Carnivorous mice spread deadly plague in prairie dog towns, study finds

August 3 2010

Stanford University researchers have identified the grasshopper mouse as the likely carrier of plague in prairie dog colonies throughout North America. Credit: Dan Salkeld, Stanford University

Prairie dogs, once abundant in the Rocky Mountains and Great Plains, have been decimated in recent decades by plague - a virulent bacterial disease spread by fleas.

Plague outbreaks periodically sweep through large prairie dog towns with thousands of inhabitants, killing virtually the entire population within months. Other prairie dogs move in and build a new colony,

which eventually is wiped out when the disease returns.

This pattern of re-colonization followed by devastation can occur over many years. The question for scientists is how does plague persist after a colony has been wiped out?

"A fundamental question in disease ecology is what happens to pathogens in between the periods when they cause all of this devastation," said James Holland Jones, an associate professor of anthropology and a center fellow at the Woods Institute for the Environment at Stanford University.

"Previous studies have suggested some sort of magical reservoir for the plague pathogen," Jones said. "Maybe it gets into the soil and infects the re-colonized prairie dog town. Or perhaps it's carried in by some carnivore. Who knows?"

Jones and his colleagues may have finally solved this longstanding mystery. The likely culprit, they say, is the grasshopper mouse, a carnivorous rodent that carries plague-infected fleas across the rigid territorial boundaries separating isolated family groups within the prairie dog colony.

"We found that when grasshopper mouse density gets high enough, you get an epizootic - the animal equivalent of an epidemic - and virtually all of the prairie dogs die," Jones explained.

This finding, published in the July 26 online edition of the Proceedings of the National Academy of Sciences, could have significant implications for understanding how infectious diseases spread in animals and humans.

"Plague, a disease caused by the bacterium *Yersinia pestis* and the

causative agent of Black Death that killed 200 million Europeans in the 14th century, arrived in the United States via San Francisco around 1900 and still infects people worldwide," Jones said.

A number of other deadly human diseases - like hantavirus, Ebola and anthrax - show the same pattern of decimating communities, disappearing and coming back years later, said Daniel Salkeld, a Stanford postdoctoral scholar and lead author of the study.

"A key element to their control and eradication is understanding where they persist in the latent phase and identifying the conditions that result in sporadic epidemics," Salkeld said.

Territorial families

The research team focused on black-tailed prairie dogs, one of five prairie dog species whose populations have dwindled over the past century because of habitat destruction, extermination and plague.

Tracking infectious diseases in prairie dogs is challenging. The burrowing rodents live in complex underground communities largely hidden from view.

"Prairie dogs are highly social ground squirrels that occupy colonies, or towns, which can extend for 500 acres and comprise 5,000 individuals or more," Salkeld said. "While the town provides a defense against predators, individual prairie dogs are highly territorial."

Prairie dogs live in small family groups, known as coteries, which they defend vigorously. A large prairie dog town may have 1,000 coteries. Together, they form a grid of small, isolated territories within the town, Jones added.

"The coteries are spread out almost lattice-like," he said. "That has implications for infectious disease transmission. Each coterie has only a few neighbors. Because prairie dogs don't venture outside their territories, they can only infect their immediate neighbors. This territoriality limits the rate of disease propagation through the prairie dog town."

Little mouse on the prairie

Plague is not transmitted directly; it is carried by fleas. For the disease to spread across an entire prairie dog town, infected fleas must find a host that can freely travel from coterie to coterie. That's where the tiny grasshopper mouse comes in.

"Grasshopper mice have no respect for prairie dog territories," Jones said. "They're nasty little beasties, and when they eat the carcass of a prairie dog that's died of plague, the fleas climb aboard the mice. The mice then schlep the fleas around to different territories, connecting family groups that otherwise wouldn't be in contact."

The idea that plague could be facilitated by grasshopper mice was first proposed by Salkeld and co-author Paul Stapp of California State University-Fullerton. However, other researchers have been skeptical of the mouse hypothesis.

"A number of people familiar with prairie dogs say there is no way that the grasshopper mouse is causing this, because they only trap a few mice a year," Jones said. "So we decided to write a computer model to determine if the number of mice being trapped is consistent with driving these plague epizootics."

Critical threshold

For the *PNAS* study, Salkeld obtained field data from the Pawnee National Grasslands in Colorado. Co-author Marcel Salathé, now at Pennsylvania State University, created a computer model that simulates plague dynamics in a large prairie dog town.

The results of the simulation revealed that plague is endemic among prairie dogs.

"Even without grasshopper mice, plague kills one or two prairie dog families at a time, but it moves very slowly and is extremely hard to detect," Jones said.

As long as the disease is confined to isolated family groups, the town can survive. But once the density of susceptible prairie dog families and grasshopper mice crosses a critical threshold, plague can sweep through and wipe out virtually the entire town, he said.

"Plague sort of smolders in the prairie dog community for long periods in between epizootics," Jones said. "The mouse is like the spark that allows the pathogen to get carried to a new place where there's more fuel. And then just the right set of events coalesces, where you have the right mouse densities and the right spatial pattern of infected prairie dogs. At that point, the mice trigger the epizootic, and suddenly you get this catastrophic mortality where nearly all the prairie dogs die of the plague, where before only a few animals were dying.

The territoriality of prairie dogs and the lack thereof in grasshopper mice is what makes the whole system work."

Provided by Stanford University