buffalo and elephants are far lower due to heavy poaching (although elephants have been increasing since the 1990 ivory ban). The wildebeest population has soared to about 1 million; human-set fires are down to about a quarter of what they were—and the acacias have returned.

Dense young stands of forest cover most of the park's hillsides and flank its grasslands. "That shows just how easy it is to get these things wrong," says Sinclair. "The Serengeti didn't turn into a desert, but a forest." And the "last tree on the Serengeti"? It's surrounded by 3-meter-tall acacias, standing limb to limb from the top of the ridge to its base. –V.M.

range from a minimum of 28 acacia species to untold numbers of beetles. So instead of visiting each square kilometer, Sinclair and Mduma are studying samples of each habitat. And instead of collecting thousands of specimens and then enlisting dozens of taxonomic specialists to identify them, as is done in the all-taxa surveys, the pair is simply "starting with the species we know or can easily identify," Sinclair says. Mduma is a small-mammal specialist, and ecologist Sinclair's first task as an undergraduate researcher in 1965 was to learn all 517 known bird species in the Serengeti by sight and song. As for the butterflies, the team is identifying them like any old-fashioned natural historian—by using a just-published field guide.

Sinclair acknowledges that this approach won't document every organism from microbe to mammal, but it will give the big picture—and how that picture is changing (see sidebar). "A list [of species] by itself isn't that helpful for conservation purposes," says Sinclair. "What we want to know is where do you find the species, what habitats are they living in, and how do these habitats change over time? The Serengeti isn't like a museum. It has cycles; it does change."

He and Mduma sample along transects—the main roads—at least once a year, spotting large birds such as shrikes, starlings, and doves. Smaller birds, such as warblers and finches, are identified by both sight and sound. Later in the survey, they will also set mistnets in the dense forests to catch more secretive bird species. For the small mammals, they will put out live traps and cover animal trails with wet sand to record tracks.

Sinclair is also drawing on his 32 years of working in the park and making informal observations. He has a habit of jotting down sightings of particular species in a pocket notebook and photographing key areas annually, giving him a huge data bank to draw on. Anne Sinclair is even combing the letters the couple wrote home over the past 30 years, pulling out notes on animal and plant sightings. "It's not very high-tech," says Sinclair, "but if you're diligent about it, in time, you can pick up patterns that you'd otherwise miss."

Among those patterns are the densities of species in their particular habitats and how these change over time. "Thirty to 40% of the park has changed its vegetation community in the last 25 years," says Sinclair, "and that change should bring an accompanying change in the fauna." For example, he and

Mduma hope to identify healthy stands of forest with abundant animals and compare them to more fragmented, disturbed forests. "That may give us some idea of how much forest is necessary to maintain the species, and an inkling about why this fragmentation is occurring," says Sinclair.

Once they have detailed data on certain habitats, they can spot-check other examples of the same habitat to see if the diversity patterns hold true. Then they can get a sense of how the whole park works by putting it all together.

The transect results, coupled with Sinclair's notebooks, are already turning up new long-term biodiversity patterns. For example, certain shrikes and thrushes have moved into the park, says Sinclair—ones "that I know for certain weren't here 30 years ago, because they are so visible. We don't yet know why this has happened." Similarly, the visit to the forest along the Grumeti River turned up a small population of black-and-white colobus monkeys, the farthest west these monkeys have ever been seen. Again, at the moment, no one knows why.

But species are disappearing, too, particularly in the riverine forests. One site had seemingly healthy populations of trogons and large-casqued hornbills in 1965. Now it has lost much of its tree cover, as well as many species of birds, including these two. "It's quite clear that some [bird] species will exist only in intact forests, ones with a complete canopy cover," says Sinclair. "We want to measure how much canopy cover is necessary for maintaining species like those." So far it seems that the canopy needn't be wide—perhaps only 50 to 100 meters—but it must extend for some distance along the river.

Eventually, the duo plans to extend the faunal inventory to the park's insects, reptiles, and fish with the aid of specialists in those fields. But because of limited funds, Sinclair imagines that only a handful of people will be involved, so many organisms would still be left out.

Tropical ecologist Daniel Janzen of the University of Pennsylvania in Philadelphia, who pioneered the idea of all-taxa inventories, cautions that to achieve his goals, Sinclair may need to identify more species. That means more people and much more money. "If you're going to invade Normandy, you're going to have to pile on the resources," says Janzen. "It's OK to start out small like they're doing, but to do the full inventory requires a massive attack. And it's going to be expensive." Without that full inventory, including, for example, the "gut flora of the buffalo," Sinclair won't have the "full Yellow Pages" of the Serengeti, adds Janzen.

Other experts, including James L. Patton, an evolutionary biologist at the University of California, Berkeley, who has begun the first small-mammal survey of the Amazon Basin, think Sinclair's more scattershot approach is feasible. "To get down to the soil microorganisms isn't always necessary," says Patton. Besides, he adds, Sinclair's focus on the Serengeti's dynamism "as the key to its biodiversity is what makes this project so neat." Raven, who is investigating the possibility of having his institution team up with Sinclair, adds that "Sinclair is gathering baseline data that will help people manage that park; you don't need every microbial organism for that."

The debate doesn't trouble Sinclair, who thinks that their count will take a minimum of 10 years and "in some ways, given the park's cycles, it will never be complete." Nor does this open-ended aspect of his research worry him: "It's a record of what we see here today in the Serengeti. It's what I wish the first European explorers in East Africa had recorded. If they'd done this, we'd have a much better understanding of how the Serengeti changes over time—and a far better idea of how to preserve it."

–Virginia Morell

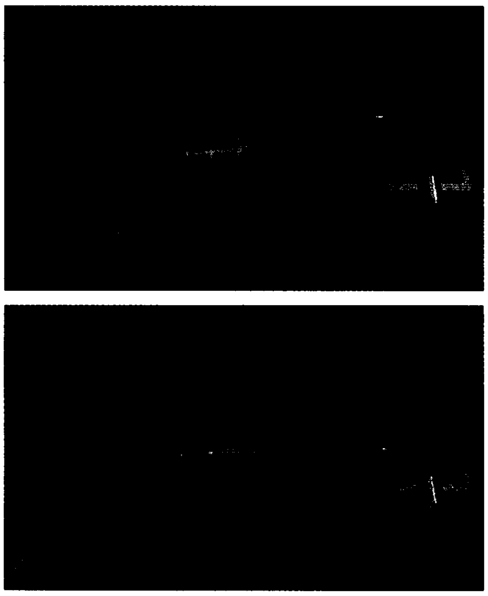
PHYSICS

Cool Sounds at 200 Decibels

The loudest controlled sounds ever made by humans were produced earlier this month—not by a rock band, but by a physicist. At the Acoustical Society of America meeting in San Diego, Timothy Lucas of MacroSonix Corp. in Richmond, Virginia, demonstrated a new "acoustic compressor" that uses ultra-intense sound waves to do the work of a mechanical pump. The technology may soon be used in everyday appliances such as refrigerators and air conditioners.

The idea of the compressor is simple: You shake a can back and forth to create vibrations in the air inside. Just as a child can produce huge waves in a bathtub by sloshing back and forth at just the right rate (a phenomenon called resonance), the air vibrations become especially intense if the can is agitated at a certain frequency. But the water in the child's bathtub will splash out if the waves start to crest. For acoustical engineers, the analogous problem is shock waves, which dissipate the sound energy as heat. By making his compressor just the right shape—essentially that of a bowling pin—Lucas was able to keep the shock waves from forming, even as the can vibrated at about 600 times a second.

How loud are the resulting sounds? The pain threshold is about 120 decibels, and a jet engine produces 150 decibels. If you stand next to a sound of 165 decibels, it will ignite your hair. The sound waves inside Lucas's compressor are about 3000 times more powerful, or about 200 decibels. But because the can's own vibrations are much smaller than the vibrations of the air, on the outside it sounds just like an ordinary compressor.



TIMOTHY LUCAS *et al.*/MACROSONIX CORP.

Sound concept. Cycles of low and high pressure driven by sound can draw a fluid into a compressor *(top)* and expel it at high pressure.

The intense sound waves oscillate between low and high pressure in certain regions; with the help of valves that open and close at the right moments, these pressure differences can suck gas into the compressor and shoot it out at high pressure. Lucas's compressor could be especially useful for refrigerators and air conditioners, which work by compressing a refrigerant—traditionally a chlorofluorocarbon. Steve Garrett, a physicist at Pennsylvania State University in University Park, explains that some of the ozone-sparing refrigerants now being used break down in the oil that lubricates a conventional compressor. But Lucas's compressor has no moving parts inside and therefore requires no lubrication. MacroSonix has already signed a licensing agreement with an appliance manufacturer.

Other specialists in acoustics call Lucas's compressor a breakthrough. "What Timothy Lucas has done is shift the debate from whether acoustic compression can be done to who can do it better," says Garrett. Lucas himself thinks his sound waves will ultimately find many other roles. "Electromagnetic waves have been commercialized for over 100 years," he says, "but the commercial application of sound waves has only scratched the surface."

–Dana Mackenzie

Dana Mackenzie is a science and mathematics writer in Santa Cruz, California.