Management of plague at Wind Cave National Park

A case study in the application of the One Health concept of disease management

By Daniel S. Licht, Kevin T. Castle, Daniel E. Roddy, and Barbara L. Muenchau

NEW AND EMERGING WILDLIFE DISEASES will likely be one of the greatest challenges confronting the National Park Service (NPS) this century. As the world "gets smaller," and people and animals move more frequently and over greater distances, diseases will likely spread. Furthermore, disease severity can be exacerbated by environmental degradation, such as pollution, climate change, species invasions, and changes in land use. Increased prevalence and severity of disease may have ominous consequences for people, wildlife, and the ecosystems upon which they both depend. In fact, many of these incipient diseases can affect both humans and wildlife. Diseases that are transmitted between humans and nonhuman animals are known as "zoonotic" diseases. The increased occurrence of such diseases may affect NPS operations more than most government bureaus, because the National Park Service provides for human safety and well-being while also conserving wildlife and ecological integrity. In this article we briefly describe the "One Health" concept of disease management, and we present a case study of the application of this framework at Wind Cave National Park, South Dakota.

One Health

The One Health concept is based on the premise that the health of people, animals, and our environments is inextricably interconnected. Specifically, One Health advocates for "the establishment of closer professional interactions, collaborations, and educational opportunities across the health sciences professions, together with their related disciplines, to improve the health of people, animals, and our environment" (One Health Commission 2010). This interdisciplinary approach is an exciting and potentially powerful model for health and disease management for veterinarians, physicians, public health officials, wildlife managers, and others.

The concept of One Health is not new; in fact, it was espoused by Rudolf Virchow and William Osler in the 19th and early 20th centuries. However, it was not until recently that the model received a renewed interest. In 2007 the American Veterinary Medical Association, behind the leadership of Dr. Roger Mahr, created a One Health Initiative Task Force to "study the feasibility of an initiative that would facilitate interdisciplinary collaboration to implement *One Health* principles." As a result of the task force report, a national One Health Joint Steering Committee was formed, with the National Park Service as a founding member. The steering committee has now become the national One Health Commission (http://www.OneHealthCommission.org), which has garnered support from multiple organizations and agencies, including the American Medical Association, American Veterinary Medical Association, and the Centers for Disease Control.

The National Park Service has been a leader in implementing the One Health approach by improving coordination, communication, and collaboration between the bureau's Wildlife Health Program (Biological Resource Management Division, Natural Resource Program Center) and its Office of Public Health. The two programs have worked side by side to investigate a number of disease issues over the last several years, including the death of a wildlife biologist from plague, a Boy Scout who was diagnosed with plague after visiting a national park and surrounding national forest,[1] a rabies outbreak near several national park units in Arizona, and unexplained deaths of coyotes and domestic dogs in a national park unit in Texas. In October 2008, the two programs formalized their collaboration by creating a joint disease outbreak investigation team to study human and wildlife disease issues in national parks. Core members of the team are a medical epidemiologist and environmental health specialist from the Office of Public Health, and a wildlife veterinarian from the Wildlife Health Program.

While it is true that in some cases an illness or disease may be isolated to people or to animals with little relevance to the other group, in many cases there is a nexus between human and wildlife health. Consider that 75% of the recent emerging infectious diseases affecting humans are of animal origin (Taylor et al. 2001). In many cases a disease can be

Figure 1. A keystone species of the Great Plains, prairie dogs are susceptible to plague, caused by a nonnative bacterium carried by fleas. Outbreaks of the disease can devastate prairie dog colonies and have ramifications for many other species and for human health.

[1] The investigation revealed that the Scout probably was not exposed while visiting the park.

In many cases a disease [of animal origin] can be fatal to both people and animals, and it can have a life history and a remedy that require input from ecologists, veterinarians, physicians, environmental scientists, and others.

fatal to both people and animals, and it can have a life history and a remedy that require input from ecologists, veterinarians, physicians, environmental scientists, and others. Plague is an example of such a disease.

Plague

Plague is caused by a bacterium, *Yersinia pestis*. The microorganism's life cycle requires both a flea and a mammal host. Rodents and lagomorphs (rabbits and hares) are the most typical mammal hosts, but carnivores and other mammals can be infected as well. *Yersinia pestis* was responsible for the notorious "Black Death" in Europe in the Middle Ages and is a classic zoonotic disease. In the case of the Black Death it was rats—ubiquitous because of poor sanitation at the time—and their fleas that played a key role in transmitting the disease to humans.

The plague bacterium likely was brought to North America via San Francisco around the beginning of the 20th century (Cully et at. 2006). From there it spread east to about the 104th meridian, or the Wyoming–South Dakota border. For the latter half of the last century the spread of the disease stalled at this imaginary line for reasons that are still unknown. Early this century, the disease was documented in southwestern South Dakota. (Interestingly, the disease moved into South Dakota at the end of a long and severe drought, suggesting that climate played a role in the eastward expansion.) The year 2007 was marked by several large die-offs of prairie dogs on the Pine Ridge Indian Reservation in southwestern South Dakota. In 2008 the disease was confirmed in prairie dog towns in the Conata Basin physiographic area just south of Badlands National Park and in prairie dog colonies about 20 miles (32 km) southeast of Wind Cave National Park.

Prairie dogs appear to have little if any immunity to plague, which is not surprising because plague is exotic to North America and thus prairie dogs did not evolve with it (Biggins and Kosoy 2001). Once a prairie dog colony becomes infected, the consequences can be catastrophic, with almost 100% mortality within a week or two in many instances (Cully et al. 2006). This can devastate the ecosystem because prairie dogs, and especially black-tailed prairie dogs (*Cynomys ludovicianus*), are keystone wildlife species (fig. 1, page 38; Kotliar et al. 2006). Among other functions, prairie dogs are prey for many predators, their burrows provide shelter, their soil-disturbing activities enhance soil health, and they maintain nutritious and diverse forage for grazing animals. When prairie dogs disappear or populations are greatly reduced, a negative ripple effect can occur throughout the system with disastrous impacts to black-footed ferrets (*Mustela nigripes*), burrowing owls (*Athene cunicularia*), swift fox (*Vulpes velox*), and other species. Although prairie dog die-offs are perhaps the most notable wildlife impact from the disease in North America, plague is known to be fatal to a wide range of species, from various mice and voles to mountain lions. Little is known about the severity of the disease in populations of these species and the impacts on the ecosystems in which they reside.

On average, 10 to 20 cases of human plague are documented every year in the United States and about 14% of these cases are fatal (Centers for Disease Control 2009). The most likely form of transmission to humans is flea bites. People often come in contact with fleas by handling live or recently dead wildlife, the nesting material of such mammals, or placing their hands in areas where fleas may reside, such as burrows. Family pets such as cats and dogs, especially those that investigate burrows, may also play a role in bringing infected fleas into contact with people. Many recent human plague cases were linked to pet cats that had become ill and then infected their owners or veterinarians (Gage et al. 2000). Less frequently, people can become infected by inhaling the bacterium or when it enters through openings in the skin. The symptoms of a plague infection in people are often flu-like at first, which can lead to misdiagnosis, with deadly results. Another common symptom is the formation of "buboes," or swollen, painful lymph nodes, which gave rise to the common name "bubonic" plague. The Centers for Disease Control and Prevention (2009) identifies "ecology-based prevention and control" as an important strategy for managing the disease, a concept that is consistent with the One Health model.

One Health, plague, and Wind Cave National Park

Wind Cave National Park is one of America's premier wildlife parks. In fact, it was established to preserve wildlife populations in addition to the cave. Since its establishment in 1903, the park has restored numerous species, including bison, elk, and pronghorn. In summer 2007 the park restored the endangered, and still extremely rare, black-footed ferret (fig. 2). This member of the weasel family is dependent on large areas of prairie dog colonies for its existence, as it relies almost entirely on prairie dogs for food and shelter.

As plague approached to within 20 miles (32 km) of Wind Cave National Park in summer 2008, park staff was faced with a series of critical and complex decisions, the most prominent of which was whether the park should proactively "dust" prairie dog towns with insecticide in the hope of killing the fleas that may spread the disease, and thereby prevent a prairie dog epizootic[2] (Cully et al. 2006). Dusting would also reduce the risk of plague infection in humans. However, broad use of insecticides on NPS lands is not common, in part because such treatment is often expensive and the nontarget impacts are not well-known. Furthermore, dusting may provide only one year of plague control. For Wind Cave National Park the approach was untested; however, its application also offered an opportunity for research, such as a study of the nontarget impacts. The following steps were part of plague management at Wind Cave National Park.

[2]An outbreak of disease in wildlife.

Figure 2. A television crew films the release of a black-footed ferret in Wind Cave National Park. An outbreak of plague could jeopardize restoration of this endangered species, which relies on prairie dogs for food and shelter.

Figure 3. Biologist Dan Licht collects fleas from a prairie dog burrow at Wind Cave. A DNA test will be used to determine if the plague bacterium is present in the gut of the collected fleas. For safety, Licht wears rubber gloves, has taped his pant leg to his boot, and has sprayed his boots and socks with insect repellent.

NPS/DANIEL S. LICHT

Assess the risk

How plague is spread and maintained across the landscape is not well understood, and this information gap was a significant shortcoming in assessing the risk to park wildlife and to human health. The nearest known plague epizootic in prairie dogs was about 20 miles (32 km) away, which is a modest distance for a dispersing coyote (*Canis latrans*) or bobcat (*Lynx rufus*) or other potential carriers of the disease. It was possible that plague would occur at the park that summer, or not for another 10 years, if ever. It was even plausible that plague was already present at the park in 2008, but at low levels that had not yet caused an epizootic in prairie dogs. Therefore, one of the park's first steps was to collect flea samples and have them analyzed for the plague bacterium. Because of the risks to human health, biologists collecting samples followed safe work practices, wearing rubber gloves and spraying insect repellent (DEET) on shoes and socks (fig. 3). The University of South Dakota quickly analyzed the fleas and reported that it did not detect plague DNA in the samples. However, the sample sizes were very small and therefore the results were statistically inconclusive. Nevertheless, the information was another piece of the puzzle the park used to determine whether to dust.

Another important factor in the decision-making process was that the park had just spent considerable money and effort in restoring endangered black-footed ferrets. The presence of plague would likely end that effort because the disease kills ferrets directly or indirectly by eliminating their food source, prairie dogs.

Conversely, a strong argument for not dusting was the time commitment, labor, and cost of such an undertaking. Dusting just one-third of the prairie dog acreage in the park would cost approximately $15,000 for supplies and other items, and require a crew of five for approximately 30 days. In addition, there were significant unknowns regarding the ecological impacts of using the insecticide deltamethrin to kill the host fleas. A wide range of species, such as tiger salamanders (*Ambystoma tigrinum*), toads, snakes, and insects, reside in prairie dog burrows where the insecticide would be applied. Even though plague is carried by a nonnative bacterium, the fleas themselves are a native species and—according to NPS policies—worthy of protection and conservation as a component of the ecosystem.

A third consideration was the human element. The dust itself, which can remain active in the burrow entrance for a year or more, could conceivably be touched or ingested by curious and unsuspecting people. A fourth concern was that the sight of park personnel driving all-terrain vehicles (ATVs) across the prairie while wearing head-to-toe protective gear could disturb visitors and leave a negative impression of park management. Yet if plague did occur in the park, and people became infected, the consequences would be very serious indeed. After reviewing the literature, conferring with experts, assessing park resources and objectives, and establishing priorities, park managers determined that dusting prairie dog burrows was the prudent course of action.

Plan for the action, including environmental compliance and job hazard analysis

In the years before the plague outbreak, the park had completed both prairie dog and black-footed ferret management plans (Wind Cave National Park 2006a, 2006b). Unfortunately, neither document adequately considered plague management and, therefore, they were inadequate for compliance with the National Environmental Policy Act (NEPA). To satisfy NEPA and minimize environmental impacts, the park completed an environmental screening form and determined that a categorical exclusion was appropriate for this action (Sec. 3.4 E[3], "Removal of individual members of a non-threatened/endangered species or populations of pests and exotic plants that pose an imminent danger to visitors or an immediate threat to park resources"). Dusting to control plague outbreaks involves spraying deltamethrin powder into prairie dog burrow entrances. Prior to using any pesticide, NPS personnel must consult with the NPS Integrated Pest Management program and obtain approval through the Pesticide Use Proposal System, and must make sure NPS staff applying the pesticide are certified for its use within their state. To reduce the likelihood of injury or harm to personnel applying the insecticide, park staff followed recommended safety procedures, namely, wearing protective clothing such as long sleeves, gloves, and eye protection. Those applying the insecticide were trained and certified in ATV use by the ATV Safety Institute so that they could safely and efficiently navigate the treatment sites (fig. 4).

Implement treatment actions

In summer and fall 2008 the park treated approximately 1,100 acres (445 ha) of prairie dog colonies with deltamethrin in hopes of preventing a plague epizootic. This area amounted to about 40% of all prairie dog acreage in the park. The great majority of the treated area included colonies used by restored black-footed ferrets. The park also opted not to treat approximately 100 acres (41 ha) of a prairie dog colony that had a small wetland (about 1 acre [0.4 ha]) in the middle of it (fig. 5). Previous studies had documented a high density of tiger salamanders using the prairie dog burrows near the wetland. By leaving this site as an undusted refugium the park reduced the risk of accidentally extirpating nontarget organisms. In 2009 the park re-treated 725 of the acres (294 ha) treated in the prior year.

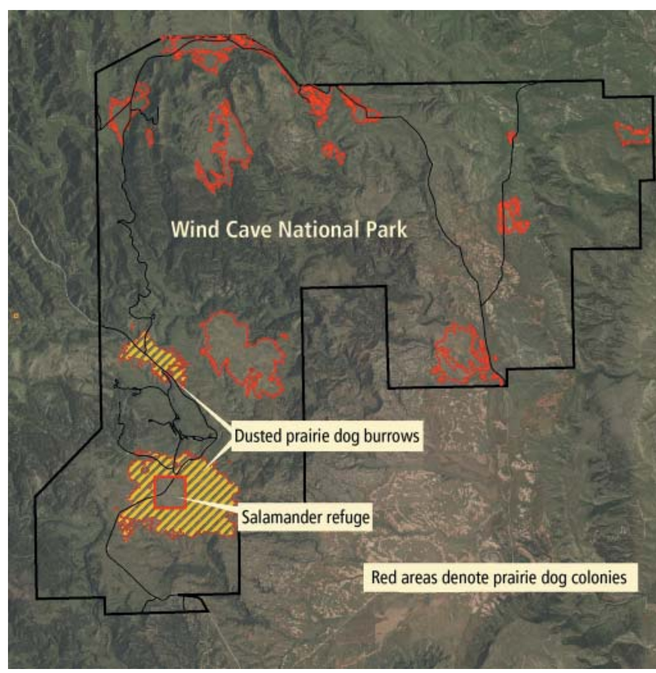
Monitoring

The concept of adaptive management requires post-treatment monitoring to test and document whether project goals are being met. As part of this approach, the park continues to collect flea samples from non-dusted colonies in an effort to determine if plague is present. The samples will be analyzed by the University of South Dakota. The university will also study the genetics of the fleas to better understand flea movement within and outside the park. The park also monitors its prairie dog colonies for evidence of plague and periodically maps the distribution of the colonies. Monitoring for outbreaks of the disease consists primarily of determining whether prairie dogs are present or absent, because plague can kill nearly all members of a colony. Although dusting is a common practice in some areas,

Figure 4. Biological Science Technician Barb Muenchau dusts a prairie dog burrow with insecticide in order to kill fleas that may be carrying the nonnative plague bacterium.

NPS/TOM FARRELL

Figure 5. In 2008, Wind Cave staff treated approximately 40% of all prairie dog colonies with the insecticide deltamethrin in hopes of preventing a plague epizootic. A 100-acre (41 ha) area with a small wetland in it was left untreated so that it could serve as a refugium for tiger salamanders.



though dusting is a common practice in some areas, little information is available about its effects on nontarget species. The potential nontarget impacts were of great concern to the park in part because of the NPS mission to conserve all flora and fauna. Therefore, the park left a portion of one prairie dog colony undusted to serve as a study site and to provide refugia for nontarget species. To better understand nontarget impacts of dusting, park staff identified the tiger salamander as an indicator species and a study subject. This salamander species resides in prairie dog burrows during the day and moves to the burrow entrances at night to feed on the rich insect community associated with prairie dog colonies (fig. 6). It is conceivable that salamanders could be harmed directly by the insecticide or indirectly through a reduction in food items. Therefore, staff conducted salamander surveys on undusted (i.e., control) and dusted (i.e., treatment) plots. Preliminary results suggested no significant impact to salamanders as a result of applying the insecticide, but additional surveys and testing are needed. The park is developing an agreement with Black Hills State University to conduct a more thorough analysis of impacts to tiger salamanders. Even if the insecticide turns out to be harmful to salamanders, the population should still persist thanks to the undusted refugia. Similarly, other organisms that could be killed by the insecticide (e.g., beetles) should persist in the refugia and be able to recolonize treated areas once the insecticide is no longer effective.

Communicate with stakeholders and partners

Accurate and timely communication with the public was deemed critical to the success of the project. Therefore, park natural resource managers worked closely with interpreters to ensure that appropriate messages were developed and went out to the public. Visitor center staff and patrol rangers were all kept in the loop, as they were on the front lines in communicating with the public. This was extremely important because field crews wearing protective gear were often visible to the public. Messages about the treatment explained that prairie dogs were the victims of plague and not the cause, and that the disease was brought to America by humans. This was very important as prairie dogs are often viewed as pests by landowners, who remove them from their land. Suggesting that prairie dogs were the cause of the disease would exacerbate that situation. The park took other steps to minimize the spread of plague, such as diligently enforcing rules regarding pets, as a dog or cat that had recently been in the western United States could be harboring plague-infected fleas from that region that could be transmitted to park wildlife.

Summary

How the National Park Service manages plague will vary from park to park because all parks differ in their goals, priorities, and environments. For example, methods used to control plague in parks with black-tailed prairie dogs (e.g., dusting burrows) may not be suitable for parks where rock squirrels or other rodents are the primary mammalian host of the disease, because their burrows are not as easily identified. And within parks that have plague, backcountry areas may be managed differently from areas with high human use. Costs will always be a consideration in determining management options.

Yersinia pestis is an exotic bacterium, and therefore its control and eradication would be supported by NPS management policies. However, eliminating the disease from North America, let alone the 25 or so units of the National Park System that host it, is

Figure 6. Tiger salamanders reside in prairie dog burrows in the vicinity of a small wetland within one of the treatment areas at Wind Cave. Staff, therefore, decided not to treat 100 acres in this area in order to create a refugium for the species.

infeasible. Therefore, a more realistic management goal is to take actions that decrease the likelihood of wildlife epizootics and minimize the risk of human infection. Current intervention methods unfortunately still trade protection of the health of one or two species for that of others. These interventions have been devised based on our old paradigm of "separate health." Future progress toward true One Health approaches to conservation management depends on research to better understand ecosystems and variables that detract from or support the balanced health of all species. We advocate that there is a great need for this type of research in order to provide for informed One Health interventions.

To meet these goals, park biologists and managers will need to use an approach that incorporates the science, tools, and methods of the wildlife, human, and environmental health professions and that acknowledges the interconnectedness of human, animal, and environmental health. That is the essence of the NPS One Health approach.

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