MERLIN D. TUTTLE

Give Bats a Break

Searches for new viruses in bats are unlikely to contribute substantially to human health, but they may threaten the future of bats.

The idea that bats could be responsible for the transmission of newly emerging and potentially deadly infectious diseases to humans began to take hold in 2002 with the discovery of a new coronavirus that caused severe respiratory infections called SARS. Coronaviruses are widespread in animals, from birds to whales, and are the cause of common colds, but SARS was different, with the 2002 outbreak killing 800 people and generating frightening headlines worldwide.

Three years later, an article in *Science* titled "Bats Are Natural Reservoirs of SARS-like Coronaviruses" announced the emerging scientific wisdom that bats were a global public health menace. Since that time, so-called virus hunters have pursued an intense international search for dangerous viruses in bats, and sensationalist media attention continues to accompany this search. "Hordes of deadly diseases are lurking in bats and sometimes jumping to people," *New Scientist* reported in February 2014, asking, "Can we prevent a major pandemic?" Several months later *Wired* piled on with an article titled "Why Bats Are Such Good Hosts for Ebola and Other Deadly Diseases," which asserted that "scientists are discovering new bat-borne viruses all the time." Such stories continue to this day; a February 2017 National Public Radio report called "Why Killer Viruses Are On The Rise" portrays bats as "arguably one of the most dangerous animals in the world," and warns that "when there are bats up in the sky, there could be Ebola in that poop that lands on your shoulder."

Yet once one delves into the world of bats and infectious diseases, these stories begin to fall apart. A closer look at what science knows about bats strongly suggests that the scientific and media furor is at best overstated, and is likely a distraction from more serious research and health problems. Above all, it turns out that while we certainly should be concerned about bats, we probably don't need to worry very much about what they might do to us. Rather, we should be worrying about what we are doing to bats in the name of science and public health.

Assume a bat

To start with, SARS and many other "emerging infectious diseases," such as Hendra, Nipa, Marburg, Ebola, and MERS, are not new diseases. They've been around for millions of years, but due to their rarity and geographic isolation have only recently been noticed by scientists, the media, and the public. Moreover, despite the intensity of scientific and media attention over the past 20 years, these diseases have together, worldwide, accounted for fewer than 1,000 human deaths annually, a miniscule

Luke Jerram

Luke Jerram's multidisciplinary arts practice involves the creation of sculptures, installations, and live artworks. He lives in the United Kingdom and creates work across the globe.

Glass Microbiology is a collection of glass models of human viruses. Unlike the colorful images of viruses that are common, Jerram's sculptures are colorless, like the viruses themselves. By extracting the color from the imagery and creating jewel-like sculptures in glass, a complex tension develops between the artworks' beauty and what they represent.

LUKE JERRAM, *SARS - Corona virus*, Glass.

He also raises an important question about how the coloring of scientific microbiological imagery affects our understanding of these phenomena. Are the images colored for scientific or aesthetic purposes? How does a viewer between actual and imagined colors in images? How does this affect the viewer's response?

Scientific publishers are beginning to accept Jerram's perspective. Photographs of his glass artworks are now used widely in medical journals, text books, and media stories in journals such as the *Lancet*, the *British Medical Journal*, and *Nature*.

The sculptures are designed in consultation with virologists from the University of Bristol, using a combination of different scientific photographs and models, and made in collaboration with glassblowers Kim George, Brian Jones, and Norman Veitch.

The *Glass Microbiology* sculptures are in museum collections around the world, including The Metropolitan Museum in New York, the Wellcome Collection in London, and the Museum of Glass in Shanghai.

proportion of the toll from diseases such as malaria, tuberculosis, and AIDS.

The Ebola story is typical. A viral disease that is often fatal to humans and other primates in tropical regions of sub-Saharan Africa, Ebola is very old, probably present in Africa for millions of years. First detected in 1976, Ebola was responsible for just 1,090 reported human deaths prior to a virulent outbreak in West Africa that started in late 2013. Unlike previous Ebola outbreaks, this one was spread by infected people into an impoverished, densely populated area of unusual susceptibility and minimal health care, where it caused 11,325 deaths.

The idea that bats could cause Ebola in humans was widespread even prior to this outbreak. As early as 2005, *Nature* published a news article titled "Fruit bats as reservoirs of Ebola virus," followed by another in 2011 titled "West Africans at risk from bat epidemics." By 2014, *Science* joined in, asking, "Are Bats Spreading Ebola Across Sub-Saharan Africa?" Meanwhile, an August 2014 National Institutes of Health news release reported that the West African

LUKE JERRAM, *Ebola*, Glass.

outbreak had been traced back to a two-year-old boy who probably had been infected by contact with a straw-colored fruit bat (*Eidolon helvum*). This leap of faith was made despite no finding of Ebola virus in any local bats, no deaths among villagers who had hunted and eaten bats, and no explanation of how a toddler could have been infected by a bat that has a three-foot wingspan and never enters buildings. Nevertheless, news headlines worldwide reported that the Ebola outbreak originated with fruit bats.

Four months later, a 30-author *EMBO Molecular Medicine* article titled "Investigating the zoonotic origin of the West African Ebola epidemic" reported that the culprit wasn't a fruit bat after all. Rather, "the index case [the toddler, that is] may have been infected by playing in a hollow tree housing a colony of insectivorous free-tailed bats *(Mops condylurus)*." BBC NEWS, CNN, and numerous other media outlets around the world dutifully reported on this latest version of the deadly bat story.

The fruit bat had been exonerated because researchers concluded that the boy had no known

LUKE JERRAM, *HIV*, Glass.

contact with fruit bats or with anyone else who might have had such contact. But the evidence against the free-tailed bats was also slim. No Ebola virus was found in these or any of a dozen other bat species examined in the area. In fact, free-tailed bats from the hollow tree where the toddler was purportedly exposed had been routinely captured, roasted, and eaten by village boys, none of whom had become sick. And although the *EMBO* paper warned against killing bats because of "crucial ecosystem services with direct and invaluable benefits to humans," the hollow tree where the bats lived was burned by villagers with the bats inside.

Guilty until proven innocent

If bats were even remotely as dangerous as postulated, why has it not been possible to explain the following facts? Why is it that I and hundreds of other bat researchers remain in good health, despite countless hours of close contact, often surrounded by thousands, even millions of bats in caves? Like veterinarians, we are vaccinated against rabies because we are sometimes bitten in self-defense by the animals we handle. However, throughout most of our careers, we have not been protected against *any* of the other deadly diseases for which bats are now speculated to serve as reservoirs.

Furthermore, why hasn't it been possible to document bat-caused disease outbreaks among the millions of people who regularly eat bats throughout the African and Asian tropics or among the many Africans, Asians, and Australians living in cities cohabited by hundreds of thousands of bats? Why are guano harvesters who spend most of their lives in major bat caves no less healthy than their neighbors? How is it that millions of tourists have safely viewed from close range the emergence during summer nights of the million-plus bats that have lived for the past 35 years under a road bridge in the middle of Austin, Texas?

For much of human history we shared caves, then thatched huts and log cabins, with bats. For the past hundred years, the trend has been reversed. Bat populations have declined and modern humans have begun living in buildings that exclude bats. Given our long history of close association, it stands to reason that we would have evolved extraordinary resistance to each other's diseases. Perhaps that explains why it has been so difficult to credibly document bats as sources of deadly diseases in humans.

In focusing on bats as the cause of SARS and Ebola, scientists started out by ignoring these commonsense observations, as well as historic facts demonstrating bats to be far safer than even our beloved dogs. Unfortunately, negative results are rarely published in leading journals, and they are unlikely to attract either major grants or sensationalist media attention. Instead, small samples have been mined for spurious correlations in support of powerful pre-existing biases, while researchers ignored evidence that pointed in the opposite direction. And as hundreds of millions of dollars became available for research on emerging viruses, the widely shared belief that bats were the culprit continued to fuel scientific attention.

But despite a decade of headlined speculation and an intensive search for an Ebola reservoir, focused primarily on tracing it to bats, the evidence against bats remains scant. The *Ebolavirus* genus includes five species (Sudan, Zaire, Bundibugyo, Tai Forest, and Reston virus), and the geographical distribution of these species along separate river basins is inconsistent with a highly mobile source. Bats would not be restricted to single river basins.

Repeated attempts to isolate infectious Ebola viruses from a wide variety of fruit- and insect-eating bats caught at outbreak locations have failed. Some serologic surveys have found evidence of exposure, but complete viral genomes—the gold standard—have not been obtained. Though bats have been artificially infected in lab experiments and remained unharmed, they have showed no evidence of viral shedding, nor has anyone successfully infected another animal with Ebola via a bat. In fact, the initially blamed straw-colored fruit bat has been found so resistant as to be an unlikely host.

Some scientists have begun calling for a much broader research focus. In a 2016 editorial in the journal *Viruses*, epidemiologist Fabian Leendertz

LUKE JERRAM, *Smallpox*, Glass.

argued that although terrestrial animals are normally presumed to be the virus hosts, rivers have their own flora and fauna, and aquatic or semiaquatic animals could provide important links to Ebola that scientists have thus far ignored. Even nonbiting insects such as mayflies could be involved, perhaps being accidentally ingested by susceptible herbivores feeding during periodic hatches. And a January 2016 *Nature* article reported that Jens Kuhn, a virologist at the National Institutes of Health's Institute of Allergy and Infectious Diseases, "thinks that bats are far too abundant and too closely associated with humans to explain an infection that has emerged just two dozen times over the past four decades." He speculated that an unsuspected host, possibly even arthropods or fungi, could be the culprit. The same report further notes that the US Agency for International Development now plans a two-year survey of the Ebola virus-transmitting potential of a widening range of animals, including rodents, livestock, dogs, and cats. Indeed, dogs have been suspected carriers of emerging viruses since 2005, but appear to have been largely ignored by researchers. Until recently, so had camels.

What hump?

First detected in Saudi Arabia in 2012, Middle East respiratory syndrome (MERS) is an illness caused by a SARS-like coronavirus. By the end of 2015, MERS had caused more than 587 deaths, 75% of them in the Middle East. It has spread to Asia, Europe, and North America, but, like Ebola, has been quickly controlled.

Due to prior speculation linking bats to the SARS outbreak, bats were initially assumed to be the source of MERS as well. When a single small fragment of a coronavirus, speculated to be closely related to the one causing MERS, was found in a bat fecal pellet, the online news site of the journal *Science* (August 22, 2013) and the news section of the journal *Nature* (August 23, 2013) rushed to blame the disease on bats. Their headlines seemed more appropriate for supermarket tabloids: "Bat Out of Hell? Egyptian Tomb Bat May Harbor MERS Virus" and "Deadly coronavirus found in bats."

But how significant was the discovery of a single small viral fragment in a bat fecal pellet? As it turned out, the tiny (182-nucleotide-long) viral snippet was not only short, but it also came from one of the least variable parts of the viral genome. Thus, the full genomes of the viruses that infect bats and humans could still vary significantly. Also, since the fragment came from a fecal pellet, it might have indicated only that the bat had eaten an insect that had fed on an infected animal. A second investigation in 2013 did not yield further corroboration, nor did subsequent intensive, multicountry searches. Instead, as covered in multiple 2016 reviews, most notably a paper by Mohd and colleagues in *Virology Journal*, a new story began to emerge.

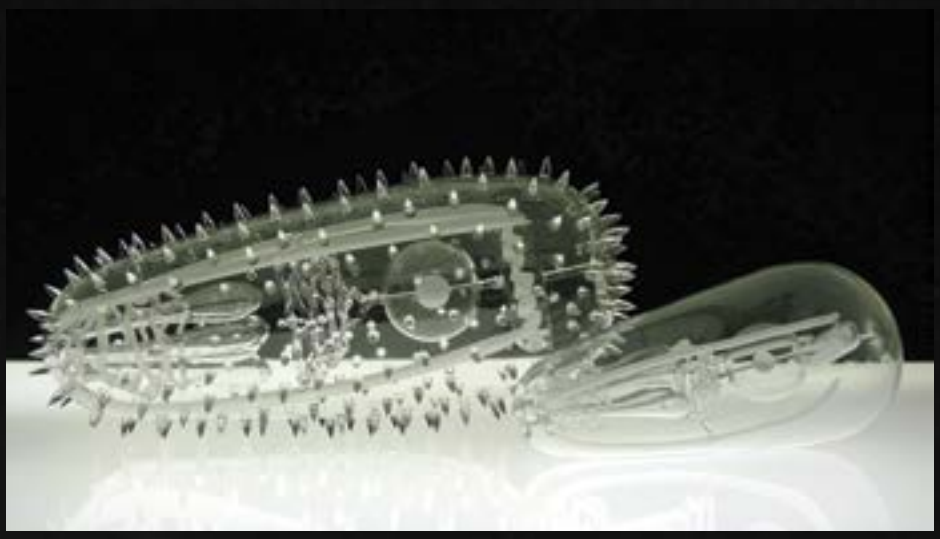
First, nasal swabs from a patient who died of MERS provided a full genome sequence of the virus that was identical to a virus found in swabs taken from his pet camels, and serologic data indicated that the virus was circulating in his camels prior to the patient's infection. Even though there was now seemingly irrefutable evidence linking MERS transmission from camels to humans, the source for humans was hotly debated. Skeptics pointed out that most primary cases of human infection appeared to have no contact with camels or other animals.

However, a series of studies began to show that the MERS-causing coronavirus was endemic and widespread in dromedary camels of East Africa and the Middle East. The Agriculture Ministry of Saudi Arabia reported that 85% of dromedary camels carried it, and 100% of retired racing camels from Spain had MERS antibodies. It was even found in long-isolated camels living on the Canary Islands. Additional studies showed significantly higher prevalence of antibodies in individuals exposed to camels. For example, four of five dedicated camel slaughterers were seropositive at a location where

LUKE JERRAM, *H1N1 - Avian Flu (Series 2)*, Glass. (Detail opposite)

59% of the camels were positive. On the flip side of the coin, no study found live MERS virus in any other animals.

The large proportion of people who contracted



LUKE JERRAM, *Malaria*, Glass.

MERS without known exposure to camels finally was traced to likely consumption of raw milk or organ meat from camels, considered by some to be delicacies. Milk easily could be contaminated through unsanitary conditions.

Studies of stored sera suggest that the MERS-causing coronavirus has been present in camels for at least several decades, and a nationwide study in Saudi Arabia found widespread circulation of different genetic variants in camels that were closely associated with the virus found in humans. Overwhelming evidence now points to dromedary camels as the primary reservoir of the MERS virus and the only source of MERS infection for humans. Camels shed live virus with no clinical signs of infection, and there is clear documentation of direct transmission to humans. Yet speculation about bats in the distant past continues. RNA fragments from coronaviruses, reported to be closely related to the one causing MERS, have been recovered from fecal pellets of several species of bats in Ghana and in four European countries, but no MERS infections are known in either humans or domestic animals in those areas.

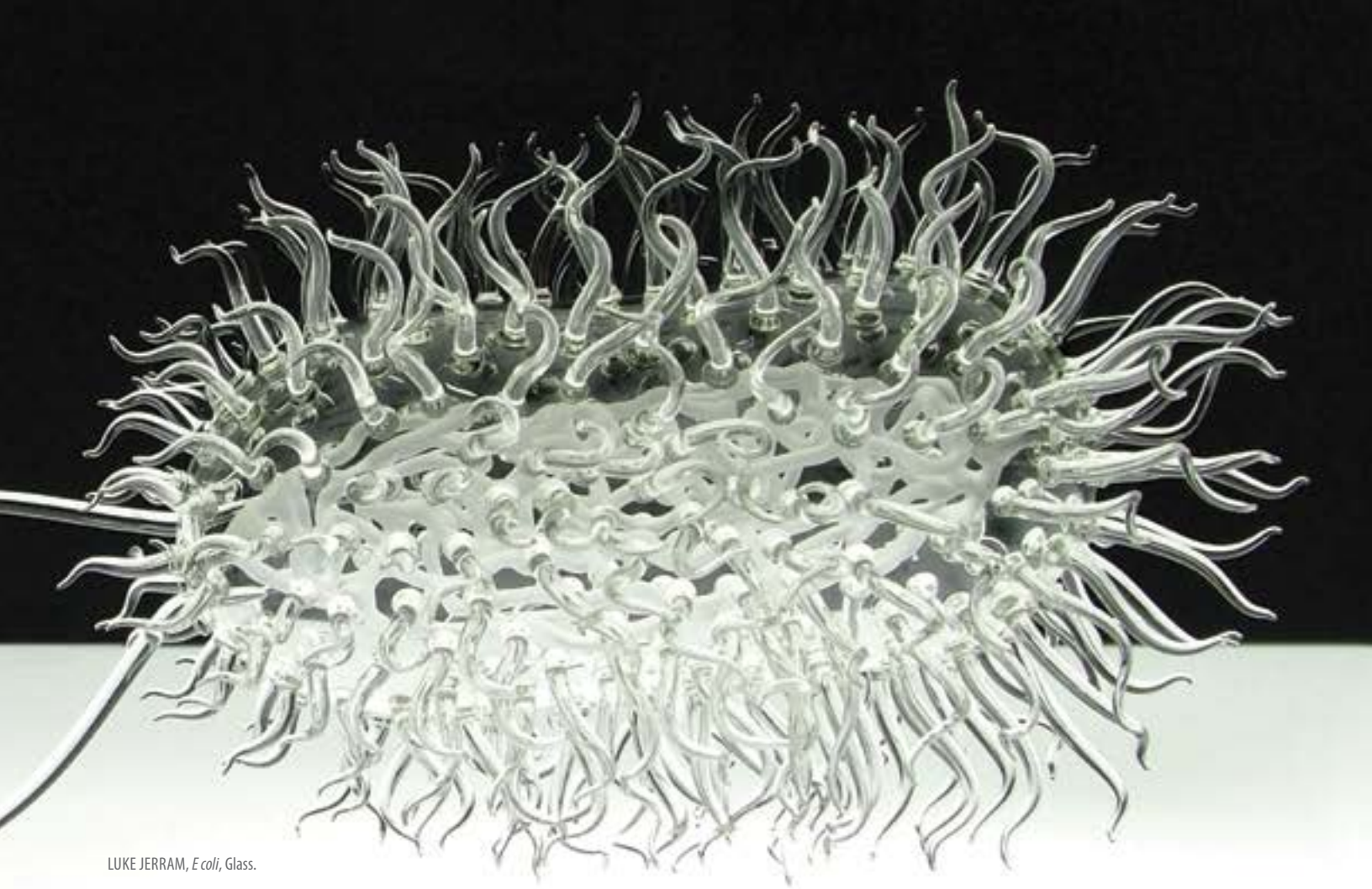
Overall, documentation of bat origins for emerging infectious diseases is mostly weak to nonexistent. Nonetheless, the scientific search for these diseases in bats continues. I have examined some 4,000 research papers on Ebola and MERS alone and found that studies of disease reservoirs focus disproportionately on bats, even when evidence of a connection to human disease is lacking. For example, by 2014 the link between dromedaries and MERS was well established, but two years later publications mentioning bats as reservoirs for MERS still considerably outnumbered papers on camel reservoirs (by about 340 to 240).

Viruses, viruses everywhere

New viruses are being found wherever scientists look for them. In one recent study, hundreds of previously undescribed viruses were found in a single human. Yet when a new one is discovered in bats, scientists and the science media often speculate about its potential as a dangerous source of future pandemic disease outbreaks, not to mention the possibility of being related to common diseases such as flu, hepatitis, or herpes.

A 2016 paper in *PLOS ONE* by Young and Olival says that "the life history traits of bats compared to other mammals may make them unique and exceptional hosts for viruses." But in reality, we know very little about viral relationships overall. A February 2015 review by Moratelli and Calisher acknowledges that "the supposed connections between bats, bat viruses and human diseases have been raised more on speculation than on evidence supporting their direct or indirect roles in the epidemiology of diseases." Key animal experiments to test how primates can be infected by bats have yet to be conducted.

In my view, the knowledge base about emerging infectious diseases is extraordinarily biased by scientists' obsession with bats. This bias is encouraged by an additional, highly practical factor: there is no group of mammals easier to sample quickly or in large numbers than bats. Bats may love the dark, but they are all too easy to put under the spotlight of scientific scrutiny.



LUKE JERRAM, *E coli*, Glass.

I know from experience, having invented the trap now used by virologists to sample bats and having collected thousands of mammals, from jaguars and tapirs to rodents and bats, for the Smithsonian. Imagine the difference in time required to obtain significant samples of carnivores, primates, or ungulates versus bats that can be trapped, hundreds at a time, as they emerge from colonial roosts. Even rodents are typically far more difficult to capture. In the hyper-competitive world of academic science, it's easier and cheaper to do research on viruses in bats than in most other species, and so that's the research that gets done. It's also more in tune with a culture that has long portrayed bats as objects of mystery and fear.

Certainly bats may serve as reservoirs for some "emerging" viruses. Live Nipah virus has been found in clinically healthy flying foxes in Bangladesh, Malaysia, and adjacent areas, and Hendra virus has similarly been isolated in Australia. Also, in equatorial Africa, close genomic matches have been demonstrated in Marburg viruses from infected bats and humans.

But Nipah appears to have been virtually eliminated as a significant public health threat by simply warning people not to raise pigs (which serve as intermediate hosts) beneath fruit trees that attract flying foxes, and by warning them not to drink raw date palm juice potentially contaminated by bats. Hendra is not directly transmitted from bats to humans, but periodically does infect horses, which have fatally infected four humans since the virus's discovery in 1994. Marburg has caused 373 human deaths since its discovery in African green monkeys in 1967, and there may be multiple animal reservoirs. Transmission from bats is rare and can be avoided entirely by not entering caves or handling bats where the disease occurs. As reported by the World Health Organization and the US Centers for Disease Control and Prevention, these three viruses combined have caused fewer than 600 human deaths in the past 20 years. They are less than trivial public health threats.

In most of the world, including in the United States and Canada, rabies is the only threat from bats. This normally fatal disease has been recognized for over 2,000 years. Transmission from bats is exceedingly rare—just one or two human fatalities per year in the United States and Canada, and even fewer in most of the rest of the world except for Latin America, where vampire bats occasionally bite humans who sleep in the open without mosquito nets. Worldwide, more than 50,000 people die annually from rabies, 99% of them having received the virus from dogs, our best friend.

Stop the bias against bats

In total, the evidence that bats are the source of emerging viral diseases is weak. The human toll of those diseases is minor relative to other infectious diseases, and public health measures to protect against any limited health threat from bats are simple, cheap, and proven.

At the same time, there is rapidly growing documentation that bats are worth billions of dollars annually to human economies and that their loss can threaten the health of whole ecosystems upon which we depend. And as demonstrated in my home town of Austin, where 1.5 million Brazilian free-tailed bats (*Tadarida brasiliensis*) have been protected for decades, they can make safe and invaluable neighbors once we simply learn to leave them alone. Our local bats consume tons of crop and yard pests nightly and attract millions of tourist dollars each summer.

Continued scientific and media bias focused on potential diseases from bats is unlikely to protect human health. But it is contributing to misallocation of scientific resources, to the acquisition of knowledge of dubious value for society, and to inappropriate public health priorities. Perhaps most damaging of all, the ongoing demonization of bats is contributing to their destruction. I have personally visited caves where thousands to millions of bats were killed because of fear that was exacerbated by scientific fad and media hype involving disease. One of my primary research caves in Tennessee was burned when public health researchers warned the owner that his bats might be rabid.

People who believe bats to be spreaders of a seemingly endless list of the world's most frightening diseases are unlikely to tolerate them in their neighborhoods. Due to premature speculation by scientists competing for grants, decades of conservation progress on bats is now in jeopardy. At a time when our future is threatened by loss of biodiversity, and budgets for health care are stretched to the limit, how can we justify continued disproportionate investment in a hunt for rare viruses in bats?

I don't believe virologists intend to harm bats. In fact, even when publishing their most frightening hypotheses linking bats to diseases, scientists typically mention the ecological value of bats and urge that they not be killed. They blame the possibility of new pandemics on human expansion into bat habitats, implying the problems are human-caused. As one who has devoted more than 50 years to studying and conserving bats, I do appreciate such sentiments. Nevertheless, available evidence suggests that bat-human contact is decreasing rather than increasing. And for anyone who doesn't directly handle bats, risk of disease is incalculably remote.

Long after it should have ended, the biased search for deadly viruses in bats appears to have become self-perpetuating, fueled by new viral discoveries, many of which would likely be made in any species that scientists choose to study. Bats are indeed unique. They play an extremely important role in ecosystems worldwide, and contribute to human well-being. But because they form large, conspicuous aggregations, yet typically rear just one young per year, bats are especially vulnerable to mass killing and extinction. It's time for researchers to better document what bats do *for* us instead of stoking fears about the remote possibility that bats might cause future pandemics. Our real fear should be the further decline of bats.

Merlin Tuttle is a leading bat researcher who founded and directed Bat Conservation International for 30 years. He now directs Merlin Tuttle's Bat Conservation and is a research fellow in the Department of Integrative Biology at the University of Texas at Austin.

Recommended reading

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