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A killer in the bat cave

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CORPSE upon corpse they lie, a carpet of emaciated, fungus-ridden carcasses. Where once healthy animals hung in slumber from the cave roof, now there is a mass grave on the floor. It is a scene that is repeated throughout the eastern US, from Vermont to West Virginia. America's bats are in crisis, under threat from a mysterious killer.

The first sign that something was up emerged in February 2006, when a caver photographed hibernating bats with white muzzles at Howe's Cave in Albany, New York state. Soon afterwards bats were observed behaving strangely - waking from hibernation early and in a state of serious starvation. Some even ventured out of their roosts during daylight to search for food. Inside the caverns, the floors were littered with bodies, most with the characteristic fuzzy white mould growing on their noses, ears and wings. So far, about a million bats have succumbed to this fate, an affliction dubbed white nose syndrome (WNS).

The fungus has recently been identified as Geomyces destructans (Science, vol 323, p 227). It is the prime suspect and the focus of an intense research effort. Even so, there remains the possibility that it is not actually the killer but just an opportunistic pathogen hitching a ride on the back of some other deadly foe.

Bats were observed behaving strangely - waking from hibernation early and in a state of serious starvation. What is known is that once the fungus appears in a cave, between 80 and 100 per cent of the bats hibernating there are likely to die. What's more, it is spreading, marching inexorably across North America. On 16 February this year, the first two cases were confirmed in Tennessee. "It terrifies everybody in the bat community," says Emma Teeling at University College Dublin, Ireland.

The few clues the killer disease has left in its wake are providing a morbidly fascinating conundrum to science. The chief suspect, G. destructans, is proving to be something of an oddity. Nobody knows where it came from and, weirdly for a fungus, it grows only in the cold, flourishing between 5 °C and 14 °C. Unfortunately, this is the same temperature as America's biggest bat hibernacula - caves and mines outside which tens of thousands of bats gather in the autumn to indulge in an orgy of food and sex before retiring inside for their long winter slumber.

Unlikely victim

That bats, of all creatures, are dying is also puzzling. They have a reputation as the carriers of disease, not the victims, and have been implicated in the spread of pathogens such as rabies, Ebola, Nipah virus and SARS - with no obvious adverse effects to their own health. Yet, in the US at least, G. destructans seems to be killing all cave-roosting bats in its path, regardless of species. That is odd too - emerging pathogens tend to be more specific in their victims. "This is the first documented evidence of mass mortality in bats," says Paul Racey at the University of Exeter, an adviser to the UK's Bat Conservation Trust.

One theory is that the fungus is killing bats indirectly, by disturbing their hibernation. When bats hibernate, they usually wake every 15 to 30 days to urinate, drink and mate. Those with WNS, however, rouse every three or four days. This could dangerously deplete their fat reserves, possibly explaining why bats with WNS are so emaciated. The fact that bats tend to wind down their immune systems to hibernate may add to their difficulties.

But there is a puzzle here, too: G. destructans is apparently not always so deadly. In Europe, there have been anecdotes of bats with fuzzy white noses since the 1980s, but the affliction was largely ignored until the American die-off. Then, in March 2009, during routine monitoring of bat caves near Périgueux, France, Teeling's group stumbled across a bat with a powdery, white fungus on its nose. Lab tests subsequently revealed that it was infected with G. destructans. Surprisingly, though, unlike the bats in America, this animal was otherwise healthy and a good weight (Emerging Infectious Diseases, DOI: 10.3201/eid1602.091391).

This may not be an isolated case. In 2008, at a scientific meeting in Bavaria, Germany, rumours of bats with white fungus on their noses prompted Gudrun Wibbelt of the Leibniz Institute for Zoo and Wildlife Research in Berlin to get involved. By spring 2009, her plea for samples had yielded results from four European countries. She won't say what she has found until her paper has been published, but if G. destructans is appearing in otherwise healthy animals the implications could be hugely important.

"The horrible worst-case scenario is that this nasty thing has just arrived in Europe and all bats are under threat," says Teeling. But the anecdotal evidence suggests this is unlikely. Instead, as the only European specimens found so far have remained healthy despite the

fungus, the most probable explanation is that G. destructans has spread from Europe, where the bats have developed some resistance to it, to the US where they haven't. "It's more than likely [that G. destructans] has been around for a long time - perhaps bats have already gone through a bottleneck in Europe," she says.

"Did Europe once have a much larger bat population that was wiped out by WNS?" asks Peter Youngbaer, the US National Speleological Society's liaison on WNS. "Is that going to be the new equilibrium in the US?" While the possibility sounds dire, it offers a glimmer of hope for North America's bats: if European bats have already survived an onslaught of the fungus there is hope that American bats can too.

The rush to unlock the genetic secrets of G. destructans is now on, with researchers hoping they can give bats a helping hand in fighting WNS. Christina Cuomo and colleagues at the Broad Institute in Cambridge, Massachusetts, are midway through sequencing the genome of an American strain of G. destructans. "At a basic level it's going to give us a kind of 'parts list' of genes which will help us understand how it is so pathogenic," Cuomo told New Scientist. Comparing this strain to one from a European bat may provide clues as to why the American version is so deadly. It will also make it possible to search for genes that are evolving rapidly, indicating how the fungus is adapting in the US. This might help researchers understand how the fungus emerged as a pathogen, if indeed it is behind the bat deaths, and suggest candidate proteins that could be targeted to stop it.

A central figure in the research effort is microbiologist David Blehert at the US Geological Survey's National Wildlife Health Center in Madison, Wisconsin. He discovered G. destructans in 2008 and has now developed a fast and cheap genetic test for the fungus to screen samples taken from bats.

Modus operandi

As well as this, Blehert and his team have looked into how the fungus spreads. Preliminary results from lab studies suggest it is transmitted by physical contact between bats. If so, the autumn "bat swarm", when hundreds of thousands of the animals gather outside their hibernacula to feed and mate, may be a peak time for spreading the infection. "The bats could be picking up spores in the cave and spreading it to swarming animals outside," he says.

Evidence supporting the idea that G. destructans, not some other pathogen, is the killer also comes from Blehert. In a study that is yet to be published, his team found DNA from G. destructans was present in soil samples from caves and mines where infected animals had been identified - but not in samples from caves where they hadn't. "This suggests it's not some ubiquitous organism," he says. "It's another piece of circumstantial evidence suggesting we may be looking at a primary pathogen spreading."

While Blehert and others continue to explore how G. destructans works, other researchers are scrambling to save the bats. The Smithsonian's National Zoological Park in Front Royal, Virginia, has set up the first captive breeding programme for the endangered Virginia big-eared bat in a bid to create a back-up population should the wild one succumb to WNS. It may only be a matter of time before this happens - a fear enhanced by the apparent arrival of G. destructans to one of the bat's strongholds, Hellhole caverns. This is also home to a major population of endangered Indiana bats and plans are afoot to breed them in captivity too.

The devastating die-off has been compared to the crisis amphibians have faced in the past decade Meanwhile, conservationists at the US Center for Biological Diversity are trying to get the small-footed bat and northern long-eared bat listed as "threatened" or "endangered". In a petition to US Secretary of the Interior, filed in January, they warned that both species "have been entirely extirpated from several hibernacula since the advent of WNS" and that the centre of the epidemic is located where there are core populations of these species. They hope that listing will focus attention on the need to conserve them.

Taking another approach, Hazel Barton at the Northern Kentucky University in Highland Heights and her team are trying to develop a fungicide to treat bats with WNS. They have tested almost 100 antifungal compounds to see whether they can kill G. destructans without harming bats or cave ecosystems. The most promising candidate kills the fungal spores on culture plates and does not harm healthy bats, but it does not seem to cure sick ones. "[It has] very strange results on the pathology of WNS bats," is all Barton will say.

Barton accepts that even if she can find an effective treatment, it would at best provide "a band-aid to give us more time". It could be used to protect pockets of endangered species, but WNS is now far too widespread to be eradicated with a fungicide. Indeed, the rapid spread of WNS is the biggest concern. In an attempt to contain it, some caves have been closed to people and others only allow limited access to researchers and cavers. However, despite the release last September of a nationwide plan to combat the fungus, containment is still being addressed only on a state-by-state basis. Meanwhile, bat experts nervously await the end of hibernation to see how far the disease has spread. "I'm hoping we will see a slowdown and a containment - that we will begin to discover that there are limitations," says Youngbaer.

That may be wishful thinking. Many researchers compare the devastating die-off to the crisis amphibians have faced in the past decade. Here the chief suspect is again a mysterious fungus, this time a new species of chytrid. Today between a third and a half of all species of amphibian are threatened by extinction. "Think of what has happened to the amphibians in 10 years," says Teeling. "We have got to solve this. It is horrendous."