Plague Management Plan

Thunder Basin National Grassland

Accepted

ROBERT ROBERTSON

Digitally signed by ROBERT ROBERTSON
Date: 2023.03.07 14:04:15 -07'00'

Purpose

The Thunder Basin National Grassland 2020 Plan Amendment amended grassland plan direction for the management of black-tailed prairie dog (*Cynomys ludovicianus*) colonies and short-stature vegetation. The amendment created new plan components, a management approach, and glossary definitions to guide management of sylvatic plague (hereafter, "plague"), a non-native bacterial disease vectored by fleas, within prairie dog colonies (see Appendix G and management approach #3). The plan components state that an integrated approach to plague management using tools such as deltamethrin and fipronil will be implemented annually on prairie dog colonies inside of management area 3.67 and may be implemented outside of management area 3.67. An objective for management area 3.67 instructs the responsible official to develop a plague management plan within three years of the approval of the 2020 plan amendment. The management approach describes an integrated approach to plague management and reiterates the objective for development of a plague management plan:

> *The Forest Service will develop a plague management plan for management [area] 3.67 within 3 years of approval of the plan amendment. This plan should be developed based on the best available scientific information and in collaboration with knowledgeable partners including the collaborative stakeholder group. The intent of the plan is to identify the techniques and priorities for plague management and develop an outyear plan for how to use integrated plague management to achieve the desired conditions and acreage objectives for management area 3.67.* (USDA Forest Service 2020a, p. 85)

This document serves as the integrated plague management plan described in the plan components and management approach of the 2020 plan amendment. As described by the management approach, this document outlines information about how available plague management tools can be used in prairie dog colonies in management area 3.67 and elsewhere on the grassland to meet the standard and guideline directing use of an integrated approach to plague management. This document refers to scientific literature throughout and incorporates by reference prior analyses of the best available scientific information contained in effects analysis and other documents associated with the 2020 plan amendment (USDA Forest Service 2019, USDA Forest Service 2020b).

An integrated approach to pest management of Yersinia pestis (i.e., the bacterium that causes plague and is vectored by fleas) is defined as:

> *A process for evaluating and selecting a program from available techniques to reduce pest populations in an ecologically, economically, and socially acceptable manner. Programs may include one or a combination of available techniques: for example, the use of pesticides, cultural or silvicultural treatments, biological control agents, host resistance, genetic control, mechanical destruction or trapping, and behavioral chemicals, including attractants and repellents. An integrated pest management program may involve periods of rest or non-application of pest management techniques.*

> *Integrated pest management encompasses integrated plague management.* (Record of Decision for the 2020 Thunder Basin National Grassland Plan Amendment pp. 80-81)

This document's primary purpose is to provide instructive and flexible guidance to Thunder Basin National Grassland staff and partners to facilitate prioritization of resources, protect selected prairie dog colonies from plague, and provide baseline knowledge of the effects and utility of plague management tools while allowing staff the discretion to respond to the situational challenges of individual applications of plague management. This integrated plague management plan is not regulation or policy, and it does not restrict management. As such, this is a living document that will be updated as new information becomes available.

This integrated plague management plan primarily provides guidance for the use of tools, especially insecticides, already approved by applicable regulatory and management agencies, including the U.S. Environmental Protection Agency and the USDA Forest Service. The plan does not provide guidance for the use of some plague management tools currently under development or that may be developed in the future. We acknowledge, however, that these currently unavailable or unknown tools may prove useful or integral to future plague management efforts, and this document should not restrict the scope of future approaches to plague management.

Background

Plague

Plague is a disease affecting humans and animals, resulting from infection by the bacterium *Yersinia pestis*. Fleas are the primary vector for transmission of *Y. pestis*. The disease is known as sylvatic plague in wildlife (Abbott and Rocke 2012). Sylvatic plague (hereafter, "plague") was introduced into the San Francisco harbor in California around 1900 with the arrival of flea-laden, rat-infested ships from Asia (Adjemian et al. 2007). The entrance of plague into North America caused human deaths but also established the disease in wild rodent populations across the western United States.

On the Thunder Basin National Grassland, plague is typically detected in black-tailed prairie dog (*Cynomys ludovicianus*) colonies because of its high virulence in that species. Plague can transmit rapidly with high mortality rates (up to nearly 100 percent in some cases) among black-tailed prairie dogs in events known as epizootics (Pauli et al. 2006). Plague can also remain active in a location between epizootics with lower transmission rates that do not cause collapse of prairie dog colony populations; this period is known as the enzootic phase (Hanson et al. 2007).

The first detection of plague on the Thunder Basin National Grassland resulted from a plague mortality event in prairie dog colonies on the eastern edge of the grassland that began in 1994 (USDA Forest Service 2002). Plague was not detected in prairie dog colonies in and around the current management area 3.67 until 2001, when an epizootic caused prairie dog colonies across the grassland to decrease in size by approximately 80% (USDA Forest Service 2020b). Since 2001, two additional landscape-scale epizootics have occurred on the Thunder Basin National Grassland, causing declines in prairie dog populations of approximately 66% between 2005 and 2006 and nearly 99% between 2017 and 2018 (USDA Forest Service 2020b). Outside of these landscape-scale epizootics, plague has also been detected in several studies conducted on individual colonies (Thiagarajan et al. 2008) and was presumed to have been actively causing mortality in colonies throughout the period from 2001 until at least 2009, suppressing prairie dog populations across the landscape (USDA Forest Service 2020a).

Plague plays a critical role in prairie dog population dynamics on the Thunder Basin National Grassland, and plague mitigation is important for the conservation of black-tailed prairie dogs and other animal species that are associated with their colonies for habitat or prey in the region (USDA Forest Service 2020b). Prairie dog populations that remain after a plague outbreak are fragmented, susceptible to predation and unpredictable events, and have reduced genetic exchange (Roach et al. 2001; Verdolin and Slobodchikoff 2002; George et al. 2013). Mitigating plague-caused prairie dog mortality is challenging because of the complexity of plague transmission and maintenance in and among colonies (Salkeld et al. 2016). Several variables related to prairie dogs and their fleas, other host and vector populations, and climate and weather affect plague occurrence and transmission in prairie dog colonies (Table 1).

Table 1. A selection of variables affecting plague occurrence and transmission in prairie dog colonies (Barnes 1993, Abbott and Rocke 2012).

Plague *Prior enzootic or epizootic plague occurrence in colony* *Proximity to other epizootic or enzootic plague activity* Prairie dogs *Individual susceptibility and body condition* *Colony population density* *Colony spatial distribution and connectivity* *Inter-colony and inter-coterie movement* *Seasonal period of activity* Prairie dog fleas *Species present* *Population density* *Transmission capability and survival once infected* *Seasonal period of activity*	Other host and vector populations *Other rodent hosts as reservoirs for* Y. pestis *Predators causing inter-colony movement of* Y. pestis *Flea species and population density on other rodents or predators* Abiotic variables *Precipitation* *Temperature* *Burrow microclimate* *Soil characteristics* *Vegetation characteristics as drivers of prairie dog nutrition and movement*

In prairie dog colonies, understanding modes of plague transmission is of particular importance for planning plague mitigation. Individual prairie dog susceptibility to plague is dependent on the magnitude of exposure to *Y. pestis* (Russell et al. 2019). Because exposure is an important determinant of mortality in prairie dogs, the rate of disease transmission likely drives epizootic and enzootic cycling (Russell et al. 2019). Critical factors in disease transmission include vector population dynamics and the movement of the disease among and within colonies. Vector flea populations vary by season, local weather, and climate (Russell et al. 2018). Prairie dog colony spatial distribution may also affect plague transmission across the landscape, with colony isolation by geographic barriers or distances greater than prairie dog dispersal capabilities lessening the risk of epizootics (Savage et al. 2011).

Plague Management Tools

Plague management can occur by monitoring or manipulating one or more of the factors that influence the occurrence and transmission of plague. Common tools used for plague management in prairie dogs include insecticides for the reduction of disease transmission rates and vaccines to decrease susceptibility to infection. Insecticides to control fleas are currently the most common and effective method of preventing plague in prairie dogs (Roth 2019).

Deltamethrin (0.05%; “Delta Dust”) is a pyrethroid insecticide that, when applied according to the label, reduces flea populations in prairie dog colonies. Deltamethrin is typically applied as a dry powder commonly referred to as “dusting.” Deltamethrin kills fleas and other non-target arthropods that contact the insecticide. A meta-analysis of prior studies on the effectiveness of plague management tools showed an approximately 88% reduction in flea populations in prairie dog colonies treated with deltamethrin (Roth 2019). It can suppress fleas for 12 months when applied at a rate of 4-6 grams per prairie dog burrow (Biggins et al. 2010; Eads et al. 2020). Flea populations tend to recover over time after deltamethrin treatment, and annual retreatment is usually necessary for continued suppression of plague transmission (Eads and Biggins 2019). One disadvantage of deltamethrin is that it is a broad-spectrum insecticide that is toxic to a wide range of terrestrial insects (Laufer et al. 1984) . As a result, there is concern that it could also affect insectivorous birds that nest on prairie dog colonies. Negative effects on breeding success of the mountain plover (*Charadrius montanus*) has been documented on prairie dog colonies where deltamethrin was used in Montana (Dinsmore et al. 2013).

Until 2021, Deltamethrin was the only plague management tool used on the Thunder Basin National Grassland. Use of deltamethrin on the grassland began in 2010 and has ranged from treating one colony up to 3,000 acres of colonies (Table 2; USDA Forest Service 2020b). Plague management did not occur on the Thunder Basin National Grassland in 2017-2018 yet resumed again in 2019 to present. In 2017 the District did not apply plague mitigation measures based upon direction from the Regional Forester. In 2018 plague had reduced the prairie dog population to a point that plague mitigation was not expected to be effective.

Table 2. Acres of prairie dog colonies on the Thunder Basin National Grassland treated with plague mitigation tools (deltamethrin and/or fipronil grain)to mitigate transmission of sylvatic plague (USDA Forest Service 2020b).

Year	Acres Plague Mitigation	Acres treated with deltamethrin	Acres Fipronil	Total Acres in MA 3.67
2010	132	132	0	3,489***
2011	1,997	1,997	0	5,600***
2012	780	780	0	10,502**
2013	3,000	3,000	0	14,906 **
2014	2,400	2,400	0	15,508**
2015	1,002	1,002	0	18,212**
2016	25	25	0	24,493 *
2017	0	0	0	24,493*
2018	0	0	0	243
2019	37	37	0	999
2020	158	158	0	3,528
2021	1,409.87	0	1,409.87	6,650
2022	2,000	1,000	1,000	

*** Efforts were combined in 2016 and 2017 to map the outer extent of intact burrows. Due to the level of activity and timing of plague in the area, all colonies mapped during that period were confirmed as active, or as very recently active following the initial occurrence of plague in the region. Islands of inactivity within active colonies were not specifically identified or excluded in those years due to the mapping focus (intact vs. active burrows).**

**** Category 1 under the 2009 Prairie Dog Strategy. Not an exact match with Management area 3.67**

***** Management Area 3.63. Not an exact match with Management area 3.67**

Because fleas can develop some resistance to deltamethrin after 5-6 years of annual treatment, cycling of plague management tools can increase the effectiveness of year-to-year plague management (Eads et al. 2018). Fipronil (0.005%) is currently available as an alternative to deltamethrin. Fipronil is applied as a grain bait for prairie dogs; this systemic insecticide kills fleas that feed on prairie dogs that have consumed the bait. The suppressive effect of fipronil on flea populations has been shown to last at least one year (Eads et al. 2019). There is concern regarding ingestion of fipronil grain by Gallinaceous birds, who are particularly sensitive to the insecticide (Lopez-Antia et al. 2015), thus timing of application must be considered to reduce non-target effects.

The Forest Service began using fipronil on the Thunder Basin National Grassland in 2021. Other insecticides have been used for plague mitigation but are generally less effective, less practical to obtain and apply, or have greater nontarget effects than deltamethrin or fipronil (Roth 2019). Land managers should consider the trade-offs between protecting prairie dogs from plague to retain their keystone effect on the grassland and potential impacts of deltamethrin and fipronil to non-target species. Effects analyses and additional information about applications, costs, and pesticide registration for deltamethrin and fipronil are available in the environmental impact statement for the Thunder Basin National Grassland 2020 Plan Amendment (USDA Forest Service 2020b).

To decrease the susceptibility of prairie dogs to plague, a sylvatic plague vaccine bait was created (Rocke et al. 2017). On average, studies testing the efficacy of vaccines have shown a 4% increase in prairie dog survival rate (Roth 2019), although other studies have not documented measurable treatment effects (Matchett et al. 2021). As of 2021, the Forest Service has not applied plague vaccines on the Thunder Basin National Grassland. Overall, alternating plague mitigation tools may be most effective when combined in an integrated approach to plague management (Tripp et al. 2017).

Monitoring is an important management tool that can guide plague mitigation activities and facilitate adaptive management (Salkeld et al. 2016). Historically, monitoring of plague activity on the Thunder Basin National Grassland has focused exclusively on the size of prairie dog colonies and incidental observation of prairie dog mortality or reduced activity. *Y. pestis* presence has been investigated as needed in response to observed prairie dog mortality through laboratory testing by the State of Wyoming or the United States Centers for Disease Control and Prevention.

Strategy for Integrated Plague Management

This plague management strategy consists of general guidance for the use of insecticidal plague mitigation tools and monitoring of plague activity. An integrated approach to plague management will be implemented annually based on plan components in the grassland plan; the guidance in this plague management strategy; availability of resources; and other situational management considerations. The Forest Service intends that annual identification and prioritization of colonies for plague management occur collaboratively with partner agencies and stakeholders, including the Thunder Basin Working Group. Initial identification of colonies for treatment is important because it may influence later treatments (see strategy item 3 below).

Based on current information about effectiveness, practicality of use, and registration, deltamethrin and fipronil should be the primary tools used to mitigate plague transmission and occurrence on the Thunder Basin National Grassland. However, the use of other insecticides and vaccines should be considered (if available), especially if monitoring information indicates flea resistance to deltamethrin and fipronil, or if future products are shown to have advantages compared to deltamethrin or fipronil. The following is a list of items that should guide an integrated approach to use of these tools:

1. Consistent with other forms of integrated pest management, action and no action (*see* 9) should be taken when and where appropriate following consideration of ecological, economic, and social aspects of plague management.
2. For effective prevention of plague in prairie dogs, it is important to apply insecticides annually in colonies within the plague mitigation emphasis areas identified as priorities by the Forest Service. Because fleas can develop resistance to deltamethrin after 5-6 years of annual application, products should be alternated on colonies. For example, a colony could receive a rotation of 3 consecutive years of deltamethrin application, followed by 1 year of fipronil application. The best approach to preventing flea resistance may in some cases involve non-application of insecticides for 1 or more years (see item 3).
3. Treatments should be repeated based on the duration of their effects (for deltamethrin and fipronil, this is typically 12 months. For example, colonies treated with deltamethrin or fipronil should be prioritized for treatment the following year.
4. In management area 3.67, treated colonies should be distributed among pastures and across natural barriers to facilitate prairie dog population resilience if plague causes reductions in colony size below grassland plan objectives and desired conditions. For

example, initial plague mitigation efforts could be distributed in colonies located north and south of the Cheyenne River in management area 3.67.

5. Selection of areas for plague mitigation should take into account proximity to state and private lands, as well as designated buffer zones. Plague mitigation treatments could be prioritized in locations that are central to the “plague mitigation emphasis” areas identified by the Forest Service and distant from buffer zones where prairie dog population control will occur.
6. To maintain the 10,000-acre objective for prairie dog colonies in management area 3.67, plague mitigation tools may be used during the same years that prairie dog control tools are used.
7. Focus application of deltamethrin during the summer (June-September) to coincide with periods of high flea activity and apply fipronil during late summer-early fall (September-October) to maximize bait uptake by prairie dogs and avoid uptake by Gallinaceous birds using prairie dog colonies in the spring.
8. The Forest Service will coordinate with the grazing permittees prior to application of fipronil grain. Grazing schedules change annually and proposed grazing timing in management area 3.67 is available by the end of April of each year. It should be noted that grazing schedules can change in response to drought conditions or other grazing needs so actual use should be confirmed closer to the prairie dog management activities if using grain-based products. Fipronil grain is only applied according to label and treatments will be monitored for consumption before allowing livestock to graze in the treatment area.
9. No action is considered as: “An integrated pest management program may involve periods of rest or non-application of pest management techniques. Integrated pest management encompasses integrated plague management.” (Record of Decision for the 2020 Thunder Basin National Grassland Plan Amendment, pp. 80-81)
10. No plague mitigation treatment will occur inside a designated or approved temporary (Record of Decision pp 73) boundary management zone.

Applicators are required to keep treatment records including location, date and time, rate and application methods, products used including EPA registration number, brand name and total amount used, weather conditions including temperature and wind should be tracked, and results of treatment should be monitored. Applicators shall make these records available to the Forest Service in addition to costs associated with the treatments. Geospatial data regarding changes in size of treated and non-treated colonies across the grassland should be used to inform subsequent treatments. To detect plague as early as possible, whenever Forest Service staff or partners observe or receive reports of unusual prairie dog mortality or reduced prairie dog activity, the location of the unusual activity should be investigated for further signs of plague, and testing for *Y. pestis* through appropriate partner agencies should occur if plague is suspected. If possible, the Forest Service and partners should develop protocols for monitoring additional variables that may be predictive of epizootics (e.g. - flea abundance and/or carnivore seroprevalence surveys) to help plan and prioritize treatments.

In the case of a known epizootic, the Forest Service should work with local governments and state and federal public health agencies to implement measures to ensure the health and safety of all grassland users and residents.

Annual Work Plan and Budget (Years 2022-2026)

Table 3. Anticipated prairie dog plague mitigation targets in the "plague mitigation emphasis" areas of Thunder Basin National Grassland's management area 3.67 during 2022-2026.

Year	Acreage Target	Colony Numbers	Treatment Type (deltamethrin and/or fipronil)	Cost
2022	2,000 acres	(Same colonies as in 2021)	1,000 acres of deltamethrin, 1,000 acres of fipronil grain	
2023				
2024				
2025				
2026				

Monitoring plan

Table 4. Current and proposed monitoring activities related to prairie dog plague mitigation. Some activities could co-occur with annual prairie dog colony mapping or other wildlife surveys.

Species	Purpose	Metric	Method (current)	Timing
Prairie dog	Monitoring	Colony area	USFS and TBGPEA partnership, conducted by Great Plains Consulting (contact Gwyn McKee)	Annually
Prairie dog	Research	Burrow density	Research in localized areas, Lauren Porensky and David Augustine (ARS), Courtney Duchardt (OSU)	2017-2024
Prairie dog	Research	Adult/pup density	Research in localized areas, Lauren Porensky and David Augustine (ARS), Courtney Duchardt (OSU)	2021-2024

Burrowing owl, swift fox, mountain plover	Monitoring	Presence/absence	USFS transects	Annually?
Mountain plover, Burrowing owl, Ferruginous Hawk, Golden eagle	Research	Abundance	Long term point counts in 3.67 (Duchardt, OSU)	2015 - foreseeable future
Mesocarnivore and ungulate	Research	Occupancy	Camera traps, mainly in 3.67 (Augustine, Porensky, Davidson, Duchardt)	2022-2025?
Sage grouse	Monitoring	Lek attendance	State lek counts	Annually
Galliformes (sage grouse) and other birds	Proposed research	Interaction w/ grain bait	Camera traps	???

References

Abbott, R. C., and T. E. Rocke. 2012. Plague. U.S. Geological Survey Circular 1372. United States Department of the Interior, Geological Survey. Reston, VA, USA. 79 p.

Adjemian, J. Z., P. Foley, K. L. Gage, and J. E. Foley. 2007. Initiation and spread of traveling waves of plague, Yersinia pestis, in the western United States. American Journal of Tropical Medicine 76(2): 365–75. pmid:17297050.

Barnes, A. 1993. A review of plague and its relevance to prairie dog populations and the black-footed ferret. Proceedings of the Symposium on the Management of Prairie Dog Complexes for the Reintroduction of the Black-footed Ferret. Biological Report 13, pp. 28-37. United States Department of the Interior, Fish and Wildlife Service. Washington, DC, USA.

Biggins, D.E., J.L. Godbey, K.L. Gage, L.G. Carter, and J.A. Montenieri. 2010. Vector control improves survival of three species of prairie dogs (Cynomys) in areas considered enzootic for plague. Vector-Borne Zoonotic Diseases 10: 17-26.

Eads, D. A., D. E. Biggins, J. Bowser, J. C. McAllister, R. L. Griebel, E. Childers, T. M. Livieri, C. Painter, L. Sterling Krank, and K. Bly. 2018. Resistance to deltamethrin in prairie dog (*Cynomys ludovicianus*) fleas in the field and in the laboratory. Journal of Wildlife Diseases 54(4):745-754. https://doi.org/10.7589/2017-10-250

Eads, D. A., and D. E. Biggins. 2019. Plague management of prairie dog colonies: degree and duration of deltamethrin flea control. Journal of Vector Ecology 44(1): 40-47. https://doi.org/10.1111/jvec.12327

Eads, D. A., D. E. Biggins, J. Bowser, K. Broerman, T. M. Livieri, E. Childers, P. Dobesh, and R. L. Griebel. 2019. Evaluation of five pulicides to suppress fleas on black-tailed prairie dogs: encouraging long-term results with systemic 0.005% fipronil. Vector-borne and Zoonotic Diseases 19(6): 400-406. https://doi.org/10.1089/vbz.2018.2339

Eads, D.A., A.C. Yashin, L.E. Noble, M.C. Vasquez,M.H.J. Huang,T.M. Livieri, P.Dobesh, E.Childers, and D.E. Biggins. 2020. Managing plague on prairie dog colonies: insecticides as ectoparasiticides. Journal of Vector Ecology 45(1): 82-88.

George, D. B., C. T. Webb CT, K. M. Pepin, L. T. Savage, and M. F. Antolin. 2013. Persistence of black-tailed prairie-dog populations affected by plague in northern Colorado, USA. Ecology 94(7):1572–83. pmid:23951717.

Hanson, D. A., H. B. Britten, M. Restani, and L. R. Washburn. 2007. High prevalence of *Yersinia pestis* in black-tailed prairie dog colonies during an apparent enzootic phase of sylvatic plague. *Conservation Genetics* 8(4):789-795.

Laufer J, Roche M., Pelhate M, Elliott M, Janes NF, and Sattelle D. 1984. Pyrethroid insecticides: Actions of deltamethrin and related compounds on insect axonal sodium channels. Journal of Insect Physiology 30(5):341-349.

Lopez-Antia A, Ortiz-Santaliestra ME, Camarero PR, Mougeot F, Mateo R. 2015. Assessing the Risk of Fipronil-Treated Seed Ingestion and Associated Adverse Effects in the Red-Legged Partridge. Environ Sci Technol. 49(22):13649-57.

Matchett, M.R., T.R. Stanley, M.F. McCollister, D.A. Eads, J.T. Boulerice, and D.E. Biggins. 2021. Oral sylvatic plague vaccine does not adequately protect prairie dogs (*Cynomys* spp.) for endangered black-footed ferret (*Mustela nigripes*) conservation. Vector-Borne and Zoonotic Diseases 21: 921-940.

Pauli, J. N., S. W. Buskirk, E. S. Williams, and W. H. Edwards. 2006. A plague epizootic in the black-tailed prairie dog (*Cynomys ludovicianus*). Journal of Wildlife Diseases 42(1):74–80. https://doi.org/10.7589/0090-3558-42.1.74

Roach, J.L., P. Stapp, B. Van Horne, and M. F. Antolin. 2001. Genetic structure of a metapopulation of black-tailed prairie dogs. Journal of Mammalogy 82(4):946–59.

Rocke T. E., D. W. Tripp, R. E. Russell, R. C. Abbott, K. L. D. Richgels, M. R. Matchett, D. E. Biggins, R. Griebel, G. Schroder, S. M. Grassel, D. R. Pipkin, J. Cordova, A. Kavalunas, B. Maxfield, J. Boulerice, and M. W. Miller. 2017. Sylvatic plague vaccine partially protects prairie dogs (*Cynomys* spp.) in field trials. EcoHealth 14(3): 438-450. https://doi.org/10.1007/s10393-017-1253-x

Roth, J. D. 2019. Sylvatic plague management and prairie dogs – a meta-analysis. Journal of Vector Ecology 44(1): 1-10. https://doi.org/10.1111/jvec.12323

Russell, R. E., D. W. Tripp, and T. E. Rocke. 2019. Differential plague susceptibility in species and populations of prairie dogs. Ecology and Evolution 9:11962-11971. https://doi.org/10.1002/ece3.5684

Russell, R. E., R. C. Abbott, D. W. Tripp, and T. E. Rocke. 2018. Local factors associated with on-host flea distributions on prairie dog colonies. *Ecology and Evolution* 8(17):8951-8972. https://doi.org/10.1002/ece3.4390

Salkeld, D. J., P. Stapp, D. W. Tripp, K. L. Gage, J. Lowell, C. T. Webb, R. J. Brinkerhoff, and M. F. Antolin. 2016. Ecological traits driving the outbreaks and emergence of zoonotic pathogens. BioScience 66(2):118-129. https://doi.org/10.1093/biosci/biv179

Savage, L. T., R. M. Reich, L. M. Hartley, P. Stapp, and M. F. Antolin. 2011. Climate, soils, and connectivity predict plague epizootics in black-tailed prairie dogs (*Cynomys ludovicianus*). *Ecological Applications* 21(8):2933-2943. https://doi.org/10.1890/10-1946.1

Thiagarajan, B., Y. Bai, K. L. Gage, and J. F. Cully, Jr. 2008. Prevalence of Yersinia pestis in rodents and fleas associated with black-tailed prairie dogs (*Cynomys ludovicianus*) at Thunder Basin National Grassland, Wyoming. *Journal of Wildlife Diseases* 44(3):731-736. https://doi.org/10.7589/0090-3558-44.3.731

Tripp, D. W., T. E. Rocke, J. P. Runge, R. C. Abbott, and M. W. Miller. 2017. Burrow dusting or oral vaccination prevents plague-associated prairie dog colony collapse. EcoHealth 14:451-462. https://doi.org/10.1007/s10393-017-1236-y

USDA Forest Service. 2002. Supplemental information report to the proposed northern Great Plains plans revision final environmental impact statement and 2001 revision Thunder Basin National Grasslands plan disclosing changes to black-tailed prairie dog habitat within proposed management area 3.63 of the Thunder Basin National Grassland plan resulting from 2001 sylvatic plague outbreak. Medicine Bow-Routt National Forests and Thunder Basin National Grassland, United States Department of Agriculture, Forest Service. Laramie, WY, USA. Available online: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5166459.pdf.

USDA Forest Service 2019. Preliminary list of potential species of conservation concern species evaluations for the Thunder Basin National Grassland [revised May 2020]. Medicine Bow-Routt National Forests and Thunder Basin National Grassland, United States Department of Agriculture, Forest Service. Laramie, WY, USA. Available at: https://www.fs.usda.gov/nfs/11558/www/nepa/110862_FSPLT3_5295753.pdf.

USDA Forest Service. 2020a. Record of decision, Thunder Basin National Grassland 2020 plan amendment. Medicine Bow-Routt National Forests and Thunder Basin National Grassland, United States Department of Agriculture, Forest Service. Laramie, WY, USA. Available online: https://www.fs.usda.gov/nfs/11558/www/nepa/110862_FSPLT3_5538534.pdf.

USDA Forest Service. 2020b. Thunder Basin National Grassland 2020 plan amendment final environmental impact statement. Medicine Bow-Routt National Forests and Thunder Basin National Grassland, United States Department of Agriculture, Forest Service. Laramie, WY, USA. Available online: https://www.fs.usda.gov/project/?project=55479.

Verdolin J. L., and C. N. Slobodchikoff. 2002. Vigilance and predation risk in Gunnison's prairie dogs (*Cynomys gunnisoni*). *Canadian Journal of Zoology* 80(7):1197–203.

Appendix A

Grassland plan direction for plague management in the Thunder Basin National Grassland 2020 Plan Amendment

The plan amendment added following guideline to chapter 1 of the grassland plan as grassland-wide direction:

> *GPA-FW-FWRP-GL-02: An integrated approach to plague management (e.g., using tools such as deltamethrin and fipronil) may be implemented to mitigate the transmission of sylvatic plague. Guideline* (USDA Forest Service 2020a, p. 45)

The plan amendment added the following objective and standard to chapter 3 of the grassland plan as direction for management area 3.67:

> *GPA-MA3.67-FWRP-O-08: Develop a plague management plan within 3 years of 2020 plan amendment approval. Objective* (USDA Forest Service 2020a, p. 71)

> *GPA-MA3.67-FWRP-ST-18: An integrated approach to plague management (e.g., using tools such as deltamethrin and fipronil) will be implemented annually. Standard* (USDA Forest Service 2020a, p. 74)

The plan amendment added the following glossary definitions for integrated pest management, integrated plague management, and prairie dog conservation tools to appendix G of the grassland plan:

> ***Integrated Pest Management (IPM)*** *– A process for evaluating and selecting a program from available techniques to reduce pest populations in an ecologically, economically, and socially acceptable manner. Programs may include one or a combination of available techniques: for example, the use of pesticides, cultural or silvicultural treatments, biological control agents, host resistance, genetic control, mechanical destruction or trapping, and behavioral chemicals, including attractants and repellants. An integrated pest management program may involve periods of rest or non-application of pest management techniques. Integrated pest management encompasses integrated plague management.* (USDA Forest Service 2020a, pp. 80-81)

> ***Integrated Plague Management*** *– See Integrated Pest Management (IPM).* (USDA Forest Service 2020a, p. 81)

> ***Prairie Dog Conservation Tools*** *– Actions used to promote the growth or prevent the reduction of prairie dog colonies. Tools may include but are not limited to: translocation of prairie dogs; plague mitigation tools, such as deltamethrin and fipronil; restrictions on recreational shooting; and vegetation management, including prescribed fire.* (USDA Forest Service 2020a, p. 81)

The record of decision for the plan amendment adopted the following management approach for sylvatic plague management:

> *Sylvatic plague (Yersinia pestis) was first detected on the Thunder Basin National Grassland in the mid-1990s, and the first landscape-scale plague epizootic among the black-tailed prairie dog population began in 2001. Since that time, plague has likely been continuously active in prairie dog colonies on the Grassland. Two subsequent landscape-scale epizootics began in 2005 and 2017.*
>
> *Plague dynamics in prairie dog colonies are not well understood, especially the mechanisms for enzootic and epizootic phases of plague in a location after it first enters a colony. Several management tools to minimize the transmission of plague can help reduce the likelihood of epizootics, including insecticides to control vector flea populations and vaccines for prairie dogs and other susceptible species.*
>
> *An integrated approach to plague management (e.g., using tools such as deltamethrin and fipronil) will be implemented annually in management area 3.67 and may be implemented outside of management area 3.67. Consistent with other forms of integrated pest management, this does not mean that action must be taken every year, but that action will be taken when and where it is determined to be appropriate following consideration of many aspects of plague management. For example, fleas can develop resistance to insecticides such as deltamethrin or fipronil, and an integrated approach to plague management may include alternating application of these products on a specific colony or not applying insecticides to a colony for 1 or more years. Plague mitigation tools may be used during the same years that control tools are used to maintain the 10,000-acre objective for prairie dog colonies in management area 3.67.*
>
> *The Forest Service will develop a plague management plan for management area 3.67 within 3 years of approval of the plan amendment. This plan should be developed based on the best available scientific information and in collaboration with knowledgeable partners including the collaborative stakeholder group. The intent of the plan is to identify the techniques and priorities for plague management and develop an outyear plan for how to use integrated plague management to achieve the desired conditions and acreage objectives for management area 3.67.* (USDA Forest Service 2020a, pp. 84-85)