that numbers in a certain range are prime that was devised by German mathematician Bernhard Riemann in 1859.

The Riemann hypothesis will probably remain at the top of mathematicians' wishlists for years to come. Despite its importance, no attempts so far have made much progress. Only the bravest of mathematicians – often those who already have major accomplishments under their belts – publicly admit to trying to solve it. "It's one of those things – you're not supposed to talk about Riemann," says Alex Kontorovich, a number theorist at Rutgers University in Piscataway, New Jersey. "People work secretly on it."

Although progress towards solving the Riemann hypothesis has stalled, the Landau–Siegel problem offers similar insights, he adds. "Resolving any of these issues would be a major advancement in our understanding of the distribution of prime numbers."

1. Zhang, Y. Preprint at https://arxiv.org/abs/2211.02515 (2022).
2. Zhang, Y. Preprint at https://arxiv.org/abs/0705.4306 (2007).
3. Zhang, Y. *Ann. Math.* **179**, 1121–1174 (2014).

WHY DO BAT VIRUSES KEEP INFECTING PEOPLE?

Landmark study reveals 'spillover' mechanism for the rare but deadly Hendra virus.

By Smriti Mallapaty

"Hey guys, could you open your wings and show me?" says Peggy Eby, looking up at a roost of flying foxes in Sydney's Botanical Gardens. "I talk to them a lot."

Eby, a wildlife ecologist at the University of New South Wales in Sydney, Australia, is looking for lactating females and their newborn pups, but the overcast weather is keeping pups snuggled under their mothers' wings. Eby has been studying flying foxes, a type of bat, for some 25 years. Using her binoculars, she tallies the number of lactating females that are close to weaning their young – a proxy for whether the bats are experiencing nutritional stress, which can make them more likely to shed viruses that can make people ill.

Australian flying foxes are of interest because they host a virus called Hendra, which causes a very rare but deadly respiratory infection that kills one in every two infected people. Hendra virus, like Nipah, SARS-CoV and SARS-CoV-2 (the virus that caused the COVID-19 pandemic) is a bat virus that has spilled over into people. These often reach humans through an intermediate animal, sometimes with deadly consequences. Scientists know that spillovers are associated with habitat loss, but have struggled to pinpoint the specific conditions that spark spillover events until now.

Australian flying foxes host a virus called Hendra, which can make people ill.

AUSCAPE/UNIVERSAL IMAGES GROUP/GETTY

After a detailed investigation, Eby and her colleagues can now predict – up to two years ahead – when clusters of Hendra virus spillovers will probably appear. "They have identified the environmental drivers of spillover," says Emily Gurley, an infectious-diseases epidemiologist at Johns Hopkins University in Baltimore, Maryland. And they have determined how those events could be prevented. The results were published in *Nature* (P. Eby *et al. Nature* https://doi.org/jmr5; 2022).

Specifically, the researchers found that clusters of Hendra virus spillovers occur after years in which the bats experience food stress. And these food shortages typically follow years with a strong El Niño, a climatic phenomenon in the tropical Pacific Ocean that is often associated with drought in eastern Australia. But if the trees the bats rely on for food during the winter have a large flowering event the year after a food shortage, there are no spillovers. Unfortunately, the problem is that "there's hardly any winter habitat left", says Raina Plowright, a disease ecologist and study co-author at Cornell University in Ithaca, New York.

The study is "absolutely fantastic", says Sarah Cleaveland, a veterinarian and infectious-disease ecologist at the University of Glasgow, UK. "What's so exciting about it is that it has led directly to solutions." Cleaveland says the study's approach of looking at the impact of climate, environment, nutritional stress and bat ecology together could bring new insights to the study of other pathogens, including Nipah and Ebola, and their viral families. The study provides "a much clearer understanding of drivers of this issue, with broad relevance to pandemics elsewhere", says Alice Hughes, a conservation biologist at the University of Hong Kong.

Urban shift

Hendra virus was identified in 1994, after an outbreak in horses and people at a thoroughbred training facility in Brisbane, Australia. Studies later established that the virus spreads from its bat reservoir – probably the black flying fox (*Pteropus alecto*) – to horses through faeces, urine and chewed-up pulp that the flying foxes spit out on the grass. Infected horses then spread the virus to people. Infections typically occur in clusters during the Australian winter, and several years can go by before another cluster emerges in horses, but case numbers have been growing since the early 2000s.

To study the mechanism of spillovers, Plowright, Eby and their colleagues collected data on the location and timing of such events, the location of bat roosts and their health, climate, nectar shortages and habitat loss over some 300,000 square kilometres in southeast Australia from 1996 to 2020. Then they used modelling to determine which factors were associated with spillovers. "I'm just in awe of the invaluable data sets that they have on the ecology," says Gurley.

Over the course of the study, the team noticed significant changes in the bats' behaviour. The flying foxes went from having predominantly nomadic lifestyles – moving in large groups from one native forest to another in search of nectar – to settling in small groups in urban and agricultural areas, bringing the bats closer to where horses and people live. The number of occupied bat roosts in general has trebled since the early 2000s, to around 320 in 2020.

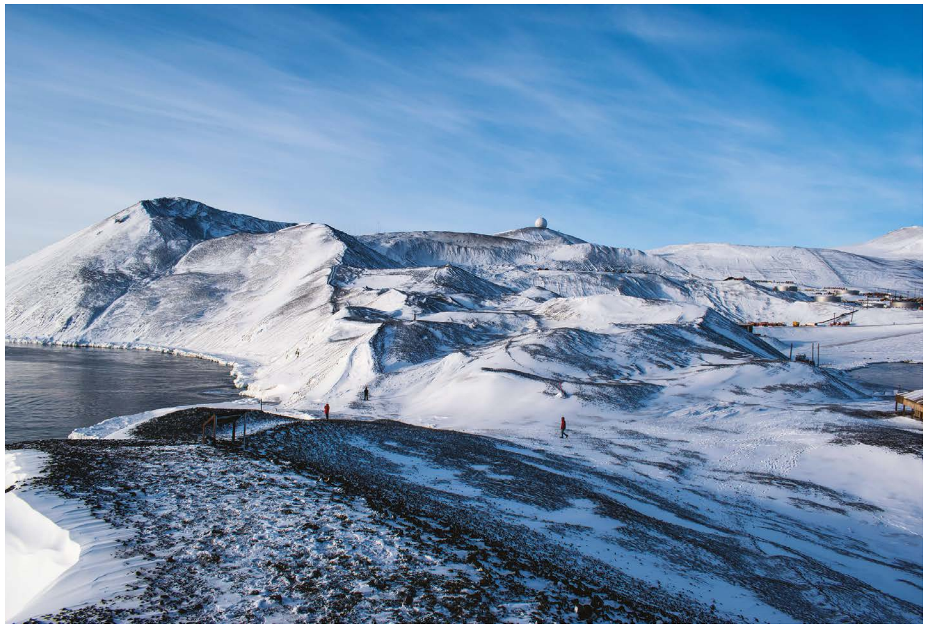
A separate study from the team found that the newly established roosts shed Hendra virus every winter, but in years following a food shortage bats shed more virus (D. J. Becker *et al. Ecol. Lett.* https://doi.org/jmr6; 2022).

In search of nectar

Modelling in Plowright and Eby's most recent *Nature* paper shows that flying-fox populations split into small groups that migrated to agricultural areas close to horses when food was scarce, and that food shortages followed strong El Niño events, probably because native eucalyptus tree budding is sensitive to climate changes. To conserve energy, the bats fly only small distances in these years, scavenging for food in agricultural areas near horses. Spillovers to horses were most likely in winters after a food shortage, says Plowright. The model was able to accurately predict in which years these would occur.

Then something unexpected happened. An El Niño in 2018 was followed by a drought in 2019, suggesting that 2020 should also have been a spillover year. But there was only one event in May and none has been detected since. "We threw all the cards back up into the air and looked carefully at all the other elements of our hypothesis," says Eby. Eventually, the team discovered that when native forests have major flowering events in winters after a food shortage, this helps to avert spillovers. In 2020, a red-gum forest near the town of Gympie flowered, drawing in some 240,000 bats. And similar winter flowering events occurred in other regions in 2021 and 2022.

The researchers suggest that these mass migrations take the bats away from horses. They propose that by restoring the habitats of the handful of species that flower in winter, authorities could reduce the number of spillovers in horses, and potentially in people.



SAM WALKER/ALAMY

Antarctica's landscape draws researchers to visit, despite the isolation.

US AGENCY FORMS PLAN TO STOP HARASSMENT IN THE ANTARCTIC

But scientists say the National Science Foundation's pledges to repair its research programme fall short.

By McKenzie Prillaman

The US National Science Foundation (NSF) is taking steps to correct a problematic culture in its US Antarctic Program (USAP), after an August report revealed that sexual harassment and assault are commonplace. But some scientists aren't sure that the agency's action plan goes far enough.

"I'm just underwhelmed by their response," says Leigh Stearns, a glaciologist at the University of Kansas in Lawrence.

Stearns and other researchers *Nature* spoke to are glad that the NSF is taking the long-standing problem seriously, but say its plan does not do enough to make it clear that the NSF will be watching for bad behaviour and will no longer tolerate harassment. The researchers would like to see a more comprehensive plan for building a culture of safety and inclusivity in the USAP.

The NSF does not tolerate any form of harassment, says a spokesperson for the agency, based in Alexandria, Virginia. The spokesperson points out that when the action plan was published in mid-September, agency director Sethuraman Panchanathan announced his commitment to ensuring that all USAP stations, field sites and NSF-funded programmes are free from harassment and sexual assault.

Scientists' concerns are heightened at the moment because dozens of researchers have headed south in the past few weeks, to undertake projects during the 2022–23 Antarctic-summer field season.

Having reviewed the NSF's plan, Stearns is especially worried about her early-career colleagues. "I wanted to hear, 'We're keeping your students safe, and this is how we're going to do it,'" she says. But she didn't get that message, so she has sent her phone number to about 50 people travelling to the ice. She told them in an e-mail: "If you need an ally, I have toddlers – I'm always awake."

'Wild frontier'

Antarctica's rugged and captivating environment draws many researchers, but its remoteness poses workplace challenges. People forget that isolated research stations and field sites are subject to the same laws as any work setting in the country that runs them, says Meredith Nash, a sociologist at the Australian National University in Canberra, who has been helping the Australian Antarctic Program to make its own culture safer. "These extreme environments are