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Landscape Ecology of Plague in the American Southwest
September 19–20, 2000
Fort Collins, Colorado

Proceedings of an American Southwest Workshop

Edited by Christopher J. Brand

Sponsored by the U.S. Geological Survey–National Wildlife Health Center

Information and Technology Report 2002–0001

U.S. Department of the Interior
U.S. Geological Survey

Contents

Executive Summary

During September 19–20, 2000, a workshop titled "Landscape Ecology of Plague in the American Southwest" was held in Fort Collins, Colorado. The workshop was funded by the U.S. Geological Survey (USGS)–Earth Surface Processes Team and sponsored by the USGS National Wildlife Health Center. Forty scientists and natural resource managers and administrators representing 8 federal agencies, 4 state agencies, 6 universities, and other local agencies and nongovernment organizations met to discuss historical and current status of plague in the United States, current activities in plague surveillance, research, and management in wildlife, and research and information needs relative to plague control and management. Eleven individual presentations on plague history, status, and trends; diagnostic technologies; epizootiological studies and observations; and control and management strategies and studies, followed by a panel discussion on the impact of plague on wildlife and ecosystems, led the way to extensive group discussions on important plague-related questions, issues and problems. Workshop attendees participated in identifying important research and information needs relevant to control and management of plague in wildlife, and in the process, established new cooperative and collaborative partnerships and enhanced existing relationships upon which future research and information needs can be met. The proceedings from this workshop are intended to be used by the natural resource managers and researchers from the various participating agencies, research facilities, as well as other stakeholders to aid in the development of future research and information programs and funding initiatives related to both zoonotic and sylvatic plague.

Terry E. Creekmore

Acknowledgements

We thank Richard Reynolds and David Miller for providing financial support through the U.S. Geological Survey (USGS)–Geologic Discipline's Southwest Workshops Project for promoting interdisciplinary studies. Dr. R.G. McLean provided helpful input into the workshop development and review of the workshop proceedings. We also thank Marta Anderson and Elizabeth Ciganovich for preparation and layout of these proceedings.

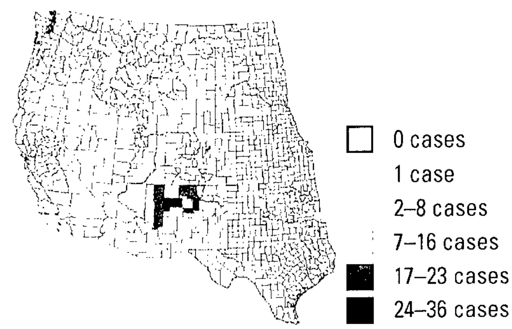
Introduction

Since the introduction of plague (*Yersinia pestis*) into the United States in 1900, this disease has spread through the West and Southwest, where a variety of rodent species serve as reservoirs for both human and wildlife infection. Plague has significantly impacted populations of rodent species such as black-tailed (*Cynomys ludovicianus*), white-tailed (*C. leucurus*), Gunnison's (*C. gunnisoni*), and Utah (*C. parvidens*) prairie dogs, often killing 90–100 percent of infected colonies. Evidence also suggests that plague may have been a factor in the near-extinction of the black-footed ferret (*Mustela nigripes*) from direct mortality as well as indirectly from decimation of prairie dogs, their sole food source, by plague.

Plague in humans is an internationally reportable disease, and an average of about 10–15 cases have been reported each year in the United States since 1975. Federal, State, and local public health agencies in plague-endemic areas invest significant resources in surveillance programs to determine the distribution and activity of plague in wildlife and to conduct follow-up epidemiological investigations to identify sources of human cases. Wild rodents, particularly rock squirrels (*Spermophilus variegatus*), are frequently shown or implicated to be the reservoir for infecting fleas that transmit the plague bacterium to humans, often involving domestic cats as links between wildlife reservoirs and human cases. Increased risk for plague in humans is often associated with expansion of residential areas into areas populated by rodent reservoirs; and pastoral life styles, particularly among Native Americans on reservations in the southwestern United States.

Plague control in wildlife in the United States has been attempted on numerous occasions, often associated with response to human cases or proactively to reduce risk of transmission to humans within a relatively localized geographic area. These programs often involve rodent and vector population suppression in addition public education and medical surveillance. While these have met with varying degrees of success, in general they do not contain the disease for long periods or over broad areas. Rodent targets of population control are often the more visible and susceptible species, while the species responsible for enzootic maintenance may not be affected by these control measures. Re-establishment of affected sites with new and naïve populations of susceptible rodents may be rapid in some situations.

Plague Cases, by County, Western United States, 1970–2000



Courtesy of the Centers for Disease Control and Prevention

Courtesy of the Centers for Disease Control and Prevention

Landscape-scale changes in the West since the early 1900s have likely changed, and will continue to change, epidemiologic and epizootiologic patterns of both zoonotic and sylvatic plague in the United States. Ruralization and suburbanization from many of our major population centers will continue to alter the risk of human exposure to plague from wild rodents; broad-scale changes affecting habitat abundance, distribution, and patchiness will likely change the transmission dynamics and impact of plague within and between wildlife species and populations; and other factors such as climate change, water distribution in arid ecosystems, and other land-use changes may also have unknown effects on the occurrence and distribution of plague.

Effective prevention and control measures for plague in wildlife, whether zoonotic or sylvatic, now and in the future, will benefit from an integrated epidemiological approach bringing together multiple disciplines, including wildlife biology and management, landscape ecology and epidemiology, molecular biology, human and wildlife disease specialties, toxicology, vaccinology, and other disciplines. We hope that the results of this workshop will be used as a seed, or nucleus, for both a broader and more thorough understanding of plague, leading to new and better plague prevention and control approaches.

Christopher J. Brand
Workshop Moderator
U.S. Geological Survey—National Wildlife Health Center

K. Max Canestorp

Workshop Purpose and Goals

To convene a workshop of scientists and resource managers to:

- Present an overview of plague in the United States and historical and current status
- Present current activities in plague surveillance, research, management, and control
- Discuss research and information needs relative to plague control
- Establish a basis for developing partnerships for future plague-related research
- Develop a guidance document or white paper for aiding the development of research programs and funding initiatives

Agenda

Tuesday, September 19

8:00–8:20 Welcome and Introduction (Christopher J. Brand)

History, Status, and Landscape Features

8:20–8:50 General topic: History and overview of plague (Ken Gage)

8:50–9:10 Spatial analysis of human plague (F. Lee De Cola)

Diagnosis and Laboratory Technologies

9:10–9:30 Laboratory diagnosis of plague: Review of diagnostic tests performed in the laboratory for the identification and confirmation of plague (May Chu)

Epizootiological Studies and Observations

9:30–9:50 Interspecific comparisons of sylvatic plague in prairie dogs (Jack F. Cully and Elizabeth S. Williams)

9:50–10:10 General topic: proposed study (Jerry Godbey and Dean Biggins)

Break 10:10-10:30

Epizootiological Studies and Observations (Continued)

10:30–10:50 Plague surveillance and flea communities on black-tailed prairie dog towns (Paul J. Young, Daniel G. Mead, Frank Ramberg, K. Max Canestorp,and Tim Vosburgh)

10:50–11:10 Investigating epizootic plague transmission: comparison of flea/host relationships within an established prairie dog colony to adjacent habitat (Lianna Hatfield-Etchberger, Bill Stroh, Brent Bibles, and Richard Etchberger)

11:10–11:40 Comparison of plague ecology between Asia and North America (Michael C. Kosoy, Ken Gage, Dean E. Biggins)

Lunch 11:40–12:40

Control of Plague in Wildlife

12:40–1:00 Plague control efforts in prairie dogs at Rocky Mountain Arsenal National Wildlife Refuge (David Seery)

1:00–1:20 Vaccination as a potential method for controlling plague (*Yersinia pestis*) in prairie dogs and other animals (Tonie E. Rocke, Susan R. Smith, Jordan Mencher, Christopher J. Brand, Jorge E. Osorio, and Dan T. Stinchcomb)

1:20–1:35 Evaluation of an oral baiting system for delivery of a recombinant plague vaccine to black-tailed prairie dogs (Terry E. Creekmore, Tonie E. Rocke, and Jerry Hurley)

Impact of Plague on Wildlife and Ecosystem Management

1:35–2:45 Panel Discussion (Pete Gober, Bob Luce, Randy Matchett, Mike Lockhart, Dave Seery)

The significance of the plague threat in the U.S. Fish and Wildlife Service: Black-tailed prairie dog 12-month finding (Pete Gober)

Black-footed ferret release site monitoring in Shirley Basin, Wyoming (Bob Luce)

Plague management during black-footed ferret reintroductions in Montana (Randy Matchett)

Break 2:45–3:05

Discussion Topics

3:05–4:00

Research and Management Information Needs

4:00–4:45

Wednesday, September 20

Continuation of Discussion Topics and Needs

8:00–10:00

Break 10:00-10:30

Preparation of Proceedings/Issue Paper

10:30–11:45 Ideas, outline, and assignments

Workshop Summary and Conclusions

11:45–12:00

Subsequent to Workshop

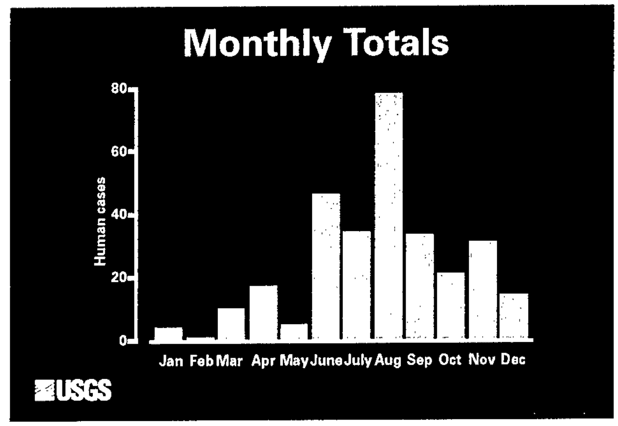
Compilation, editing, and publication of Proceedings

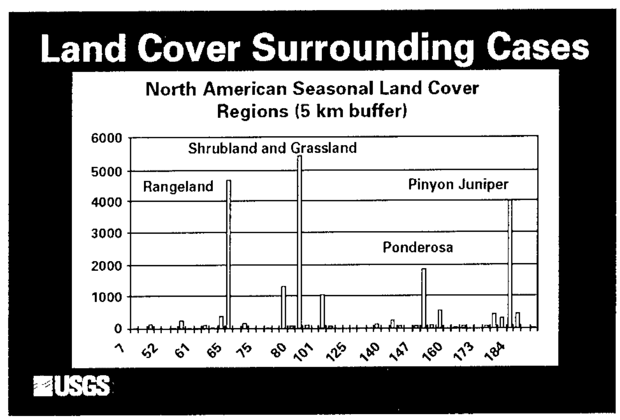
Abstracts

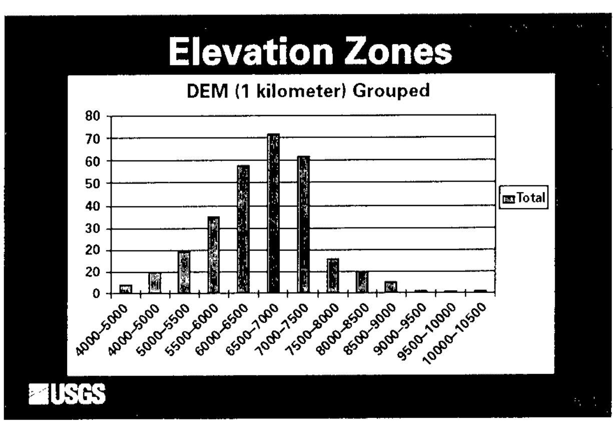
Spatial Aanlysis of Human Plague

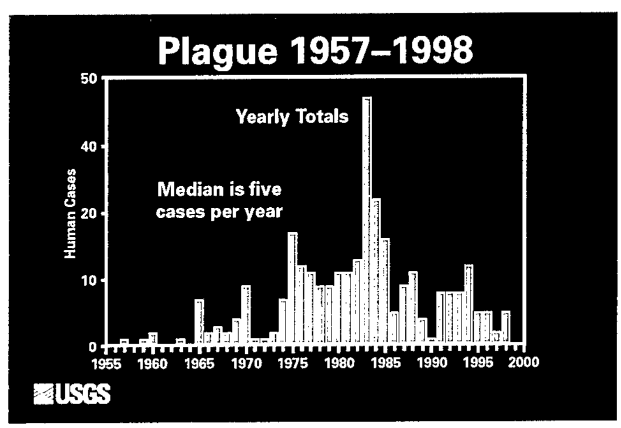
F. Lee De Cola, U.S. Geological Survey, National Center, Reston, Virginia

During the period 1957–1998, 294 cases of human plague were recorded in the Four Corners states of the United States, at a median rate of 5 per year. We have analyzed these events in time and space in order to map a risk surface that describes where disease incidence may be unusually high. The cases have occurred in three major waves separated by the years 1971 and 1990, the peak year being 1983, with almost 40 cases. Spectral analysis reveals a yearly cycle (minima in February, maxima in August) with a greater-than-yearly tendency. Spatial binning reveals clustering at multiple scales, the largest associated with urban areas and Native American reservations. The number of cases within each county were normalized by area and population, then associated with centroids as inputs to ordinary kriging, which created a "risk surface" that indicates regions where the disease may be endemic. Work is continuing on the association among plague and such environmental factors as elevation and land cover; but the linkages among hosts, vectors, and microbes at multiple scales will continue to challenge advanced geospatial analysis.









Interspecific Comparisons of Sylvatic Plague in Prairie Dogs

Jack F. Cully, U.S. Geological Survey, Kansas Cooperative Fish and Wildlife Research Unit, Division of Biology, Kansas State University, Manhattan, Kansas

Elizabeth S. Williams, Department of Veterinary Sciences, University of Wyoming, Laramie, Wyoming

Of the three major factors (habitat loss, poisoning, and disease) that limit the abundance of prairie dogs today, sylvatic plague caused by *Yersinia pestis* is the one that is currently beyond human control. Plague epizootics frequently kill more than 99 percent of prairie dogs in infected colonies. Although epizootics of sylvatic plague occur throughout most of the range of prairie dogs in the United States and are well described, long-term maintenance of plague in enzootic rodent species is not well documented or understood. We review the dynamics of plague in white-tailed (*Cynomys leucurus*), Gunnison's (*C. gunnisoni*), and black-tailed (*C. ludovicianus*) prairie dogs, as well as in their rodent and flea associates. We use epidemiological concepts to support an enzootic hypothesis in which the disease is maintained in a dynamic state by prairie dogs and other rodent species, which requires the transmission of *Y. pestis* to be slower than recruitment of new susceptible mammal hosts. Major effects of plague on black-tailed prairie dogs are to reduce colony size, increase variance in colony populations, and increase inter-colony distances within colony complexes. In the presence of plague, black-tailed prairie dogs will probably survive in complexes of small colonies that are usually greater than 3 km from their nearest neighbor colonies or that undergo severe population fluctuations.

R.B. Forbes

Plague Surveillance and Flea Communities on Black-Tailed Prairie Dog Towns

Paul J. Young[1], Daniel G. Mead[2], and Frank Ramberg, University of Arizona, Tucson, Arizona

K. Max Canestorp, U.S. Fish and Wildlife Service, Pueblo Chemical Depot, Pueblo, Colorado

Tim Vosburgh, Fort Belknap Fish and Wildlife Department, Fort Belknap Agency, Montana

The species composition and index of activity of flea populations were monitored monthly on black-tailed prairie dog (*Cynomys ludovicianus*) towns on the Ft. Belknap Indian Reservation in northern Montana and on the Pueblo Chemical Depot (PCD) in central Colorado from May 1999 through May 2000. There were seasonal and geographic differences in the flea communities found in both areas. Five species of fleas (*Oropsylla hirsuta, Pulex simulans, Thrassis fotus, Peromyscopsylla hesperomys,* and *Micropsylla sectilis goodii*) were recovered from prairie dog burrows in Colorado throughout the year. *O. hirsuta* was the dominant flea species throughout the year, accounting for over 95 percent of all fleas recovered, but was most common in late-spring and early summer 1999 concurrent with a sylvatic plague epizootic. Virtually the entire study area was affected by the plague outbreak and flea activity declined rapidly once the prairie dog populations had been decimated. The greatest index of flea activity (11–25 fleas/burrow) occurred in July, during the plague outbreak. By October 1999 the index of flea activity ranged from 0.0 to 0.8 fleas/burrow. Seven species of fleas (*Atheca wagneri, O. hirsuta, O. tuberculata cynomuris, O. brunneri, O. rupestris, Peromyscopsylla hesperomys,* and *Thrassis bachii bachii*) were recovered from prairie dog burrows on the Ft. Belknap prairie dog complex. Flea activity was bimodal with peaks of *O. tuberculata cynomuris* in May, and of *O. hirsuta* in September. A sylvatic plague epizootic on some towns within the Ft. Belknap complex occurred concurrently with a fairly high index of activity for *O. hirsuta* (6.4 fleas/burrow), however, not all areas with high indices of activity were affected. Only two flea species, *O. hirsuta* and *Peromyscopsylla hesperomys,* were common to both study areas, and were only represented by a few specimens on each area. The loss of most of the prairie dogs on PCD by October 1999 prevented an accurate comparison of the natural seasonal change in flea populations among geographic sites.

Current addresses:

[1]PJY: Prairie Ecosystems Research Group, McGregor, Iowa

[2]DGM: College of Veterinary Medicine, The University of Georgia, Athens, Georgia

*Oropsylla tuberculata cynomuris—
Frank Ramberg*

K. Max Canestorp

Investigating Epizootic Plague Transmission: Comparison of Flea/Host Relationships Within an Established Prairie Dog Colony to Adjacent Habitat

Lianna Hatfield-Etchberger, Bill Stroh, Brent Bibles, and Richard Etchberger, Utah State University, Uintah Basin Branch Campus, Vernal, Utah

Bill Stroh, Bureau of Land Management, Vernal District Office,Vernal, Utah

Endangered black-footed ferrets (*Mustela nigripes*), as well as their prairie dog prey, are extremely susceptible to sylvatic plague, which is a major concern of the Black-Footed Ferret Reintroduction Program. Black-footed ferrets were released in the Coyote Basin of northeastern Utah in the fall of 1999. We initiated a pilot study last summer to investigate plague transmission in Coyote Basin white-tailed prairie dog (*Cynomys leucurus*) colonies.

Plague epizootics tend to occur when the population size of rodents such as prairie dogs increases. An increase in population size has been observed over the last several years by monitoring the white-tailed prairie dog population in the Coyote Basin of northeastern Utah. Interestingly, the prairie dog density did not increase. Instead, the population increased by expansion into adjacent areas atypical of short grassland prairie dog habitat. Active burrows have been found in dense sage-brush and on hillsides. This observation suggests that prairie dog expansion may lead to increased exposure to a flea species capable of transmitting plague. This increased exposure may result from either overlapping ranges between the prairie dogs and the responsible flea vector or by expansion into an area with increased frequency of the vector. Our pilot study asked whether there is a difference in flea/host relationships between established prairie dog habitat and adjacent habitat. If so, then insight to the particular flea vector species and the host reservoir species will be invaluable in designing future monitoring and prevention techniques. Results of the pilot study will be discussed.

Richard Etchberger

Comparison of Plague Ecology Between Asia and North America

Michael C. Kosoy and Ken Gage, Centers for Disease Control and Prevention, Fort Collins, Colorado

Dean E. Biggins. U.S. Geological Survey, Midcontinent Ecological Science Center, Fort Collins, Colorado

Expansion of plague caused by *Yersinia pestis* into North America from its likely origins in Asia has dramatic ecological and evolutionary ramifications due to its lethality and extraordinary host range. The three biovars of *Y. pestis* (Antiqua, Medievalis, and Orientalis), based on whether they produce nitrous acid or ferment glycerol, circulate in Asia, but only Orientalis has been found in North America. Despite homogeneity of *Y. pestis* as a single type, 40.9–55.7 percent of plague isolates in many Asian plague foci differed by one or more characteristics. Diversity of *Y. pestis* in North America is much lower compared to Asia.

Over 200 mammalian species in 73 genera are known to become naturally infected with plague. Some mammals are highly sensitive to plague, while other species are at least moderately resistant. Wild rodent species from New Mexico ranged from homogeneously susceptible to plague to completely resistant. Rodent species which are very susceptible to plague include the western harvest mouse (*Reithrodontomys megalotis*), silky pocket mouse (*Perognathus flavus*), piñon mouse (*Peromyscus truei*), white-throated woodrat (*Neotoma albigula*), Mexican woodrat, (*N. mexicana*), and least chipmunk (*Eutamias minimus*). Many carnivores appear to be quite resistant to plague, but domestic cats became acutely ill, as do some *Mustela* spp.

Mammal species that are sufficient to maintain plague in natural systems were defined as primary hosts (Fenyuk, 1948). Secondary hosts may facilitate spread of plague, but are not able to maintain plague for extended periods without the primary hosts. Rall (1965) proposed monohostality for all plague foci based on his investigations in central Asia, wherein a single rodent species is required to maintain plague in a particular focus. A unique variant of *Y. pestis* is adapted to that primary host, although some other animal species may participate in circulation of the bacterial variant. For example, only the great gerbil (*Rhombomys opimus*) is necessary to sustain plague in the mid-Asian deserts. Some other investigators suggest that maintenance of plague requires a combination of coexisting rodent and/or lagomorph species. The proportion of individuals resistant or susceptible to plague in a rodent population is a measure used to characterize the role of rodent species in transmission and maintenance of plague in Asia. In Asia, the proportion of resistant individuals was about equal for great gerbils (50–80 percent), little susliks (*Spermophilus pygmaeus*; 50–70 percent), and midday gerbils (*Meriones meridianus*; 44–60 percent) (Atshabar, 1999).

Global Distribution of Plague

Countries reported plague, 1970–2000

■ Probably sylvatic foci

Courtesy of the Centers for Disease Control and Prevention

In Asian rodents, partial resistance to plague was correlated with both genotypic and phenotypic characteristics including blood groups in great gerbils and marmots (*Marmota baibacina*), hereditary ability to utilize oxygen in jirds, several biochemical variables in Libyan jirds (*Meriones libycus*), level of corticosteroids in blood plasma of midday gerbils, and epigenetic cranial features in the great gerbil and marmots. Plague bacteria can persist in some Asian rodents for extended periods; *Y. pestis* survived in long-tailed susliks (*S. undulatus*) for 692 days (Maevsky et al.,1988).

Relatively resistant species of *Microtus* and *Peromyscus* may maintain plague infection in western North America. A few individuals in a population of *M. californicus* were determined to be asymptomatically infected with *Y. pestis* (Goldenberg et al., 1964). Populations of prairie dogs, nevertheless, have remained highly susceptible after repeated exposure to plague epizootics, although seroconversion occurred in a small proportion of Gunnison's prairie dogs (*Cynomys gunnisoni*) exposed to a plague epizootic (Cully et al., 1997).

Silky pocket mouse—J.O. Wolff

Western harvest mouse—G.C. Rinker

Least chipmunk—G.L. Tweist

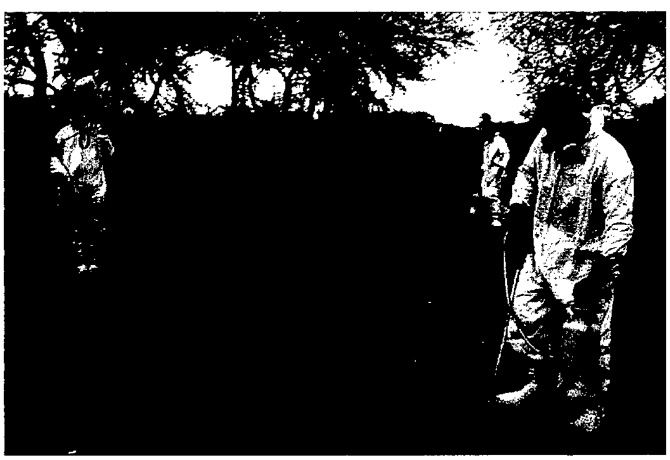
Mexican woodrat—R.B. Forbes

Plague Control Efforts in Prairie Dogs at Rocky Mountain Arsenal National Wildlife Refuge

David Seery. U.S. Fish and Wildlife Service, Rocky Mountain Arsenal National Wildlife Refuge, Commerce City, Colorado

Plague epizootics have periodically reduced black-tailed prairie dog (*Cynomys ludovicianus*) colonies at Rocky Mountain Arsenal National Wildlife Refuge (Refuge) by 95–99 percent in the last 10 years. Prairie dogs are considered a keystone species at the Refuge, supporting a wide variety of wildlife species [burrowing owls (*Athene cunicularia*), ferruginous hawks (*Buteo regalis*), bald eagles (*Haliaeetus leucocephalus*)] and therefore warrant protective efforts. Efforts to contain or control these epizootics have primarily focused on the use of an insecticide (Pyraperm®, a synthetic pyrethrin) to control fleas, the primary plague vector. A new insecticide, Deltadust®, was also applied on a test basis to limited areas. Control procedures proceeded under the assumption that controlling the plague vector (fleas) would slow down or potentially stop an epizootic from spreading.

The insecticide powder was applied according to label directions, using Birchmeier PD-5 powder dusters, with powder applied directly into burrow openings at an application rate of approximately 1 ounce per burrow. Personal protective equipment (PPE) included a full Tyvek® suit, rubber gloves and boots, and half-face respirator with particulate cartridges. Control procedures were activated when plague was confirmed or suspected in any active colony on the Refuge. Plague was confirmed (Centers for Disease Control Plague Lab, Fort Collins, Colorado) in large-scale die-offs of prairie dogs at the Refuge in 1988–89, 1994–95 and 2000. Because the incubation period in prairie dogs is not known precisely, and thought to vary from 7–14 days, the active plague boundary, or "front," is not observable. This front lies ahead of the "plagued-out" zone, where virtually 100 percent mortality occurs. In 1994 these control procedures occurred in active areas of colonies immediately outside the "plagued-out" zone, with very little actual control achieved. At best the plague front only slowed as it encountered the dusted area, with mortality eventually reaching virtually 100 percent. This was probably due to dusting areas where the prairie dogs were already infected, but had not yet succumbed to the plague bacteria (*Yersinia pestis*).



David Seery

A different approach was taken in 2000, with the control area placed at increasing distances from the plague front. With control procedures starting in January and ending in August and with distances increasing from 200 meters to over 400 meters, some degree of control of the plague epizootic has been achieved. There are several small "islands" of active prairie dog colonies existing within plagued-out areas, along with several large areas remaining untouched. We have never seen this occur in previous epizootics. Even though it is still possible to incur significant losses from this plague epizootic, we are seeing signs of the plague slowing down. A total of 128.7 ha of prairie dog colonies were dusted from 13 January to 27 September 2000. Of the total, 69.2 ha were dusted with Pyraperm® for plague control, 29.9 ha with Deltadust® for plague control, 5.3 ha with Deltadust® for a field trial study, and 24.3 ha with Pyraperm® on prairie dog relocation sites. A total of 138.6 kg of Pyraperm® (6.24 kg of active ingredient) was applied to 93.5 ha (1.48 kg/ha) and 54.1 kg of Deltadust® (0.027 kg of active ingredient) applied to 35.2 ha (1.53 kg/ha).

As of September 1, 2000, there were still 284 ha of active prairie dog colonies remaining on the Refuge. This represents over 42 percent of the active area mapped in May, 2000 (665 ha). We will continue to monitor for plague activity for the duration of the year and apply insecticide dust to as much of the remaining active colonies as time and weather conditions allow.

Vaccination as a Potential Method for Controlling Plague (*Yersinia pestis*) in Prairie Dogs and Other Animals

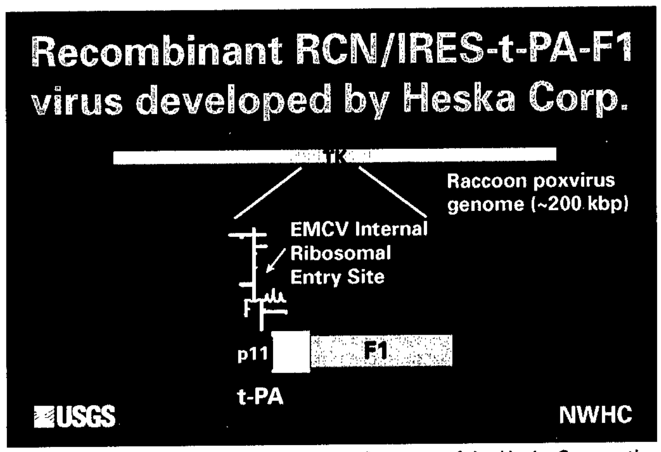
Tonie E. Rocke, Susan R. Smith, Jordan Mencher, and Christopher J. Brand. U.S. Geological Survey, National Wildlife Health Center, Madison, Wisconsin

Jorge E. Osorio[1], and Dan T. Stinchcomb. Heska Corporation, Fort Collins, Colorado

Preliminary experiments are being conducted to evaluate vaccination as a means for controlling plague in wild animals using a recombinant plague vaccine developed by the Heska Corporation. This vaccine, which utilizes raccoon pox virus (RCN) as a vector for the F1 capsular antigen of *Y. pestis*, was originally produced for use in domestic cats. A major advantage of using an RCN-vectored vaccine over a traditional protein vaccine, such as the F1 protein, is that it can be delivered orally, a critical requirement for immunization of free-ranging wildlife. Initial experiments were conducted in mice. Groups of mice were vaccinated with the recombinant plague vaccine either by intramuscular injection or oral administration and boosted at 4 weeks post-initial immunization (PI). Control animals received diluent only. Upon challenge with virulent plague at 6–8 weeks PI, all animals injected intramuscularly survived, as well as half the animals that received the vaccine by the oral route, while all the control mice died. Immunized animals developed high antibody titers to the F1 antigen. Additional work is in progress to improve oral uptake of the vaccine. Also, experiments are currently ongoing to determine if black-tailed prairie dogs (*Cynomys ludovicianus*) and black-footed ferrets (*Mustela nigripes*) can be effectively immunized with the vaccine either by oral or parenteral routes of administration. The potential use of vaccination to control plague in prairie dogs and other animals will be discussed.

Current Address:

[1]JEO: Powder Ject Vaccines, Madison, Wisconsin



Courtesy of the Heska Corporation

Christopher J. Brand

Christopher J. Brand

Evaluation of an Oral Baiting System for Delivery of a Recombinant Plague Vaccine to Black-Tailed Prairie Dogs

Terry E Creekmore[1] and Tonie E. Rocke, U.S.Geological Survey, National Wildlife Health Center, Madison, Wisconsin

Jerry Hurley, U.S. Department of Agriculture, National Wildlife Research Center, Fort Collins, Colorado


Terry E. Creekmore


Terry E. Creekmore

Laboratory and field studies were conducted between July and October, 1999, to identify bait preference, biomarker efficacy, and bait acceptance rates for delivering an oral plague vaccine to black-tailed prairie dogs (*Cynomys ludovicianus*). Twenty captive prairie dogs were offered alfalfa baits containing either alfalfa, alfalfa with 5 percent molasses, or alfalfa with 5 percent molasses and 4 percent salt. Based on results of these trials, we selected a bait containing alfalfa with 7 percent molasses and 1 percent salt for field trials to determine bait acceptance rates. Three biomarkers (DuPont dye, iophenoxic acid, and tetracycline) were administered to captive prairie dogs to determine their efficacy. Two field trials were conducted at separate prairie dog colonies located at Buffalo Gap National Grassland, South Dakota. In Trial 1, three baits containing tetracycline were distributed around each active burrow entrance and an additional bait was placed inside the burrow (1,276 baits total). In Trial 2, baits were distributed at the same density as Trial 1, but along transects spaced 10 m apart (1,744 baits total). Trapping began 3 days after bait distribution, and 30 prairie dogs were captured at each site to determine acceptance rates. In Trial 1, 67 percent of the prairie dogs captured had tetracycline deposits indicative of bait consumption. In Trial 2, 83 percent of the prairie dogs had ingested a bait. Approximately 15 percent of the animals in both trials ate more than one bait. *Opisocrostis hirsutus* fleas were found on 64 of 70 (91 percent) of the prairie dogs captured during this study.

Current Address:

[1]TEC: Wyoming Department of Health, State Veterinary Laboratory, Laramie, Wyoming

Panel Presentations

The Significance of the Plague Threat in the U.S. Fish and Wildlife Service: Black-Tailed Prairie Dog 12-Month Finding

Pete Gober. U.S. Fish and Wildlife Service, Pierre, South Dakota

The Fish and Wildlife Service published a notice of a 12-month finding regarding the black-tailed prairie dog (*Cynomys ludovicianus*) in the *Federal Register* on February 4, 2000. The finding indicated that the current status of the black-tailed prairie dog warranted its listing as a Threatened Species pursuant to the Endangered Species Act, but a proposed rule was precluded by work on other higher priority species. The finding noted that a significant recent decline in black-tailed prairie dog occupied habitat has occurred due to several factors; the most influential being the widespread occurrence of sylvatic plague.

Sylvatic plague is an exotic disease foreign to the evolutionary history of North American species. Plague was first observed in wild rodents in North America near San Francisco, California in 1908. The first reported incidence of plague in black-tailed prairie dogs noted in published literature occurred in Texas in 1946. Plague has been in the United States for approximately 100 years and in black-tailed prairie dogs for approximately 50 years, allowing very little time for any resistance to evolve in native wildlife. Some species may act as hosts or carriers of the disease and show little or no symptoms. However, prairie dogs demonstrate nearly 100 percent mortality when exposed to plague and do not develop effective antibodies or immunity to the disease.

Currently plague is widespread throughout 66 percent of the historic range of the black-tailed prairie dog including all of Arizona, Colorado, Montana, New Mexico, Texas, and Wyoming, and portions of Kansas, Nebraska, North Dakota, and Oklahoma. South Dakota is the only State within the range of the species which has not documented plague in black-tailed prairie dogs, although plague antibody titers have been detected in a badger (*Taxidea taxus*), coyote (*Canis latrans*), and red fox (*Vulpes fulva*) collected in the southwestern portion of the state. Major plague epizootics usually occur in the western portion of black-tailed prairie dog range, lesser epizootics occur further east, and positive antibody titers are detected in some mobile species still further east. This implies that the eastern portions of the species' range provide a more secure habitat. However, habitat conversion of rangeland to grassland has occurred in a generally east-to-west progression throughout the species' range and largely precluded the occurrence of the species. If unsuitable lands (e.g., urban areas, cultivated lands, forested areas, etc.) and lands impacted by plague are not considered, approximately 10 percent of the black-tailed prairie dog's historic range is suitable habitat, with South Dakota providing the bulk of plague-free suitable habitat.

Bruce Gill

Plague, once established in an area, becomes persistent and periodically erupts, with the potential to extirpate local black-tailed prairie dog populations. Data from the Rocky Mountain Arsenal National Wildlife Refuge in Colorado, where the impacts of the disease on black-tailed prairie dogs have been carefully studied, illustrates that plague can significantly depress black-tailed prairie dog populations. Several outbreaks have decimated the complex, reducing the amount of occupied habitat by 99 percent on two occasions. Moreover, subsequent population recovery has been only approximately 50 percent of the previous population peak for the two periods of recovery. Black-tailed prairie dog populations may be extirpated on the refuge subsequent to additional epizootics.

Plague outbreaks will probably recur where they have previously occurred. Epizootics in prairie dogs may be sporadic and localized in small colonies, but in large interconnected colonies may affect large areas. However, large colonies may also have a better chance of some recolonization by individuals which escape infection by chance. Small isolated colonies, where populations are not buffered by large numbers and where recovery may be hampered by limited immigration from other colonies, may not recover.

Although there are apparent large numbers of individual black-tailed prairie dogs, the black-tailed prairie dog, as a colonial species occurring in isolated groups, may have difficulty in coping with the challenges of plague and other threats without the advantage of its historic abundance and wide distribution. The appropriate time for successful management intervention to stabilize a colonial species such as the black-tailed prairie dog may be earlier than for some other species. Accordingly, the vulnerability of the species to population reductions may be related less to its absolute numbers across its range than to the number of colonies in which it exists, their size, their geospatial relationship, and

Courtesy of the Centers for Disease Control and Prevention

the number and nature of threats to the species; the most influential of which is the widespread occurrence of plague.

For the purposes of the 12-month finding, plague was considered an imminent threat because it is ongoing. Plague was considered a threat of moderate magnitude because it is not affecting all populations at once and some recovery may occur via unaffected adjacent populations before plague recurs. Plague has impacted the black-tailed prairie dog throughout a significant portion of its range and could spread eastward into the remainder of the black-tailed prairie dog range. If plague epizootics increase in frequency and/or expand into the remainder of the black-tailed prairie dog range, the overall magnitude and immediacy of threats to the species and consequently its listing priority could change. At this time adverse impacts to black-tailed prairie dogs due to plague are largely beyond management control. However, research is being conducted in the hope that findings may be put to practical use regarding improved management of this disease in native wildlife.

Black-Footed Ferret Release Site Monitoring in Shirley Basin, Wyoming

Bob Luce, Wyoming Game and Fish Department, Black-Tailed Prairie Dog Conservation Team, Rock Springs, Wyoming

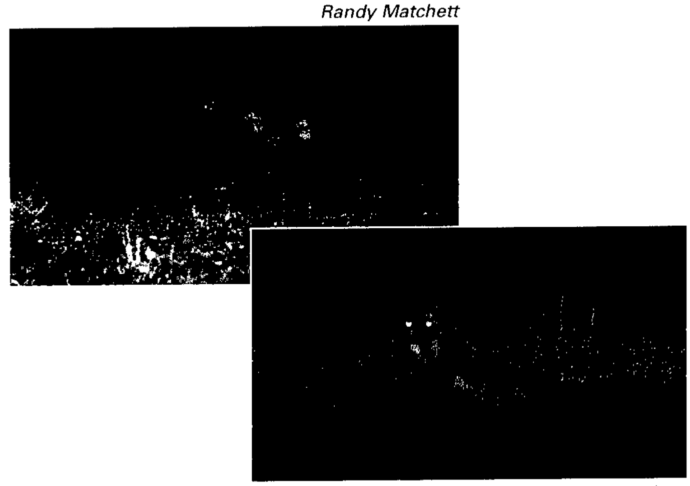
Captive-raised black-footed ferrets (*Mustela nigripes*) were reintroduced in Shirley Basin, Wyoming, from 1991–1994. Two-hundred twenty-eight ferrets were released in a white-tailed prairie dog (*Cynomys leucurus*) complex of approximately 57,510 hectares. On-site monitoring of a portion of the complex (approximately 8,000 hectares) included black-footed ferret spotlight surveys (1991–1996 and 2000); prairie dog population estimation (1991–2000) using the Biggins et al. (1993) model; plague surveillance via collection of dead prairie dogs; and use of blood serology to track seroprevalance of plague and canine distemper in coyotes (*Canis latrans*), badgers (*Taxidea taxus*), and deer mice (*Peromyscus maniculatus*).

During the 10-year project the white-tailed prairie dog population decreased from a high of just over 31,000 prairie dogs to a low of about 7,000, a 78 percent decline (Figure 1). Black-footed ferret releases were terminated in 1994 when the prairie dog population fell below 50 percent of the 1991 base population. Black-footed ferret July spotlight surveys on approximately 8,000 hectares indicated a minimum population of 8 ferrets in both 1995 and 1996, including 1 litter in each year. An August 2000 survey located 15 ferrets including 4 litters. Black-footed ferrets found in 2000 were only in parts of prairie dog colonies with a density greater than the mean for the colony.

Plague was first documented in Shirley Basin in 1986. Data from 1991–2000 indicate presence of plague may be a function of annual precipitation and/or density of rodent populations. The largest number of plague-positive prairie dogs were found in 1991 and 1992 when prairie dog populations were at a 10-year high and May precipitation was above the 9-year average. During 2000, one of the driest years in the last two decades, no plague was detected in either prairie dogs or deer mice.

Persistence of a black-footed ferret population in Shirley Basin since cessation of releases in 1994 is an indication that ferrets can persist in a white-tailed prairie dog complex in which plague is continuously present, at least for the short-term. The prairie dog population level has fluctuated widely between years, affecting the amount of ferret habitat available, but ferrets have survived, apparently by emigrating to areas with a high density of prairie dogs. Since only 8,000 of the 57,510 hectares in the complex were surveyed, the potential exists for presence of a significant population outside of the survey area.

Randy Matchett



Randy Matchett

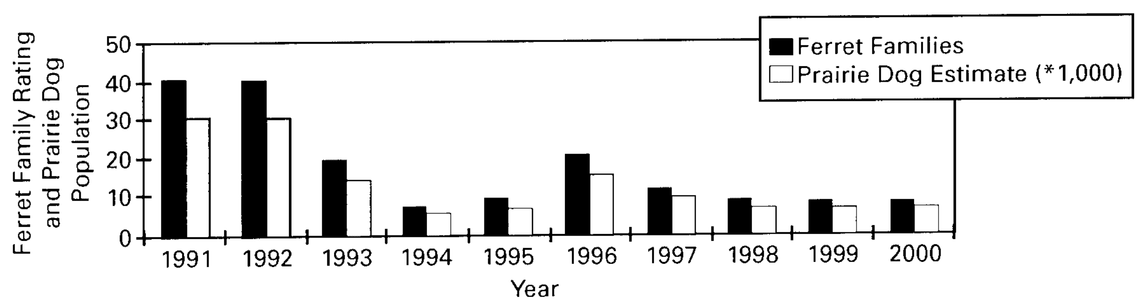


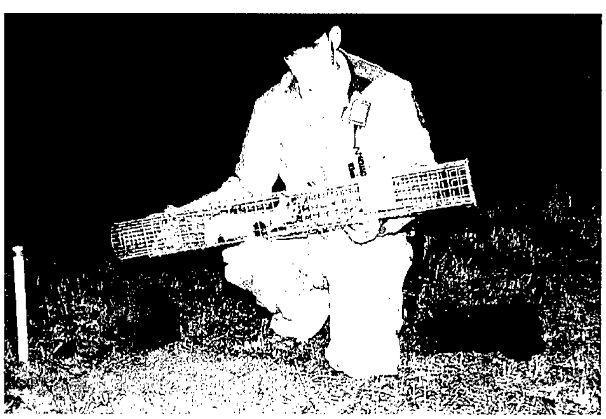
Figure 1. Black-footed ferret family rating and white-tailed prairie dog population in Shirley Basin, Wyoming.

Plague Management During Black-Footed Ferret Reintroductions in Montana

Randy Matchett. U.S. Fish and Wildlife Service, Lewistown, Montana

Black-tailed prairie dog (*Cynomys ludovicianus*) populations and acreage generally increased throughout the 1980's in Phillips and Blaine Counties, north-central Montana. These counties contain the most dense and widespread prairie dog acreage in Montana. Most of the acreage is on the Charles M. Russell National Wildlife Refuge (CMR), Bureau of Land Management (BLM). or the Fort Belknap Reservation (FBR) lands. Approximately 50,000 acres of prairie dogs were present in 1990, mostly interconnected by the "7 km-rule" area used to evaluate black-footed ferret (*Mustela nigripes*) release sites.

Extensive planning was conducted during the early 1990's to develop prairie dog management plans and black-footed ferret reintroduction strategies for the first release targeted for 1993 on CMR. Prairie dog management discussions focused on when, how and to what extent prairie dog control efforts would be applied to stem their expansion. Plague hit in 1992 with the observation of many prairie dog colonies disappearing, including the 1,300-plus acre Manning Corral colony. Despite many attempts, no plague-positive fleas or prairie dogs were collected. Plague was implicated as the cause from the quick and nearly total disappearance of prairie dog colonies and by 85 percent of 53 coyotes (*Canis latrans*) testing positive for plague antibody during January 1993, the first confirmation of plague in Phillips County. Prairie dog colonies continued to disappear through 1996 and hundreds of coyotes collected through helicopter gunning continued to test 70-90 percent antibody-positive for plague. By 1995–96, a low of around 7,200 acres of prairie dogs, outside of FBR, was estimated in Phillips County, down from the estimated high of nearly 29,000 acres in 1990.


Randy Matchett

Black-footed ferrets were released on CMR during 1994 in the UL Bend area in extreme southern Phillips County, which was unaffected by plague and contained roughly 3,000 acres of prairie dogs. A total of 171 kits were released from 1994–1999 and 168 wild-born kits have been observed from 1995–2000. The fall 2000 ferret population at UL Bend was at least 67 (Fig. 1).

The only management action available to attempt protection of prairie dogs and ferrets/habitat is application of insecticide to reduce flea populations. Pyraperm 455 Dust (0.5 percent permethrin) was applied during 1993 to approximately 2,500 acres in the UL Bend area and in BLM's "40-Complex." All of the active ferret reintroduction area at UL Bend was dusted again in 1996 (2,600 acres) in an attempt to protect this budding ferret population. Pyraperm 455 Dust was applied to more than 75,000 burrows across 3,400 acres during 1997. Pyraperm 455 is no longer available, but has been replaced with DeltaDust. A large amount of effort and expense was involved in these dusting efforts designed to keep plague from erasing the even larger investments placed in black-footed ferret recovery in this area.

Fleas were monitored pre- and post-dusting during 1993 and 1996, and as expected and advertised, Pyraperm 455 greatly reduced flea populations, but we have no idea what impact reduced flea populations had on the incidence or spread of plague. Prairie dog and ferret populations have grown steadily at UL Bend, but we cannot conclude dusting prevented plague in this area. As wildlife managers, our logic was that if we could muster the resources to dust, it could only diminish the risk of plague impacting prairie dogs and black-footed ferrets. We did not want to be in the position of not dusting, when it was possible, and then have plague devastate this ferret reintroduction program.

There was, and currently is, considerable controversy over the usefulness of dusting: does it prevent plague? What secondary effects might there be on other insect and bird life (especially for mountain plovers (*Charadrius montanus*) and burrowing owls (*Athene cunicularia*) that nest on prairie dog colonies)? Is it too expensive and impractical to apply to large enough areas to have any meaningful long-term influence? Following similar logic, if development of a plague vaccine for prairie dogs (and other reservoir rodents?) is successful, will the cost, mechanics, and continual need for re-treatments across vast expanses of land be practical or attainable? We need more information on what triggers a plague epizootic, what are the reservoirs/transmission paths and circumstantial conditions, and what factors might we use to predict the location or severity of outbreaks.

Providing for the widest possible distribution and abundance of prairie dogs must be a component of plague management. It seems unlikely that surgical treatments with dusting and/or vaccination programs for plague could treat large enough areas to have any lasting effect on long-term conservation. In my opinion, a large meta-population management strategy (or as Pete Gober calls it "the shell game") with many more prairie dogs in many more places than are currently being discussed in conservation planning has the best chance of providing for the long-term viability of prairie dogs and the associated wildlife that derive part or all of their needs from prairie dog-modified environments.

Randy Matchett

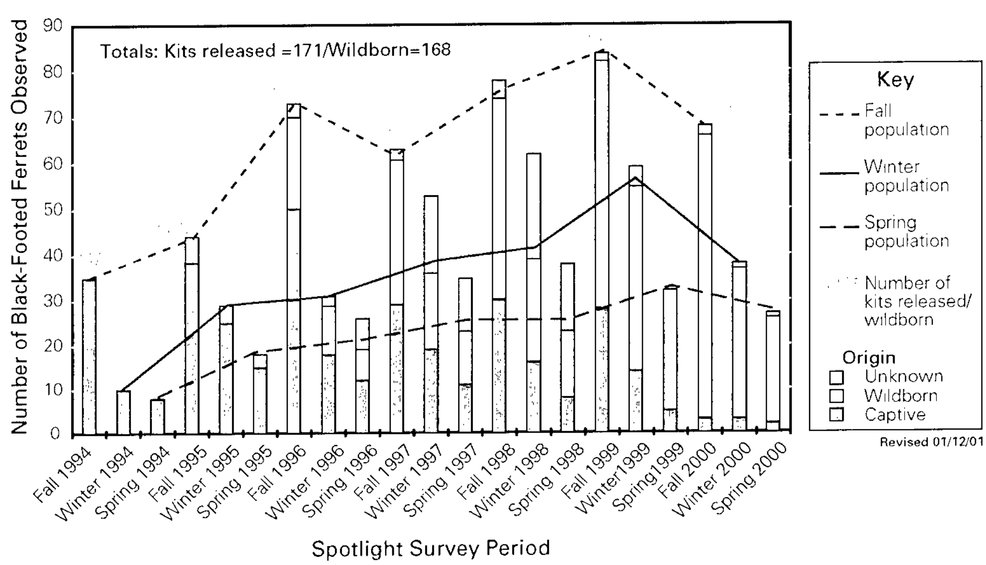


Figure 1. UL Bend National Wildlife Refuge black-footed ferret population, Phillips County, Montana.

Group Discussion and Identification of Research and Information Needs

A group discussion session was held during the afternoon of September 20 to bring out additional questions, observations, and ideas of the participants on issues relating to plague in wildlife. Many of the questions and ideas expressed in this session served as a sounding board and base of information for identification of specific research needs. These needs encompass a broad array of levels of resolution: national to local scales; applied research to basic research; development and testing of diagnostic and control tools; species versus ecosystem focused; sylvatic cycle to zoonotic cycle; information and education; response action plans; and monitoring, surveillance, and reporting. Opportunities to fund and carry out these research needs in the future will be determined to a large extent by the specific mission, focus, and criteria of the funding agency or specific call for proposals, as well as by the time frame and dollar restrictions for various funding sources. One suggestion was made that a single coordinating body for plague be established to 1) track ongoing research and information projects at all levels, 2) to serve as a body to assist researchers in priorities, focus, and targeted funding sources with the various funding agencies/sources; 3) to assist funding agencies/sources in objective review of plague-related proposals; and 4) to facilitate collaboration and coordination among researchers. The following is a non-prioritized list of research and information needs identified during these discussions:

- Burrow ecology
  —prairie dog/other rodent interactions in burrow
  —flea/other rodent interactions
  —other species interactions
  —survival of *Y. pestis* in burrows—soil, carcasses, invertebrates

- Seasonality, abundance, and succession of flea species
  —differential susceptibility of flea species
  —efficiency of different species as vectors of plague
  —flea host range and preference
  —life histories

- Modeling human-induced landscape changes influence on plague ecology (climate, land use, corridors)

- Metapopulation and landscape dynamics of inter-colony transmission

- Comparative studies between plague-free and epizootic and enzootic areas

- Susceptibility studies of various wildlife, particularly prairie dogs
  —standardization of studies: isolate(s), routes, challenge dose, etc.
  —nature of differences in susceptibility

- Comparative ecology and epidemiology of prairie dog species with regard to plague

- Identification of plague reservoir species and reservoir dynamics
  —prairie dog ecosystems and other ecosystems
  —role in epizootics in prairie dogs and other rodents

- Is mortality from plague density-dependent in prairie dog populations? Other rodent populations?

- Historical summary of plague
  —Gage and Kosoy review *in prep.* for Journal of Entomology

- Contingency plans for plague outbreaks
  —include site-specific plans versus general guidelines and standard operating procedures
  —involve land owners as well as land/wildlife managers in planning and operational steps as appropriate
  —ensure cooperation among federal, state, and local agencies through memoranda of agreement and other forms of commitment
  —develop public information and education materials; establish protocols for media/public affairs needs: need a stable information source while meeting agency public affairs-specific needs. Via county public health?
  —address specific diagnostic criteria and sources; identify specific control options; identify equipment/supplies availability; address legal and policy issues
  —specifically develop in-place plans for ferret release sites and for problem urban sites
  —there are no existing contingencies specific for plague outbreaks in place for National Parks and many other public land agencies
  —Contingency plans need to be represented as an "authoritative" voice by participating agencies
  —Contingency plans also needed for occurrence of plague in other rodent or lagomorph species

- Is plague emerging in wildlife?
  —not explosive expansion, but slow increase in humans because of human encroachment
  —historically a public health issue; now becoming a wildlife issue
  —epidemiological data gathering traditionally based on individuals is inadequate to deal with wildlife zoonoses
  —good topic for epidemiological and landscape modelers

- Prairie dog survivors: who are they and what does it mean?
  —have assumed they have "dodged the bullet" and have no more inherent resistance than victims
  —standardized susceptibility testing between populations of a species as well as between species

- Use of prairie dogs as food for captive ferrets

- Molecular epidemiology of plague
  —genotyping of *Y. pestis* from different locations, out breaks, and species
  —analysis of patterns
  —source tracking, implication on reservoirs, interspecies dynamics, and spread of disease

- Role of flea-bite, contact and aerosol transmission in prairie dogs

- Plague vaccination and delivery systems
  —efficacy in various wildlife species, effects on non-targets
  —raccoon-pox vector and F1-V to be tested
  —parallels to rabies recombinant vaccine, future potential, alternative vaccines
  —need for microencapsulation methods
  —selection of vital areas or sites for field trials, such as ferret release sites
  —oral bait distribution system for prairie dogs—density, timing, uptake and response
  —individual vaccination for black-footed ferrets
  —regulatory requirements and considerations

- Long-term studies of plague in prairie dogs
  —selection of study sites
  —epizootic and interepizootic period included
  —impact and recovery studies

- Use of insecticides and insect growth regulators
  —past and current studies
  —non-target species and ecological effects

- Involve Mexico in prairie dog/plague issues
  —complex situation with private landowners and cultural issues
  —include in clearinghouse development and representation

- Role of tularemia and other diseases in prairie dog epizootics
  —tularemia reported in past but not in recent times: are we missing it?
  —criteria for diagnosing cause of epizootics

- Guidance to land managers in addressing prairie dog management and public health and safety with regard to plague in public access areas

- Clearinghouse for plague information and studies
  —up-to-date source of information about epizootics
  —surveillance reporting system
  —other plague-related information
  —include molecular biology, genetic, and ecological information
  —will help identify more specific and detailed questions to answer
  —proposed USGS-BRD/FWS project
  —input required from local, state, and federal agencies, universities, and other research scientists

- "Plague Team" as an advisory group
  —for black-tailed prairie dog team
  —revive black-footed ferret disease committee
  —other listed species teams?

- Convene regular symposium on plague—biannual?

List of Participants

Mike Antolin	Department of Biology Colorado State University Fort Collins CO 80523-1878	(970) 491-1911 Fax: 970-491-0649 antolin@lamar. colostate.edu
Mark Ball	U.S. Forest Service Pawnee National Grassland 660 "O" St. Greeley CO 80631	(970) 353-5004 Fax: 970-346-5014 mball@fs.fed.us
Christopher Brand	U.S. Geological Survey National Wildlife Health Center 6006 Schroeder Rd. Madison WI 53711	(608) 270-2440 Fax: 608-270-2415 christopher_brand@usgs.gov
May Chu	Centers for Disease Control Division of Vector Borne Infectious Diseases P.O. Box 2087 Fort Collins CO 80522	(970) 221-6458 Fax: 970-221-6476 mcc4@cdc.gov
Terry Creekmore	Wyoming Department of Health State Veterinary Laboratory 1174 Snowy Range Rd. Laramie WY 82070	(307) 742-6638 Fax: 307 721-2051 tcreek@state.wy.us
Jack (Buck) Cully	U.S. Geological Survey Kansas Cooperative Fish and Wildlife Research Unit Kansas State University Manhattan KS 66506	(785) 532-6534 bcully@ksu.edu
F. Lee De Cola	U.S. Geological Survey 521 National Center 12201 Sunrise Valley Dr. Reston VA 20192	(703) 648-4178 Fax: 703-648-4165 ldecola@usgs.gov
Donna Dees	Fort Collins Natural Resources Department 281 N. College Fort Collins CO 80524	(970) 416-2133 ddees@ci.fort-collins.co.us
Ken Gage	Centers for Disease Control Division of Vector Borne Infectious Diseases P.O. Box 2087 Fort Collins CO 80522	(970) 221-6450 Fax: 970-221-6476 klg0@cdc.gov
Colin Gillin	Tufts University Center for Conservation Medicine Rocky Mountain Field Office P.O. Box 1330 Wilson WY 734-0595	(307) 734-0595 Fax: 307-734-0596 cagillin@aol.com

Pete Gober	U.S. Fish and Wildlife Service 420 S. Garfield #400 Pierre SD 57001	(605) 224-8693 X 24 pete_gober@fws.gov
Jerry Godbey	U.S. Geological Survey Midcontinent Ecological Science Center 4512 McMurry Ave. Fort Collins CO 80524-3400	(970) 226-9460 X 237 Fax: 970-226-9230 jerry_godbey@usgs.gov
Lianna Hatfield-Etchberger	Uintah Basin Branch Campus Utah State University 1680 West Hwy 40 Vernal UT 84078	(435) 789-6100 Fax: 435-789-3916 liannah@ext.usu.edu
Ryan Kogut	Fort Collins Natural Resources Department 281 N. College Fort Collins CO 80524	(970) 416-2133 ddees@ci.fort-collins.co.us
Michael Kosoy	Centers for Disease Control Division of Vector Borne Infectious Diseases P.O. Box 2087 Fort Collins CO 80522	(970) 221-6404 Fax: 970-221-6476 mck3@cdc.gov
Julie Kreeger	National Black-footed Ferret Conservation Center 2362 Highway 34 Wheatland WY 82201	(307) 322-5933 tkreeger@wyoming.com
Kate Larsen	Wildlife Health Lab Colorado Division of Wildlife 317 W. Prospect Fort Collins CO 80526	(970) 472-4371 Fax: 970-472-4457 kate.larsen@state.co.us
Robert Leachman	U.S. Fish and Wildlife Service 764 Horizon Dr. Grand Junction CO 81506	(970) 245-3920 X 18 Fax: 970-245-6933 robert_leachman@fws.gov
Dan Licht	National Park Service 1709 Jackson St. Omaha NE 68102	(402) 221-3603 dan_licht@nps.gov
Mike Lockhart	U.S. Fish and Wildlife Service 410 E. Grand Ave. Suite 315 Laramie WY 82070	(307) 721-8805 mike_lockhart@fws.gov

Bob Luce	Wyoming Game and Fish Department Black-tailed Prairie Dog Conservation Team 1338 Kimberly Ave. Rock Springs WY 82901	(307) 362-9558 Fax: 307-362-9558 bobluce@wyoming.com
Randy Matchett	U.S. Fish and Wildlife Service C. M. Russel NWR Box 110, Airport Rd. Lewistown MT 59457	(406) 538-8706 X 227 randy_matchett@fws.gov
Jordan Mencher	U.S. Geological Survey National Wildlife Health Center 6006 Schroeder Rd. Madison WI 53711	(608) 270-2478 Fax: 608-270-2415 jordan_mencher@usgs.gov
Ken Morgan	Colorado Farm Bureau P.O. Box 5647 Denver CO 80217	(970) 663-5110 Fax: 303-749-7703 kmorgan@colofb.com
Erin Myers	Wildlife Health Lab Colorado Division of Wildlife 317 W. Prospect Fort Collins CO 80526	(970) 472-4371 Fax: 970-472-4457 erin.myers@state.co.us
John Oldemeyer	General Delivery Silver Gate MT 59081	(406) 838-2431 oldemeye@verinet.com.
Pam Reynolds	New Mexico Environment Department Vector Control 525 Camino de los Marquez Suite 5 Santa Fe NM 87501	(505) 476-8531 Fax: 505-476-8541 pam_reynolds@ nmenv.state.nm.us
Richard Reynolds	U.S. Geological Survey Geologic Division MS980, Box 25046, DFC Denver CO 80225	(303)236-1303 Fax: 303-236-5349 rreynolds@usgs.gov
Tonie Rocke	U.S. Geological Survey National Wildlife Health Center 6006 Schroeder Rd. Madison WI 53711	(608) 270-2451 Fax: 608-270-2415 tonie_rocke@usgs.gov
Tom Roffe	U.S. Geological Survey Central Regional Office FWP Bldg. 1400 S. 19th Ave. Bozeman MT 59718-5496	(406) 994-5789 Fax: 406-994-4090 troffe@montana.edu

David Seery	U.S. Fish and Wildlife Service Rocky Mountain Arsenal National Wildlife Refuge Building 111 Commerce City CO 80022-1748	(303) 289-0232 Fax: 303-289-0597 dseery@rma.army.mil
Bernard Shanks	U.S. Geological Survey 12201 Sunrise Valley Dr. Reston VA 20192	(703) 648-4084 Fax: 703-648-4238 bernard_shanks@usgs.gov
Kimothy Smith	Keim Genetics Lab Department of Biological Sciences Box 5640 Northern Arizona University Flagstaff AZ 86011-5640	(520) 523-4418 X0639 anthraxkls@msn.com
Susan Smith	U.S. Geological Survey National Wildlife Health Center 6006 Schroeder Rd. Madison WI 53711	(608) 270-2453 Fax: 608-270-2415 susan_smith@usgs.gov
Bill Stroh	Bureau of Land Management 170 S. 500 E Vernal UT 84078	(435) 781-4481 Fax: 435-781-4410 bill_stroh@blm.gov
Dan Tripp	Deptartment of Biology Colorado State University Fort Collins CO 80523	(970) 491-2058 dtripp@lamar.colostate.edu
Gary Witmer	USDA/APHIS/WS National Wildlife Research Center 4101 La Porte Ave. Fort Collin, CO 80521-2154	(970) 266-6095 Fax: 970-266-6095 gary.w.witmer@usda.gov
Dallas Virchow	University of Nebraska Room 306B Biochemistry Bldg. Lincoln NE 68583-0759	(402) 472-8961 dvirchow1@unl.edu
Margaret Wild	National Park Service Biological Resources Management Division 1201 Oak Ridge Dr., Suite 200 Fort Collins CO 80525-5589	(970) 225-3593 Fax: 970-225-3585 margaret_wild@nps.gov
Paul Young	Prairie Ecosystems Research Group 11259 Iowa Ave. McGregor IA 52157	pjyoung@netins.net

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