Gunnison's & White-Tailed Prairie Dog

Statewide Conservation Planning Workshop

Final Report

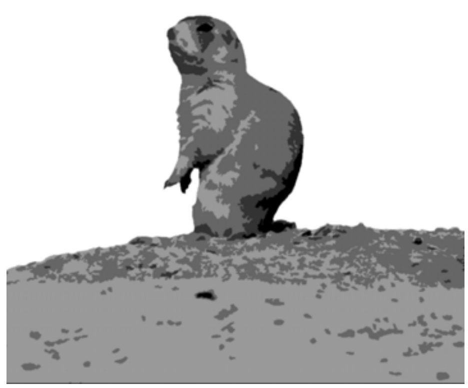
16-18 May 2007
Grand Junction, CO

White-Tailed and Gunnison's Prairie Dogs in Colorado
Statewide Conservation Planning Workshop

16 – 18 May, 2007
Grand Junction, Colorado

Workshop Design and Facilitation:
IUCN / SSC Conservation Breeding Specialist Group

Workshop Organization:
Colorado Division of Wildlife,
Department of Natural Resources



WORKSHOP REPORT

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A contribution of the IUCN/SSC Conservation Breeding Specialist Group, in collaboration with the Colorado Division of Wildlife / Department of Natural Resources.

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White-Tailed and Gunnison's Prairie Dogs in Colorado Statewide Conservation Planning Workshop

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White-Tailed and Gunnison's Prairie Dogs in Colorado
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Executive Summary

Introduction

Concern over the long-term viability of Gunnison's and white-tailed prairie dog populations resulted in a petition to list the species under the Endangered Species Act in 2004. The petition cited habitat loss/conversion, shooting, disease, a history of eradication efforts, and inadequate federal and state regulatory mechanisms as threats to the long-term viability of the species. A Conservation Strategy and Plan (Western Association of Fish and Wildlife Agencies [WAFWA] 2006) for both the Gunnison's and the white-tailed prairie dog was completed that provided management and administrative guidelines to assist in the development of state management plans for 2 prairie dog species and associated ecosystems. Actions under the Conservation Strategy and Conservation Plan were designed to: 1) promote conservation of the species and its habitat; 2) reduce threats to populations due to commercial, recreational, scientific, or educational purposes; 3) identify specific research needs; 4) examine existing regulatory mechanisms and their ability to maintain populations; 5) reduce the risk of factors negatively impacting populations such as plague; and 6) increase landowner participation in prairie dog conservation efforts.

To help the Colorado Division of Wildlife (CDOW) meet the objectives outlined in the WAFWA Conservation Strategy and Plan, the Conservation Breeding Specialist Group (CBSG) of IUCN-The World Conservation Union's Species Survival Commission was invited by CDOW to design and conduct a set of workshops to produce a population viability analysis (PVA) and a set of draft conservation strategies for Gunnison's and white-tailed prairie dogs in Colorado. The product of this effort, known as a Population and Habitat Viability Assessment or PHVA, consists of a detailed action plan for future management of the species and selected elements of their habitat within Colorado that can serve as an important component of the statewide conservation plan. This interactive, participatory workshop is designed to broaden stakeholder involvement and enhance information sharing across scientific, social, and economic groups/interests.

For more than three months before the PHVA workshop, CBSG conducted a PVA in collaboration with a variety of State and Federal prairie dog biologists and conservation agency representatives. This analysis consists of a computer simulation that incorporates our knowledge of the biology and ecology of the species – rates of reproduction and survival, population structure, habitat requirements, etc. – and projects the relative performance of prairie dog populations under alternative scenarios of management or lack thereof. Using these alternative projections of population performance, typically described as relative rates of population growth or decline, species managers and interested stakeholders can determine the most effective practices to minimize the risk of extinction of the two prairie dog species in Colorado.

The PHVA workshop was organized and hosted by the Colorado Division of Wildlife in early May 2007. Participants in the workshop represented a wide variety of stakeholder domains, including academic and tribal biologists, wildlife managers, habitat management experts, legislative representatives, and other interested parties. The general goals of the workshop were to assist stakeholders to: 1) use a demographic simulation model (PVA) to guide and evaluate species management and research activities; 2) formulate priorities for a practical management program for long-term survival of the species in a fragmented environment; and 3) promote effective collaborations between stakeholder domains that foster conservation of Gunnison's and white-tailed prairie dog habitat while accommodating responsible economic development in the region.

The Workshop Process

The PHVA workshop began on 16 May 2007, with approximately fifty-five participants gathered together at the Country Inn conference facilities in downtown Grand Junction, Colorado. After a brief set of opening remarks by Dr. Tom Nesler, Wildlife Conservation Statewide Manager for Colorado Division of Wildlife, each participant was then asked to introduce themselves and to share with the group their personal goal for the workshop, and to give the group their opinion of the greatest challenge to sustainable management of Gunnison's and white-tailed prairie dogs across the state. Common themes expressed during this session revolved around the difficulties of aligning species conservation strategies with agricultural development in the state – particularly when the focal species are routinely seen by the state's residents as pests. Drs. Pam Schnurr and Amy Seglund from CO Division of Wildlife then gave brief presentations on the history of statewide conservation planning for these species, and summarized our knowledge of the species' basic biology. Dr. Philip Miller, the workshop facilitator from CBSG, introduced the PHVA workshop philosophy and the role of population modeling in the decision-making process; this led into a more detailed presentation on the structure and results of the PVA, conducted before this workshop as a way to inform the biological aspects of prairie dog viability as it relates to long-term species management.

Based on detailed discussions during the workshop planning stages, a total of six working group topics were identified that would form the basis of the meeting's subsequent activities:

- Range Condition, Livestock and Predation
- Agriculture and Poisoning
- Oil and Gas Development
- Plague and Drought
- Shooting
- Urbanization

All workshop participants were invited to choose which group they wanted to join. Through this process of self-selection, workshop participants were provided with the opportunity to contribute their information and perspective in the most effective way.

In the afternoon of the workshop's first day, the working groups began moving through a set of structured tasks set forth by the workshop facilitator. First, each group was asked to amplify those relevant issues / challenge statements identified earlier, to identify new challenges of importance to their specific topic, and to prioritize them according to an agreed criterion. The groups were then brought together as a larger group, and each working group shared their information and was able to provide commentary and perspective with their peers. This process of working group sessions, followed by plenary reports and discussion, continued throughout the workshop.

Once issues were identified and prioritized, the participants met in plenary on the morning of workshop Day 2 to review the collective body of knowledge around the primary activities that may impact prairie dog population viability. Throughout this process, the group placed an emphasis on separating known facts from assumptions, identifying the important justifications around each assumption, and (perhaps most importantly) flagging areas where potentially important information is missing. Through this process, the subsequent identification of management and / or research priorities was greatly enhanced.

Once information assembly was complete, each working group was asked to brainstorm, refine and prioritize objectives specifically designed to address the issues identified previously. Each group brought their top five priority objectives to a plenary session on the afternoon of workshop Day 2, and the entire group was then asked to provide an overall sense of priority for these objectives based on the importance of achieving them for successful management of Gunnison's and white-tailed prairie dogs. This task was accomplished by giving each participant five colored adhesive dots and asking them to distribute those dots amongst those objectives they see as most important to resolve. Since these objectives are directly tied to the issues identified in the early stages of the workshop, the workshop design facilitates the resolution of the needs of the diverse stakeholder domains that are present.

With objectives in hand, each working group then began the task of identifying specific strategies that would achieve those objectives. These strategies are intended to include important details such as the individual responsible for moving the strategy forward, a timeline for completion of the strategy, important collaborators, and specific obstacles to be overcome if the strategy is to be completed. With this level of detail, those agencies responsible for managing and recovering the species have a valuable set of comprehensive recommendations that can be used to guide future actions.

Workshop Results

<u>Population Viability Analysis</u>

The PVA analysis was conducted using the popular software package *VORTEX*, developed by CBSG for use in the larger conservation planning community. The modeling effort was specifically designed to (*i*) determine those aspects of prairie dog demography that are primary factors in driving population growth; (*ii*) evaluate known current threats (specifically plague, shooting, and poisoning) for their severity in the context of species extinction risk; and (*iii*) investigate the efficacy of alternative management options for the two species in Colorado, including mitigation of plague outbreaks through burrow dusting activities.

Demographic sensitivity analysis indicates that the growth of Gunnison and white-tailed prairie dog populations is highly sensitive to juvenile female mortality as well as to adult female reproductive success (i.e., number of adult females successfully weaning a litter of pups). These results suggest that focusing more intense ecological research on these aspects of prairie dog biology can lead to more accurate demographic analyses. Moreover, management recommendations where appropriate that target these aspects of the species' biology are expected to have the greatest positive impact on long-term population viability.

Current simulations (and field observations) indicate that prairie dog populations, if free from natural or anthropogenic stressors, can show strong demographic dynamics. This greatly reduces the risk of extinction for even the smallest populations on the landscape. However, plague epidemic events are a major threat to the future survival of prairie dog populations in Colorado, particularly in combination with other stressors such as drought that can be present on the landscape. Our models indicate that the frequency of such events is a critical factor in determining the long-term impacts. What seems like a relatively modest reduction in the severity of plague epidemics, effected through flea dusting practices, can lead to a dramatic reduction in the long-term impacts of epidemics.

Other potentially threatening activities – namely, shooting and poisoning – were studied through the PVA process. Lower rates of shooting-based mortality appear to be sustainable in otherwise demographically robust (i.e., plague-free) prairie dog populations. However, populations appear to become less stable when shooting is practiced during the primary reproductive period when pup production would be compromised. These results effectively confirm the utility of imposing a seasonal closure on shooting in the spring, when reproductive activity is at its peak. Additionally, current poisoning practices greatly reduce the long-term survival of even the largest prairie dog towns. This reduction in viability is, as expected, more acute when poisoning is implemented more frequently.

Overall, results from this PVA analysis suggest that management practices currently proposed for prairie dogs – activities such as flea dusting among prairie dog burrows, seasonal shooting closures, and restrictions in the geographic extent of poison use – can have measurable positive impacts on the long-term viability of prairie dog populations. Careful consideration of both the extent and the scope of selected management options must occur so that conservation of an important prairie resource in Colorado can be achieved within an atmosphere of social, political and cultural acceptance.

Objectives for Prairie Dog Management in Colorado

Shown below is a prioritized list of the top objectives identified by each working group, presented in a plenary session on Day 2 of the workshop and then evaluated independently by the entire body of participants. Each workshop participant prioritized the objectives based on their perception of the value of an objective in contributing to a Conservation Strategy that will provide for prairie dog population viability in a socially supportive environment

1. Develop effective management techniques to ensure large-scale prairie dog population resilience in the presence of plague
2. Develop a prioritized, collaborative prairie dog research program that addresses key conservation practices to include (i) "healthy" prairie dog populations, (ii) interactions between livestock grazing and prairie dog populations, (iii) prairie dog distribution across land ownership classes, (iv) relationship between fire ecology and prairie dog population ecology.
3. Improve our understanding of the epidemiology and dynamics of plague in prairie dog communities.
4. Minimize habitat loss and degradation in the context of oil and gas development.
5. Conserve the functional integrity of the ecosystem in order to sustain all of the dependent components in the context of oil and gas development.
6. Develop an incentive plan for private landowners to maintain an appropriate population of prairie dogs in priority areas as part of a functioning agricultural / range business operation.
7. Maintain sustainable prairie dog populations while providing for recreational shooting opportunities.
8. Develop demonstration projects showing the nature of the relationship between current grazing management practices and healthy prairie dog habitat.
9. Maintain connectivity between prairie dog colonies to the maximum extent possible in the context of oil and gas development.
10. Develop adaptive prairie dog best management practices that utilize the best available information in the context of oil and gas development.
11. Develop and/or implement appropriate surveillance and monitoring strategies to (i) facilitate further research and analysis of plague dynamics; (ii) facilitate immediate management of plague outbreaks.
12. Develop improved communication between livestock industry representatives and natural resource management agencies in order to more effectively discuss the relationship between grazing management and prairie dog population ecology.
13. Minimize future habitat loss and fragmentation through urbanization within prairie dog occupied range in parcels of 10 - 40 acres.
14. Collect data related to oil and gas impacts on prairie dogs and their ecosystems.
15. Determine appropriate jurisdictional boundaries where poisons can be used.
16. Improve public understanding of prairie dog population biology and the impacts of shooting.
17. Develop an understanding of prairie dog population recovery dynamics after plague outbreaks.
18. Develop scale-appropriate analytical methods when assessing ecosystem condition. Refocus on existing protocols and work with appropriate agencies to accomplish this.
19. Determine feasibility and efficacy of, and implement techniques to assist in, prairie dog population recovery after plague outbreaks.
20. Develop better tracking protocols for use of poisons in prairie dog habitats.
21. Improve our understanding of how agricultural conversion affects prairie dog population biology and ecology.

22. Increase educational and awareness activities on prairie dog biology and disease issues for landowners with parcels of 10 - 40 acres.
23. Minimize the impacts of agricultural practices on local prairie dog communities.
24. Preserve and enhance recreational shooting opportunities and resultant economic benefits.
25. Develop better education programs for the proper use of prairie dog poisons.
26. Collect information on the impacts of shooting on prairie dog population biology and ecology.
27. Continue to allow shooting as a prairie dog control method.
28. Create new policies for more effective prairie dog habitat management in urban areas (10 - 40 acres).
29. Develop a rationale to support the decisions on appropriate jurisdictions for poison use.
30. Increase educational and awareness activities on prairie dog biology and disease issues in areas that are not suitable for prairie dogs (< 10 acres).
31. Integrate decisions on where to use poisons with the broad stakeholder community.
32. Minimize habitat fragmentation resulting from agricultural conversion.
33. Minimize the impacts of prairie dog communities on local agricultural practices.
34. Reduce predation from domestic and wild species on prairie dogs in parcels between 10 and 40 acres.

It is particularly noteworthy to observe the emphasis that workshop participants placed on the management and increased understanding of plague and its impacts on Gunnison’s and white-tailed prairie dog populations in Colorado. In addition, the explicit integration of prairie dog population management with critical economic activities on the landscape – as embodied in Objectives 2, 4, 5, and 6 – represents an important bridge between stakeholder interests that is a defining characteristic of the PHVA workshop process.

The strategies constructed by each working group, tied to the objectives they specified in their own deliberations (and, where appropriate, for those objectives classified as high priority overall in plenary), are to be found in each of the individual working group reports within this document.

By combining the use of rigorous scientific analysis of biological data with thoughtful and structured discussion of the needs of diverse stakeholder domains, this PHVA workshop was a valuable tool for natural resource management priority-setting in Colorado. Those involved in its organization and implementation hope that it will serve as a model for other responsible threatened species conservation planning efforts in the region.

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II
Population Viability Analysis

Population Viability Analysis for the Gunnison's Prairie Dog (*Cynomys gunnisoni*) and White-tailed Prairie Dog (*Cynomys leucurus*) in Colorado

DRAFT REPORT

Report prepared by:
Philip S. Miller
IUCN / SSC Conservation Breeding Specialist Group

In collaboration with

Members of the
Gunnison's and White-tailed Prairie Dog
Conservation Plan Steering Committee

Population Viability Analysis for Gunnison's Prairie Dog (*Cynomys gunnisoni*) and White-tailed Prairie Dog (*Cynomys leucurus*) in Colorado

Philip Miller, Conservation Breeding Specialist Group
and
Gunnison's and White-tailed Prairie Dog Conservation Plan Steering Committee Members

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Philip Miller, Conservation Breeding Specialist Group
and
Gunnison's and White-tailed Prairie Dog Conservation Plan Steering Committee Members

Introduction

Concern over the long-term viability of Gunnison's and white-tailed prairie dog populations across the state of Colorado stem from their apparent decline in numbers and distribution due predominantly to plague and a lesser extent to historic overgrazing by livestock, poisoning campaigns, conversion of lands to agriculture, urban development, and recreational shooting. The development of a State Conservation Plan for Colorado is part of a range-wide effort identified in the Western Association of Fish and Wildlife Agencies Final Prairie Grasslands Memorandum of Understanding. The purpose of the State Conservation Plan will be to: 1) promote conservation of both species and their habitats; 2) identify specific research needs; 3) examine existing regulatory mechanisms and their ability to maintain viable populations; 4) reduce the risk of factors negatively impacting populations; and 5) increase stakeholder participation in prairie dog conservation efforts. Given these goals for the State Plan, a quantitative analysis of prairie dog population dynamics, particularly in the context of those processes seen as potentially threatening to the species' long-term persistence, is an important component of the larger natural resource management decision-making process.

Population viability analysis, or PVA, can be an extremely useful tool for investigating current and future risk of Gunnison's and white-tailed prairie dog population decline or extinction. The need for and consequences of alternative management strategies can be modeled to suggest which practices may be the most effective in conserving prairie dog populations in its wild habitat. *VORTEX*, a simulation software package written for population viability analysis, was used here as a vehicle to study the interaction of a number of prairie dog life history and population parameters, to explore which demographic parameters may be the most sensitive to alternative management practices, and to test the effects of selected management scenarios.

The *VORTEX* package is a simulation of the effects of a number of different natural and human-mediated forces – some, by definition, acting unpredictably from year to year – on the health and integrity of wildlife populations. *VORTEX* models population dynamics as discrete sequential events (e.g., births, deaths, sex ratios among offspring, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or random variables that follow specified distributions. The package simulates a population by recreating the essential series of events that describe the typical life cycles of sexually reproducing organisms.

PVA methodologies such as the *VORTEX* system are not intended to give absolute and accurate "answers" for what the future will bring for a given wildlife species or population. This limitation arises simply from two fundamental facts about the natural world: it is inherently unpredictable in its detailed behavior; and we will never fully understand its precise mechanics. Consequently, many researchers have cautioned against the exclusive use of absolute results from a PVA in order to promote specific management actions for threatened populations (e.g., Ludwig 1999; Beissinger and McCullough 2002; Reed et al. 2002; Ellner et al. 2002; Lotts et al. 2004). Instead, the true value of an analysis of this type lies in the assembly and critical analysis of the available information on the species and its ecology, and in the ability to compare the quantitative metrics of population performance that emerge from a suite of simulations, with each simulation representing a specific scenario and its inherent assumptions about the available data and a proposed method of population and/or landscape management. Interpretation of this type of output depends strongly upon our knowledge of prairie dog biology in its habitat, the environmental conditions affecting the species, and possible future changes in these conditions.

The *VORTEX* system for conducting population viability analysis is a flexible and accessible tool that can be adapted to a wide variety of species types and life histories as the situation warrants. The program has been used around the world in both teaching and research applications and is a trusted method for assisting in the definition of practical wildlife management methodologies. For a more detailed explanation of *VORTEX* and its use in population viability analysis, refer to Appendix I, Lacy (2000) and Miller and Lacy (2003).

Specifically, we were interested in using this preliminary analysis to address the following questions:

- Can we build a series of simulation models with sufficient detail and precision that describe the dynamics of Gunnison's and white-tailed prairie dog populations across Colorado with reasonable accuracy?
- What are the primary demographic factors that drive growth of Gunnison's and white-tailed prairie dog populations?
- How vulnerable are small, fragmented populations of Gunnison's and white-tailed prairie dog in Colorado to extinction under current management conditions? How small must a population become to increase its risk of extinction to an unacceptable level?
- What are the predicted impacts of plague on Gunnison's and white-tailed prairie dog populations in Colorado?
- What are the predicted impacts of current shooting practices on Gunnison's and white-tailed prairie dog populations in Colorado?
- What are the predicted long-term impacts of poisoning practices on Gunnison's and white-tailed prairie dog populations in Colorado?
- Can we devise reasonable management practices to reduce predicted impacts of these activities on Gunnison's and white-tailed prairie dog populations in Colorado?

Baseline Input Parameters for Stochastic Population Viability Simulations

In developing appropriate input datasets for our stochastic simulation models, we referred primarily to the fieldwork reported in Hoogland (2001, 2007), Cully (1997) and Biggins (Pers. Comm.), with additional data coming from Colorado Division of Wildlife (CDOW) data on prairie dog biology and human activities around the state. Other specific studies used as justification for input are given below.

<u>Breeding System</u>: Female prairie dogs are sexually receptive for a single day during the breeding season each year (Hoogland 1999, pers. Comm.) and will mate with up to 5 males (Hoogland 1998). Females copulate with multiple males to maximize reproductive success and promote genetic diversity among

litter mates. The probability of pregnancy and parturition in GPDs was 92% for females that copulated with 1 or 2 males, as compared to 100% for females that copulated with at least 3 males (Hoogland 1998). In addition, litter size was found to vary directly with the number of female's sexual partners (Hoogland 1998). The frequency of multiple paternities can be as high as 77% (Haynie et al. 2003).

For the PVA we employed a polygynous mating system in all our models since we were unable to modify the breeding system as a function of population density. We predict that this will not have significant demographic impacts on the population compared to a more complex model of density-dependent breeding strategies.

Age of First Reproduction: *VORTEX* considers the age of first reproduction as the age at which the first the female produces young not simply the onset of sexual maturity. Females of both species of prairie dogs can begin breeding as yearlings and produce young (i.e., one year of age). Age of first reproduction for male Gunnison's prairie dogs is variable, and appears to depend on the number of older, breeding males in the population (Rayor 1985, 1988; Hoogland 1996). About 50% of white-tailed males breed at one year of age, but the other 50% do not breed until they are two years old (Hoogland 2007 and references therein). We used one year of age as the first age or reproduction for both males and females.

Age of Reproductive Senescence: In its simplest form, *VORTEX* assumes that animals can reproduce (at the normal rate) throughout their adult life. Both prairie dog species have been documented to live to 5 – 6 years of age, although very few individuals actually survive that long. We have set the maximum breeding age at five years of age, with no discernible reduction in breeding tendency (i.e., no reproductive senescence).

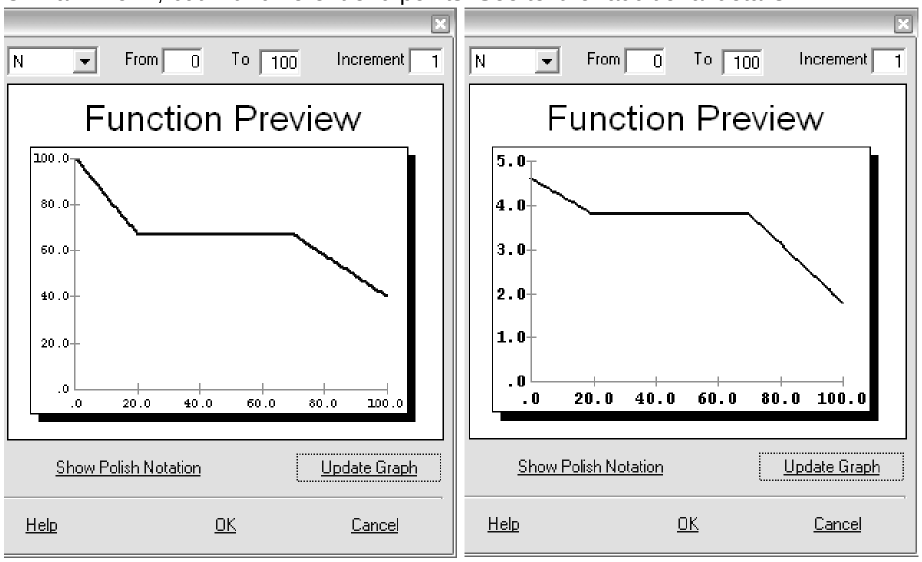
Offspring Production: Because of the difficulty in directly observing litters immediately after birth, we defined "reproduction" for our purposes here as the production of weaned litters. With this definition, we modified data from Hoogland (2001, 2007) and Cully (1997) to account for observations of higher reproductive output at low prairie dog densities. Specifically, we used species-specific parameters to define the percentage of adult female prairie dogs that successfully wean litters in the average year, as a function of density (defined here as the ratio of population size *N* to carrying capacity *K*):

Table 1. Density-dependent reproductive parameters used in prairie dog simulation models. See text for additional information.

	Population Density		
Species	Low (N/K = 0.0)	Medium (0.2 < N/K < 0.7)	High (N/K = 1.0)
	Adult females weaning a litter (%)		
Gunnison's	100	82	40
White-tailed	100	67	40
	Mean litter size at weaning		
Gunnison's	4.6	3.8	1.8
White-tailed	6.0	5.47	2.8

Furthermore, we assumed that as population density increases, the percentage of adult females that wean a litter in a given year will decrease linearly as in Figure 1 below.

Figure 1. Graphical representations for percentage of adult females weaning a litter (left) and mean litter size at weaning (right) for simulated Gunnison's prairie dog populations. Functions for white-tailed reproductive performance are qualitatively similar in form, but with different end points. See text for additional details.



Based on these data, we observe that female Gunnison's prairie dogs are expected to produce smaller litters at weaning more frequently, while white-tailed females produce larger litters at weaning less frequently. The comparative impact of these differences is not immediately apparent and will have to await explicit analysis.

Annual environmental variation in female reproductive success is modeled in *VORTEX* by specifying a standard deviation (SD) for the proportion of adult females that successfully wean a litter within a given year. Data from Hoogland (1998, 2001, Pers. Comm. 2007) indicate a significant level of variability in this parameter. We specified that the standard deviation in the percentage of adult females weaning a litter is 15%, while the standard deviation around the mean litter size at weaning was set at 2.0.

Male Breeding Pool: In many species, some adult males may be socially restricted from breeding despite being physiologically capable. This can be modeled in *VORTEX* by specifying a portion of the total pool of adult males that may be considered "available" for breeding each year. While specific data from the field on this parameter are lacking, we assume that all males of reproductive age are equally capable of breeding with an adult female.

Mortality: *VORTEX* defines mortality as the annual rate of age-specific death from year x to $x + 1$; in the language of life-table analysis, this is equivalent to $q(x)$.

For both species, data from Hoogland (2001) indicate that survivorship of juveniles is consistently <50%. In order to develop mortality rates for sub-adult and adult age classes, we assumed two alternative mortality schedules indicative of sylvatic plague (and perhaps other diseases) acting as either enzootic or non-enzootic in the system (Table 2). In an enzootic scenario, plague operates at a relatively low level each year, thereby increasing average annual rates of mortality above a more benign non-enzootic scenario where disease does not play a major role in determining these long-term rates. These alternative mortality schedules grew out of lengthy discussions among species experts with differing views of the causes of significantly different survivorship rates between Gunnison's and Utah prairie dogs reported in Hoogland (2001).

Table 2. Age-specific prairie dog annual mortality rates under alternative conditions of enzootic or non-enzootic sylvatic plague. See text for additional details.

Age Class	% Mortality (SD)			
	Gunnison's		White-tailed	
	Females	Males	Females	Males
Non-Enzootic				
0 – 1	52.0 (10.0)	55.0 (10.0)	52.0 (10.0)	55.0 (10.0)
1 – 2	33.0 (5.0)	35.5 (5.0)	33.0 (5.0)	35.5 (5.0)
2 – 3	31.0 (5.0)	48.0 (5.0)	31.0 (5.0)	48.0 (5.0)
3 – 4	13.5 (5.0)	60.0 (5.0)	13.5 (5.0)	60.0 (5.0)
4 – 5	100.0	100.0	100.0	100.0
Enzootic				
0 – 1	52.0 (10.0)	55.0 (10.0)	52.0 (10.0)	55.0 (10.0)
1 – 2	66.0 (5.0)	74.0 (5.0)	66.0 (5.0)	74.0 (5.0)
2 – 3	66.0 (5.0)	60.0 (5.0)	66.0 (5.0)	60.0 (5.0)
3 – 4	60.0 (5.0)	50.0 (5.0)	60.0 (5.0)	50.0 (5.0)
4 – 5	100.0	100.0	100.0	100.0

Inbreeding Depression: *VORTEX* includes the ability to model the detrimental effects of inbreeding, most directly through reduced survival of offspring through their first year. There are no direct data on rates of inbreeding in wild populations of Gunnison's or white-tailed prairie dogs, nor the impacts on demographic rates if it were to occur. Hoogland (1982) postulates that inbreeding is actively avoided among black-tailed prairie dogs. Consequently, we did not include inbreeding effects in this analysis.

Catastrophic Plague Epidemics: In addition to our assumptions about the enzootic nature of sylvatic plague in Colorado prairie dog populations, we included periodic plague epidemics that could have potentially very severe demographic impacts. Catastrophes are singular environmental events that are outside the bounds of normal environmental variation affecting reproduction and/or survival. Natural catastrophes can be tornadoes, floods, droughts, disease, or similar events. These events are modeled in *VORTEX* by assigning an annual probability of occurrence and a pair of severity factors describing their impact on mortality (across all age-sex classes) and the proportion of females successfully breeding in a given year. These factors range from 0.0 (maximum or absolute effect) to 1.0 (no effect), and in the most basic implementation, are imposed during the single year of the catastrophe, after which time the demographic rates rebound to their baseline values.

We assumed that plague epidemics would occur at intervals of 5, 10, or 15 years (equivalent to annual probabilities of occurrence of 0.20, 0.10, or 0.0667). Moreover, we simulated two different levels of severity for a given epidemic, with either 92% (range: 89% – 95%) or 99% (range: 98.5% – 99.5%) of the total population killed by the epidemic. The variability in plague severity was accomplished by writing simple functions in *VORTEX* that included normal distributions around the specified mean severity.

Finally, an additional set of models was developed in which we assumed a specific level of plague management in a given prairie dog colony. This management takes the form of dusting the colonies with chemicals that reduce the numbers of fleas in the colony and, hence, the rate of transmission of the infectious agent among prairie dogs. The efficacy of this dusting was simulated through a reduction of the severity of a given epidemic down to 80% (range: 77% – 83%) in the year that an epidemic was deemed to occur.

Initial Population Size: Our initial baseline simulation models were initialized with a total of 10,000 individuals. As *VORTEX* is constructed assuming an immediate pre-breeding census, all individuals comprising the initial population are at least one year of age. Subsequent models, designed explicitly to investigate the effects of small population size on extinction risk, were initialized with between 25 and 3000 individuals. *VORTEX* distributes the specified initial population among age-sex classes according to a stable age distribution that is characteristic of the mortality and reproductive schedules described previously.

It is important to recognize that the populations simulated here do not correspond to specific known colonies or complexes of Gunnison's or white-tailed prairie dogs in Colorado. In addition, we are focusing our analyses on individual populations (colonies or demographically well-connected complexes) and not on the species as entire entities across the state.

Carrying Capacity: The carrying capacity, K, for a given habitat patch defines an upper limit for the population size, above which additional mortality is imposed randomly across all age classes in order to return the population to the value set for K.

The estimation of a carrying capacity is a very difficult process. The approach taken in this analysis was to assume that most prairie dog populations are not at their long-term ecological carrying capacity and therefore have the opportunity for growth (or decline) from one year to the next. Therefore, we assumed for all models in this analysis that carrying capacity was equivalent to twice the initial population size for a given scenario.

Iterations and Years of Projection: All population projections (scenarios) were simulated 500 times. Each projection extends to 50 years, with demographic information obtained at annual intervals. All simulations were conducted using *VORTEX* version 9.70 (March 2007).

Simulating the Impacts of Human Activity on Gunnison's and White-tailed Prairie Dog Population Dynamics

Once the baseline demographic parameters were established, additional work was directed to determining the mechanisms through which specific human activities within prairie dog habitat may influence the two species' population dynamics into the future. The two primary activities investigated here were shooting and poisoning. Each individual activity is discussed in detail below.

Shooting

We simulated four different levels of shooting-based mortality across all age classes of white-tailed and Gunnison's prairie dog. Specifically, we assumed that 5%, 10%, 15% or 20% mortality is imposed across all age-sex classes in addition to the baseline mortality rates discussed above.

We also investigated the impact of removing the current seasonal closure rules, in effect 1 March – 14 June. The seasonal closure serves to protect population reproduction because higher mortality in pregnant females and those with dependent young will also result in fewer successful females. Thus, under the seasonal closure scenario, mortality increases but reproduction is not affected. To simulate the removal of the seasonal closure, we imposed the same simulated additions to mortality while also decreasing the percentage of adult females that successfully wean a litter. This is because shooting during the current closure season will lead to removal of pregnant females and those dependent young that lose their mother during this time if she is removed from the population. In particular, we assume that 80% of the shooting mortality occurs during the time period of 1 March to 14 June; therefore, the reduction in the percentage of successful females is 80% of the specified increase in shooting mortality. For example, if shooting imposes an additional 10% increase in mortality, then there would be an 8% reduction in the percentage of adult females weaning a litter.

In deriving these values for additional shooting-based mortality, we are not making explicit statements about the extent to which this mortality is additive or compensatory. Our only concern is the total increase in mortality above that which would be expected in the absence of such activity.

Poisoning
The application of various poisons throughout the state can be an effective means of prairie dog population control. Information presented by experts in the field indicate that baited poisons were 75-85% effective while fumigants could be as high as 95%. We simulated the use of these poisons by eliminating a total of 85% of a given simulated prairie dog population in the year of poison application. We also assumed that these poisons were used at two different frequencies: either every three years or every five years. In the intervening years between poison application, demographic rates were assumed to be normal (baseline levels).

Definitions of Simulation Modeling Results

Results reported for selected modeling scenarios include:

$\underline{r_s}$ (SD) – The mean rate of stochastic population growth or decline (standard deviation) demonstrated by the simulated populations, averaged across years and iterations, for all simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity.

$\underline{P(E)_{50}}$ – Probability of population extinction after 50 years, determined by the proportion of 500 iterations within that given scenario that have gone extinct within the given time frame. “Extinction” is specifically defined here in our *VORTEX* model as the absence of either sex.

$\underline{N_{50}}$ (SD) – Mean (standard deviation) population size at the end of the simulation, averaged across all simulated populations, including those that are extinct.

$\underline{GD_{50}}$ – The gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity.

Baseline Model Projections

Table 3 gives the summary results from the four baseline models representing the different demographic profiles (combinations of differential reproductive output and mortality rates) discussed in the preceding section. Note that all four scenarios – from the “most optimistic” non-enzootic white-tailed model to the “least optimistic” enzootic Gunnison’s model – show rather robust population growth dynamics. More specifically, the white-tailed reproductive profile leads to higher growth rates – suggesting that the higher frequency of weaning litters, even if those litters are smaller on average than those of Gunnison’s prairie dogs, leads to more vigorous population growth. Moreover, as expected, scenarios including higher mortality from enzootic plague show lower growth rates than those where plague mortality is absent.

A representative trajectory for a single iteration of the enzootic white-tailed model is shown in Figure 2. Variability in growth rate over the timeframe of the simulation, producing short-term fluctuations in population size of as much as 50%, seems to be realistic when compared to field census data for actual prairie dog colonies or complexes (Seglund et al. 2005, 2006). As a result, we feel comfortable that these four baseline models are good starting points for realistic examinations of future risks among Gunnison's and white-tailed prairie dog populations in the face of human activities that may impact species persistence.

Table 3. Colorado prairie dog PVA. Mean demographic performance across 500 iterations for fifty-year baseline model projections for each demographic profile. "Non-Enzootic" and "Enzootic" refer to alternative mortality schedules in the absence or presence of enzootic sylvatic plague, respectively, while "White-Tailed" and "Gunnison's" denote alternative descriptions of reproductive performance. Initial size of each population is 10,000 and carrying capacity is 20,000. See text for additional information on model construction and definitions of result metrics.

Scenario	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
Non-Enzootic White-Tailed	0.084 (0.199)	0.000	19,001 (1519)	0.999
Non-Enzootic Gunnison's	0.039 (0.203)	0.000	18,096 (1871)	0.999
Enzootic White-Tailed	0.055 (0.272)	0.000	17,666 (2537)	0.998
Enzootic Gunnison's	0.026 (0.274)	0.000	16,679 (2766)	0.998

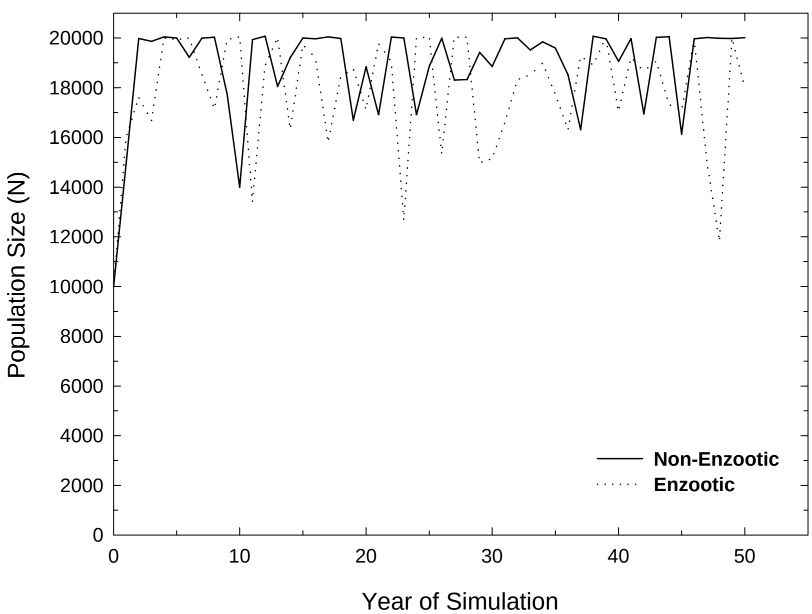


Figure 2. Representative 50-year trajectories for simulated white-tailed prairie dog populations in the presence and absence of enzootic disease (plague) mortality. Note the smaller extent of variation in population size when enzootic plague is absent. Variation in population size through time in any single iteration, and average growth rate over many iterations of this dataset, are considered to be realistic in their portrayal of prairie dog population dynamics.

Demographic Sensitivity Analysis

During the development of the baseline input dataset, it quickly became apparent that a number of demographic characteristics of Gunnison's and white-tailed prairie dog populations were being estimated with varying levels of uncertainty. This type of measurement uncertainty, which is distinctly different from the annual variability in demographic rates due to extrinsic environmental stochasticity and other factors, impairs our ability to generate precise predictions of population dynamics with any degree of confidence. Nevertheless, an analysis of the sensitivity of our models to this measurement uncertainty can be an invaluable aid in identifying priorities for detailed research and/or management projects targeting specific elements of the species' population biology and ecology. To conduct this demographic sensitivity analysis, we identified a selected set of input parameters whose estimates we see as considerably uncertain. We then develop proportional minimum and maximum values for these parameters (see Table 4).

For each of these parameters we construct two simulations, with a given parameter set at its prescribed minimum or maximum value, with all other parameters remaining at their baseline value. With the six parameters identified above, and recognizing that the aggregate set of baseline values constitute our single baseline model, the table above allows us to construct a total of twelve additional, alternative models whose performance (defined, for example, in terms of average population growth rate) can be compared to that of our starting baseline model.

For the entire suite of sensitivity analysis models, we will consider a generic population of 5,000 individuals and a carrying capacity of 10,000 individuals. This population is large enough to be relatively immune from excessive demographic uncertainty that is characteristic of small populations. Furthermore, carrying capacity is large enough to allow for significant population growth and to observe proper demographic dynamics.

The proportional sensitivity of a given simulation model, S, is given by

$$S = [(\lambda_{Min} - \lambda_{Max}) / (0.2 * \lambda_{Base})]$$

Where $\lambda = e^r$ is the annual rate of population growth calculated from the simulation and subscripts *Min*, *Max* and *Base* refer to simulations that include the minimum, maximum, and baseline values of the appropriate parameter, respectively. Using this formulation, model parameters with large S values show strong differences in λ when values are manipulated (modified from Heppell et al., 2000).

Table 4. Uncertain input parameters and their stated ranges for use in demographic sensitivity analysis for a simulated white-tailed prairie dog population under baseline conditions of enzootic disease (plague) mortality. Parameter estimates for mean litter size and % adult females weaning a litter are designated for high / medium / low density conditions, while adult mortality estimates are given for specific age classes, specifically 1-2 year olds / 2-3 year olds / 3-4 year olds. Highlighted rows indicate those demographic parameters that show the highest sensitivity, *S*, as listed in the far right-hand column of the table (absolute values are used in parameter ranking). Stochastic population growth rates for each simulation are not reported here for brevity but are available from the author. See accompanying text for more information.

	Parameter Estimate			
Model Parameter	Minimum	Baseline	Maximum	*S*
% Female Juvenile Mortality	46.8	52.0	57.2	0.155084
Mean Litter Size	5.4 / 4.92 / 2.5	6 / 5.47 / 2.8	6.6 / 6.02 / 3.1	-0.09505
% Adult Females Weaning a Litter	100 / 60.3 / 36	100 / 67 / 40	11 / 73.7 / 44	-0.08008
% Adult Female Mortality	59.4 / 59.4 / 54	66 / 66 / 60	72.6 / 72.6 / 66	0.06006
% Adult Male Mortality	49.5	55.0	60.5	0.025013
% Juvenile Male Mortality	66.6 / 54 / 45	74 / 60 / 50	81.4 / 66 / 55	0.00000

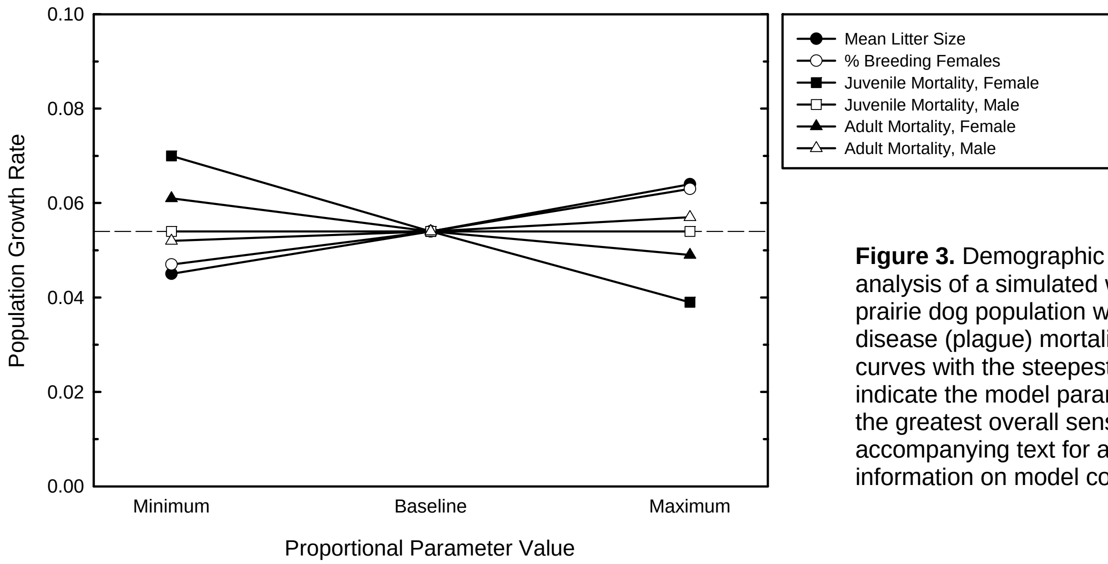


Figure 3. Demographic sensitivity analysis of a simulated white-tailed prairie dog population with enzootic disease (plague) mortality. Those curves with the steepest slope indicate the model parameters with the greatest overall sensitivity. See accompanying text for additional information on model construction.

The results of the sensitivity analysis are shown in tabular form in Table 4 and graphically in Figure 3. Those lines with the steepest slope – specifically, juvenile female mortality, mean litter size, and adult female breeding (weaning) frequency – show the greatest degree of response in terms of population growth rate to changes in those parameters and, hence, the greatest sensitivity. These parameters can then be targeted in subsequent field activities for more detailed research and / or demographic management.

Table 6. Colorado prairie dog PVA. Output from risk analysis models with different initial population sizes under the enzootic Gunnison's demographic profile. Results for the three additional demographic profile model sets are not shown here, largely because the growth dynamics are even more robust than those presented here. See text for additional information on model construction and output metrics.

Initial Population Size	r_s (SD)	PE_{50}	N_{50} (SD)	GD_{50}
25	0.034 (0.324)	0.006	40 (9)	0.4748
50	0.031 (0.302)	0.000	80 (16)	0.6981
75	0.029 (0.291)	0.000	123 (24)	0.7918
100	0.028 (0.285)	0.000	163 (29)	0.8408
250	0.026 (0.275)	0.000	410 (72)	0.9324
500	0.026 (0.274)	0.000	818 (144)	0.9658
750	0.026 (0.274)	0.000	1229 (204)	0.9770
1000	0.025 (0.273)	0.000	1626 (285)	0.9827
2000	0.026 (0.273)	0.000	3305 (554)	0.9914
3000	0.025 (0.271)	0.000	4970 (824)	0.9942

Risk Analysis I: Impacts of Population Size on Gunnison's and White-Tailed Prairie Dog Population Dynamics

Our results of this analysis, in which population size was varied across a range of 25 to 3000 individuals for each of the four baseline demographic profiles, indicate that Gunnison's and white-tailed prairie dog populations have the capacity for robust population growth in the absence of significant demographic disturbance from either natural or anthropogenic events. For brevity, Table 6 shows results from only one of the four demographic profile model sets: enzootic Gunnison's demographics, the "least optimistic" of the four profiles in terms of population growth potential. Even here, all population growth rates are strong and, with the exception of the smallest population that shows only a very small risk, there is no risk of population extinction among the scenarios.

Despite this negligible risk, it is perhaps worthwhile to note that the smaller populations – in particular, those of no more than approximately 100 individuals – show rather high rates of loss of genetic diversity during the course of the 50-year simulation. While inbreeding and its potential deleterious effects have not been included in this model, there remains the possibility that such low levels of genetic variability in these small populations may lead to longer-term problems for populations that may otherwise show little or no demographic shortcomings in the short-term.

With this set of models as a background, our remaining analyses focus on various natural and anthropogenic processes – specifically, sylvatic plague epidemic, shooting and poisoning – that may compromise the long-term growth potential of Gunnison's and white-tailed prairie dog populations in Colorado.

Risk Analysis II: Impacts of Plague Epidemics on Gunnison's and White-Tailed Prairie Dog Population Dynamics

Our investigation of plague epidemics begins with a method of sensitivity analysis very similar to that discussed in more detail previously. In particular, we constructed a comparative analysis of the sensitivity of our models to variation in either the frequency of the epidemic or the severity of the event. The parameter estimates are given in Table 5, and the graphical results of this analysis are shown in Figure 4.

Table 5. Uncertain plague epidemic input parameters and their stated ranges for use in demographic sensitivity analysis for a simulated white-tailed prairie dog population under baseline conditions of enzootic disease (plague) mortality. Highlighted row indicates the demographic parameter with the highest sensitivity, *S*, as listed in the far right-hand column of the table (absolute values are used in parameter ranking). Stochastic population growth rates for each simulation are not reported here for brevity but are available from the author. See accompanying text for more information.

	Parameter Estimate			
Model Parameter	Minimum	Baseline	Maximum	*S*
Epidemic frequency (annual probability)	0.055	0.067	0.080	0.050
Epidemic severity (multiplicative factor)	0.120	0.100	0.080	-0.020

These results indicate that our baseline simulation models are relatively more sensitive to changes in the frequency of plague epidemics in comparison to a similar proportional change in the severity of the same type of event. An increase in the frequency of plague epidemic leads to a reduced ability of the population to demographically rebound following the event. In contrast, if the epidemic is relatively infrequent but more severe the population – if not rendered extinct outright from the epidemic itself – will retain the capacity to rebound rather strongly from the event. This is even more probable given the fact that our models include an increased reproductive output at lower population densities. This feature of the model likely leads to a comparatively more robust prairie dog population at lower densities. But even this advantage can not easily be overcome when catastrophic plague epidemics repeatedly produce dramatic declines in population size with relatively higher frequency.

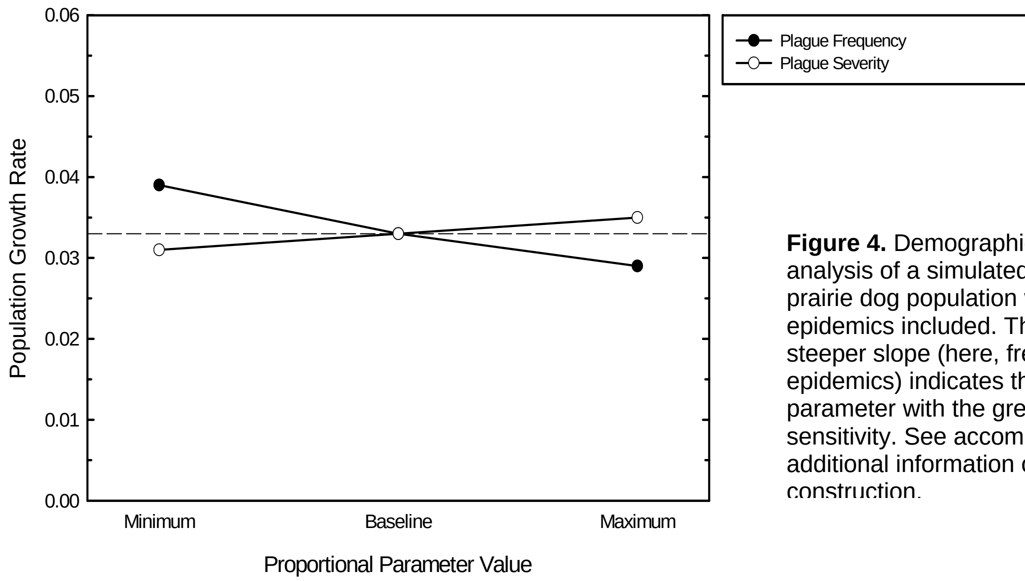


Figure 4. Demographic sensitivity analysis of a simulated white-tailed prairie dog population with plague epidemics included. The curve with the steeper slope (here, frequency of epidemics) indicates the model parameter with the greatest overall sensitivity. See accompanying text for additional information on model construction.

The management consequences of such a finding require additional discussion. In particular, it will be of value to determine the relative efficacy of management actions designed to reduce the frequency of plague epidemics in comparison to those that may decrease their severity. Economic considerations of the relative costs of alternative management options to achieve a particular outcome are also important.

The implications of this plague epidemic sensitivity analysis are plainly evident in Figure 5. The population shows a robust ability to recover from a single epidemic event that eliminates more than 90% of the population, but is unable to withstand repeated epidemics over a short period of time and rapidly declines to extinction in the face of frequent disease events. It is important to remember that the ability of our simulated prairie dog populations to recover from relatively isolated epidemic events is facilitated by the higher levels of reproductive ability at lower population densities. This feature is supported by field observations that document occasional recovery of colonies or complexes following catastrophic declines in numbers of individuals, presumably due to a disease event like plague.
As discussed in the previous section on simulation model input parameters, plague can act as an enzootic

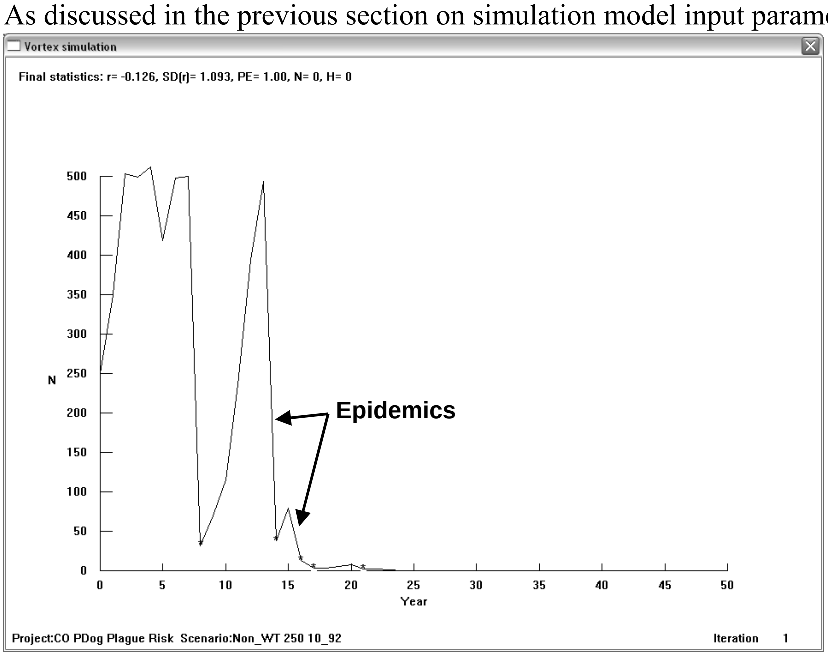


Figure 5. Representative fifty-year trajectory of a simulated white-tailed prairie dog population with the inclusion of plague epidemics (frequency of once every ten years, 92% severity). See text for additional information on model construction.

mortality factor in addition to creating dramatic population declines through epidemic events. An investigation of the interactions between underlying plague-based mortality and the frequency and severity of plague epidemics (Figure 6) leads us to conclude the following:

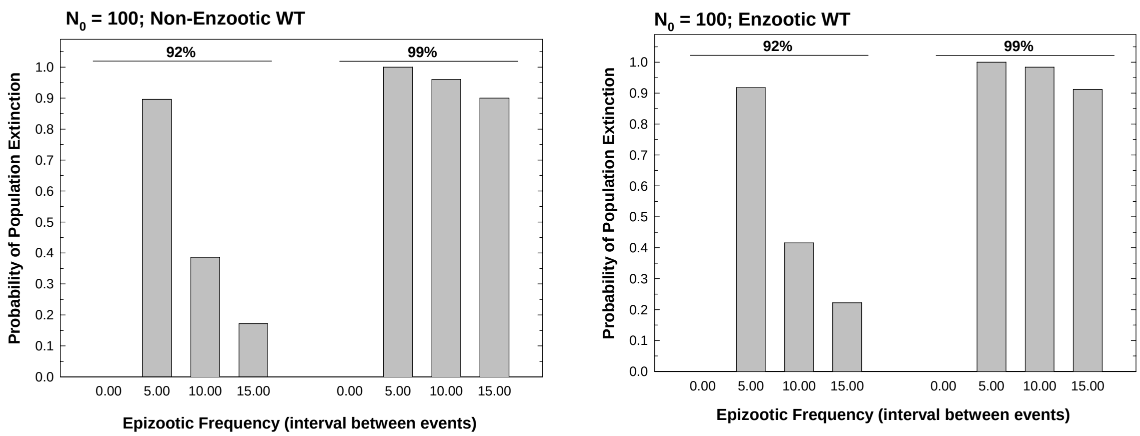


Figure 6. Fifty-year extinction probabilities for a simulated population of white-tailed prairie dogs in the presence of plague epidemics. Initial population size is 100 individuals. Epidemic frequency intervals are in years, and bars are grouped according to alternative assumptions regarding the severity of a given epidemic (92% or 99% of the population eliminated). Gunnison's prairie dog models give very similar results and are therefore not reported here for clarity. See text for additional information on model construction.

- When the severity of epidemic plague is relatively mild (i.e., 92% mortality), the frequency of the epidemics is a major factor in determining the overall risk of prairie dog population extinction. More frequent plague epidemics lead to a much higher extinction risk.
- Very severe plague epidemics – those that eliminate approximately 99% of the population – lead to very high extinction risks even when the frequency of those epidemics is relatively low.
- The presence of enzootic plague affecting the underlying annual mortality rates does not appear to play a significant role in determining the fate of a population exposed to plague epidemics.

Figure 6 shows only those results for a small set of models for white-tailed prairie dogs; models with similar starting parameters and assuming a Gunnison's – type demographic profile show nearly identical results and, therefore, have not been included in the figure for general clarity of presentation. Given the full range of output data reported here, the results are clear: epidemic plague as described here, based on our best estimates of its demographic character, can be a critical factor in determining the long-term persistence of Gunnison's and white-tailed prairie dog populations.

The full body of simulation models constructed to study plague in Gunnison's and white-tailed prairie dogs in Colorado – a total of 360 unique input datasets, each simulated with 500 iterations – can be summarized graphically to give us a more broad picture of the risks posed by this natural process. Each of the four demographic profiles was simulated under alternative assumptions regarding initial population size, plague frequency (defined here as the number of years on average separating each event) and plague severity. The fundamental unit of presentation of the results from these models is a 2 x 5 matrix with the individual cells corresponding to the 10 different initial population sizes making up the analysis (see Figure 7).

25	75	250	750	2000
50	100	500	1000	3000

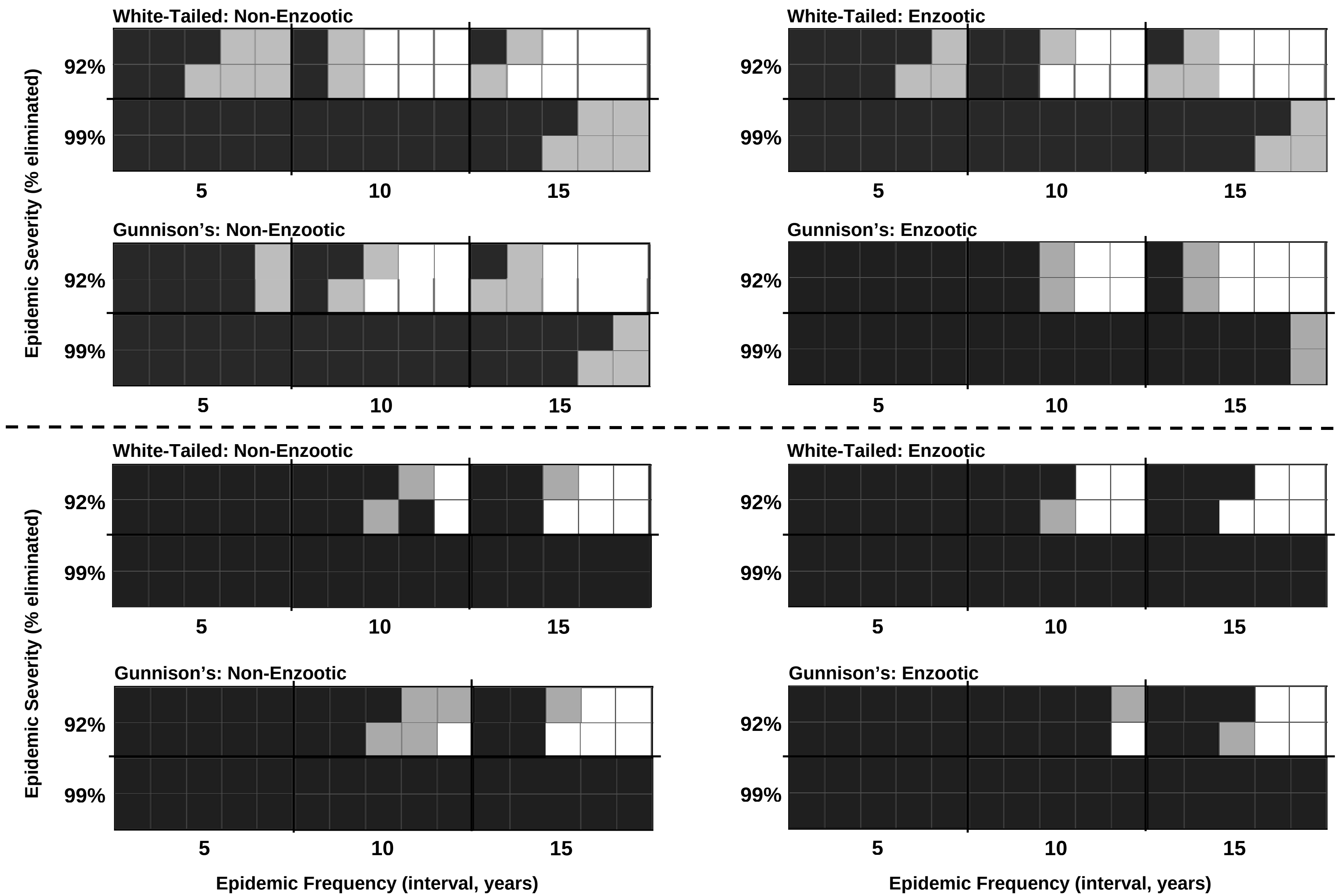
Figure 7. Fundamental unit of presentation of plague models, with each element of the 2 x 5 matrix corresponding to a unique model scenario with a different initial population size ranging from 25 to 3000 individuals. The cells are arranged so that the progression of increasing population size can be read broadly from the upper left to the lower right corners of the matrix.

These 10-block matrices are then combined within each of the four demographic profiles to produce a composite of the 60 models corresponding to all the combinations of initial population size, plague frequency, and plague severity. These composite matrices are shown in Figure 8.

The color-coded output metric displayed in the top half of figure 8 is a general estimate of extinction risk for a given scenario, with the darkest gray color indicating a “high” risk of extinction (P(E) > 0.50), the light gray a “moderate” risk (P(E) < 0.50), and the white a “low” risk (P(E) < 0.20). With these definitions, we are able to see that both the frequency and the severity of plague epidemics are major factors in determining the risk of prairie dog population extinction. In particular, we are able to see that the underlying demographic profiles are also important factors in governing this risk. Specifically, we see in the non-enzootic white-tailed profile matrix that 33 of the 60 scenarios show a “high” risk of population extinction, while 44 of the 60 scenarios show that same category of risk in the enzootic Gunnison’s demographic profile. These two profiles represent the best and worst cases, respectively, for underlying demographic performance in the absence of plague epidemics. Therefore, we can conclude (not surprisingly) that those populations with poorer demographic performance are more vulnerable to extinction from plague epidemics than their more demographically vigorous counterparts.

The mode of presentation of these results in Figure 8 allows us to address an interesting aspect of endangered species management policy in the context of risk assessment. The top half of Figure 8 is constructed using a specific set of thresholds for high, moderate and low levels of risk. In fact, most people would consider these thresholds – including a 20% risk of extinction defined as “low” – to be unacceptably high. Stated another way, these thresholds would typify a highly *risk tolerant* approach, where relatively high risks of extinction are considered acceptable for the purposes of developing management strategies. On the other hand, others involved in risk analysis and interpretation may adopt an approach where only very low levels of risk are considered acceptable. This *risk averse* approach is demonstrated in the bottom half of Figure 8, where the previous thresholds for risk have now been modified so that P(E) > 0.10 is now considered “high”, P(E) < 0.10 is “moderate”, and P(E) < 0.05 is considered “low”. Under these more strict definitions, many more individual modeling scenarios will come out as displaying a high risk of extinction. This is borne out when inspecting the bottom half of Figure 8 for a given demographic profile and comparing it to the top half.

Adopting a relatively more risk-tolerant or risk-averse approach in this situation may have significant consequences for the intensity of management required to achieve a specific goal, often linked to reducing population extinction risk to an acceptable level. A risk-averse approach implies a more intensive management effort, while a greater tolerance for risk allows greater flexibility in developing management options – but at a potentially much higher cost if those options fail. Careful consideration of one’s approach to risk, and the willingness to develop management options appropriate to that approach, should be an important component of developing a comprehensive endangered species conservation strategy.


White-Tailed: Non-Enzootic
White-Tailed: Enzootic
Gunnison's: Non-Enzootic
Gunnison's: Enzootic
92%
99%
5
10
15
Epidemic Severity (% eliminated)
Epidemic Frequency (interval, years)

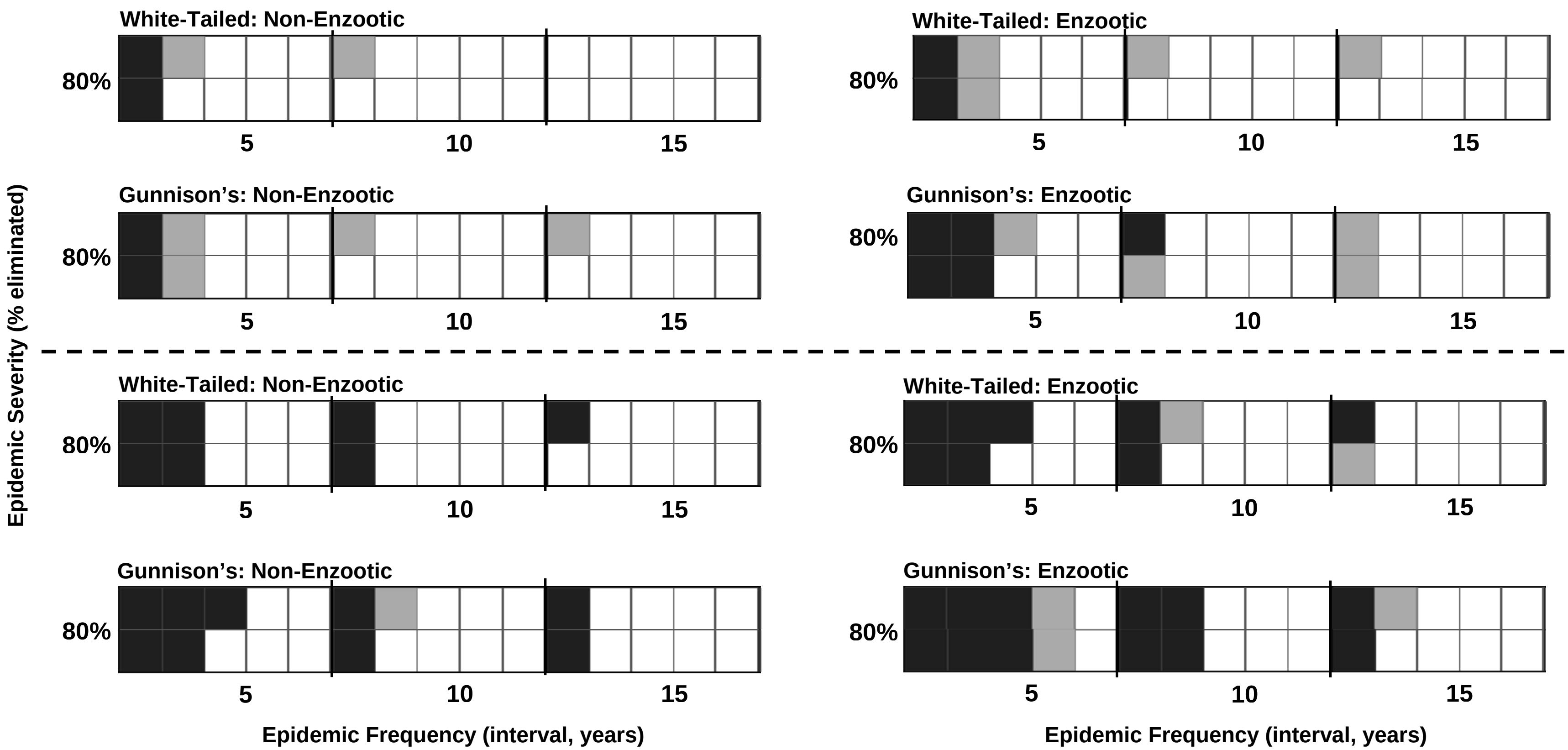


Figure 8 (*preceding page*). Extinction probabilities for models investigating the impact of plague epidemics on simulated prairie dog populations under the four alternative baseline demographic profiles. Each larger matrix is composed of smaller 2 x 5 blocks with each cell corresponding to a model with a specific initial population size (see Figure 7 for more information). The top half of the Figure (separated by the dashed line) assumes a risk-tolerant approach, while the bottom half assumes a more risk-averse approach, both defined by the thresholds for high, moderate and low risk corresponding to the shading in each cell. Top half of the figure (risk tolerant): dark gray, probability of population extinction (P(E) > 0.50; light gray, P(E) < 0.50; white, P(E) < 0.20. Bottom half of the figure (risk averse): dark gray, probability of population extinction (P(E) > 0.10; light gray, P(E) < 0.10; white, P(E) < 0.05.

Figure 9. Extinction probabilities for models investigating the impact of plague epidemics on simulated prairie dog populations under the four alternative baseline demographic profiles and the addition of burrow dusting as a potential means of flea control and, subsequently, mitigation of impacts of plague. Dusting is assumed to reduce the severity of a given epidemic from 92%-99% to 80%, while maintaining the same frequency of events. The top half of the Figure (separated by the dashed line) assumes a risk-tolerant approach, while the bottom half assumes a more risk-averse approach, both defined by the thresholds for high, moderate and low risk corresponding to the shading in each cell. See Figure 8 legend and text for additional information on model construction and interpretation of results.

Next, we investigated the effects that could result from a given level of burrow dusting with chemical agents that could reduce the intensity of plague epidemics down to 80% from the original estimates of 92% - 99%. White-tailed prairie dogs appear to have less severe die-off (80-85%) and seem to survive plague better than Gunnison's prairie dogs (CDOW, pers. comm.). Figure 9 gives the results from this second set of analyses. As is plainly evident from the Figure, this level of reduction in intensity of epidemics leads to a dramatic decline in the extinction risk of affected prairie dog populations. Although we still see the same general trends as before in the absence of dusting – lower baseline demographic performance and higher epidemic frequency leading to increased relative risk – the overall picture is considerably improved with the addition of dusting as a method for flea control.

It is very important to note here that there is no explicit definition in this analysis of the amount of dusting effort (manpower, financial resources, time, etc.) required on the ground to achieve a given level of mitigation of plague epidemic severity. A separate analysis, outside the purview of this or any PVA, must be undertaken to consider this critical relationship and its implications for prairie dog disease management.

Risk Analysis III: Impacts of Shooting on Gunnison's and White-Tailed Prairie Dog Population Dynamics

Demographic analyses of the impacts of shooting were conducted under the assumptions of (i) continuation of the current seasonal shooting closure or (ii) future retraction of the current seasonal closure.

When the current seasonal shooting closure remains in place (Figure 10), nearly all scenarios except those with the highest levels of shooting-based mortality show positive population growth and low to negligible risk of extinction. The smallest populations – specifically, those of less than about 100 individuals – show some rather aberrant demographic behavior resulting from the relatively large random fluctuations in birth and death rates from one year to the next. In addition, and as seen in previous sections of this analysis, more robust demographic profiles such as the non-enzootic white-tailed models show comparatively higher rates of population growth across all levels of added shooting-based mortality.

When the current seasonal shooting closure is retracted (Figure 11), all scenarios show a decrease in mean stochastic growth rate and, if it were present in the presence of the closure, an increase in the overall population extinction risk. However, the precise extent of this reduced demographic performance is clearly dependent on the underlying demographic profile. A more robust profile like that of the non-enzootic white-tailed scenario set show less impact of closure removal than does the set of scenarios defined by the enzootic Gunnison's demographic profile. The bulk of this difference appears to be due to the inclusion of enzootic plague-based mortality in deference to the alternative reproductive output values that define white-tailed vs. Gunnison's scenario sets. Therefore, the impact of shooting on prairie dog population persistence may be tied rather closely to the presence of low-level enzootic plague in these populations – particularly when they are small in size (i.e., < 250 individuals).

Of course, the addition of plague epidemics would dramatically reduce the viability of all scenario sets presented in Figure 10, effectively wiping out any variation in population performance that may result from the underlying demographic profile. As a result, particular scenarios combining the processes of plague and shooting were not developed for this analysis.

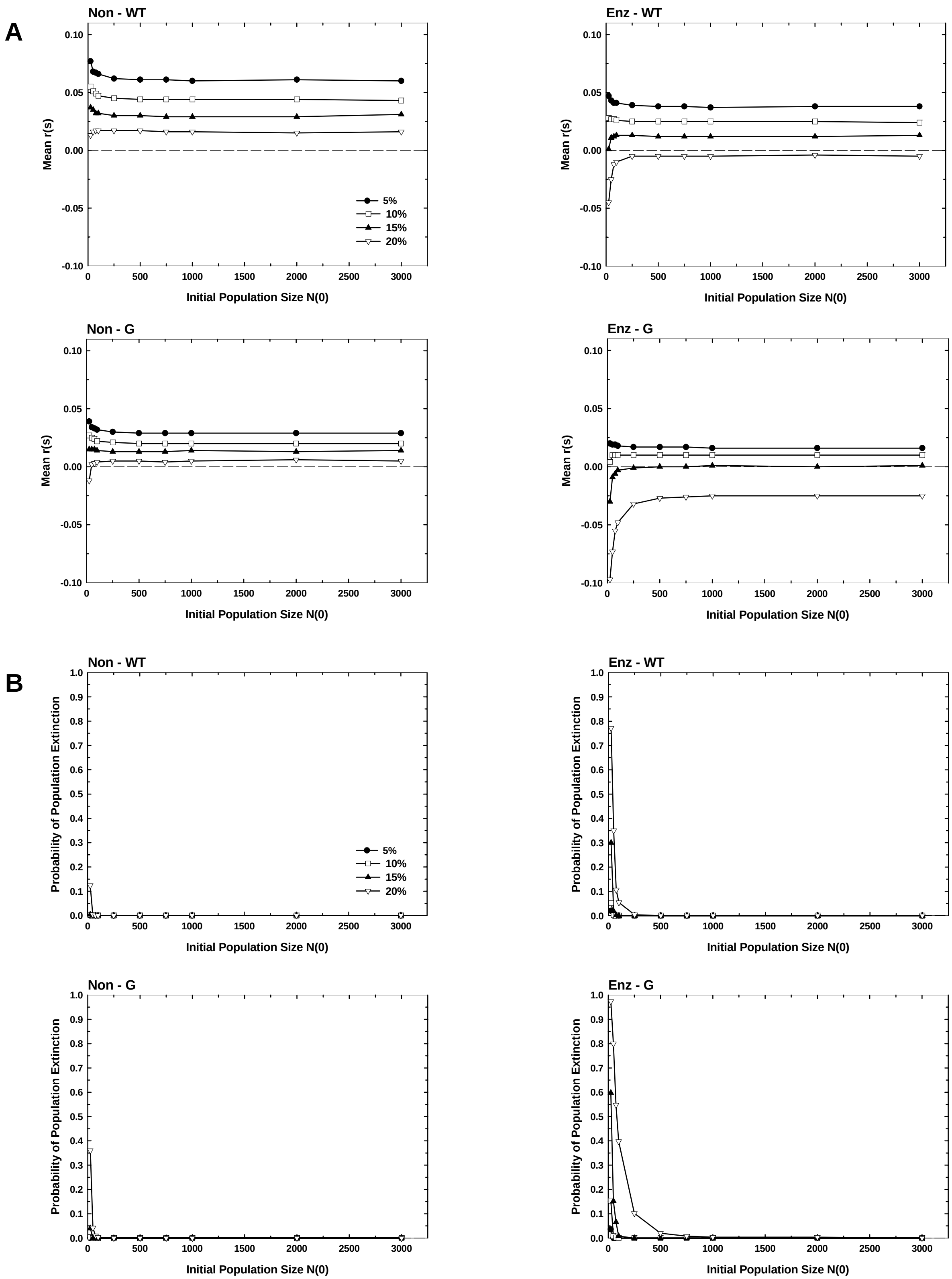


Figure 10. Mean stochastic population growth rate (A) and risk of extinction (B) for simulated populations of prairie dogs in Colorado under increasing rates of shooting-based mortality, and in the presence of the current seasonal closure. See text for additional details of model construction.

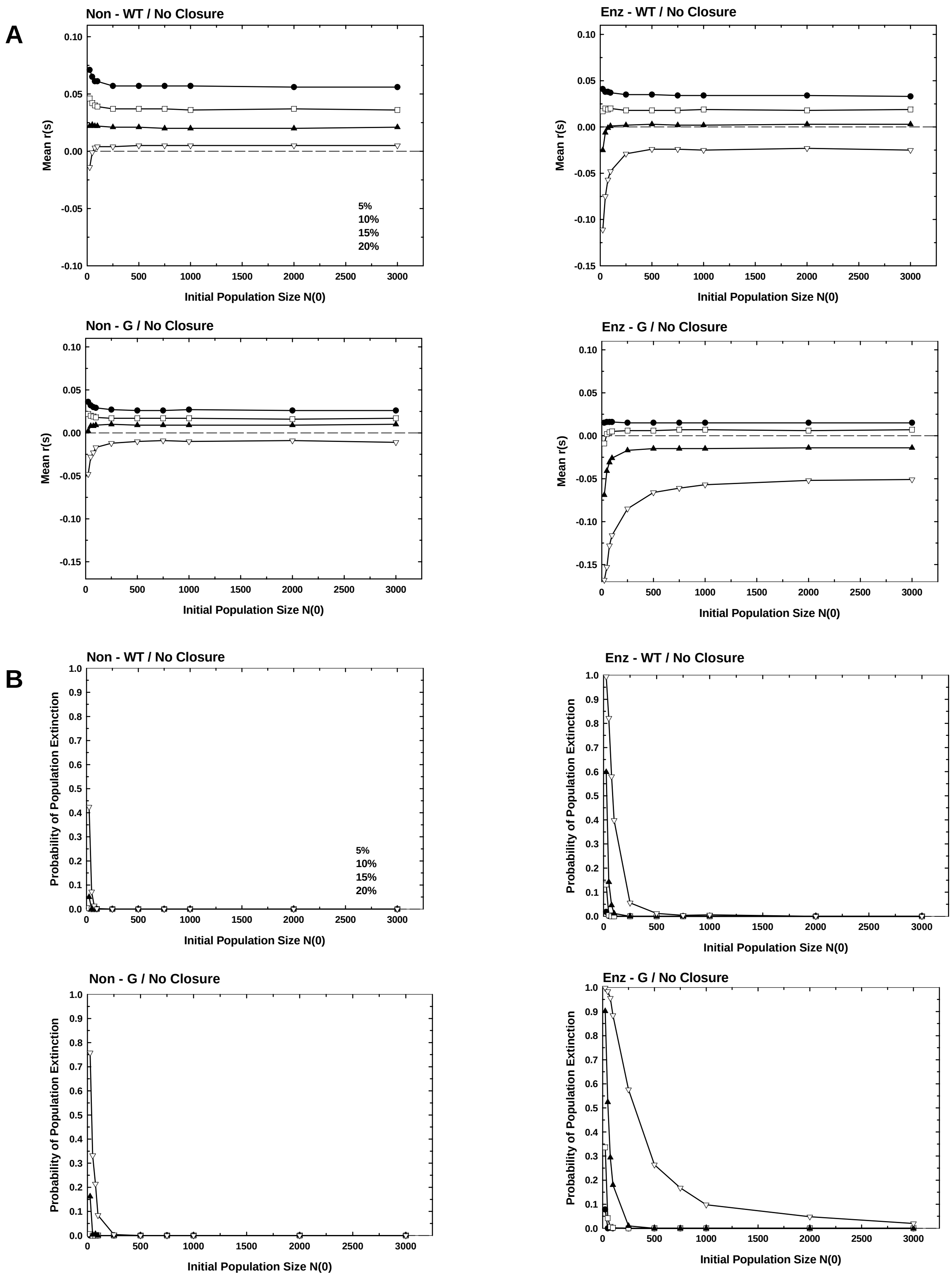


Figure 11. Mean stochastic population growth rate (A) and risk of extinction (B) for simulated populations of prairie dogs in Colorado under increasing rates of shooting-based mortality, and in the absence of the current seasonal closure. See text for additional details of model construction.

Risk Analysis IV: Impacts of Poisoning on Gunnison's and White-Tailed Prairie Dog Population Dynamics

As expected, the periodic application of poison to prairie dog populations, assuming 85% efficacy of the agent, has dramatic effects on their long-term size trajectory (e.g., Figure 12). Due to the underlying robust growth potential inherent in each of the four demographic profiles, less frequent poison application (in our case, every five years) leads to an enhanced opportunity for the population to rebound if still extant. However, Figure 13 shows that even lower frequency poison application leads to very high risks of population extinction over the 50-year time period of the simulation.

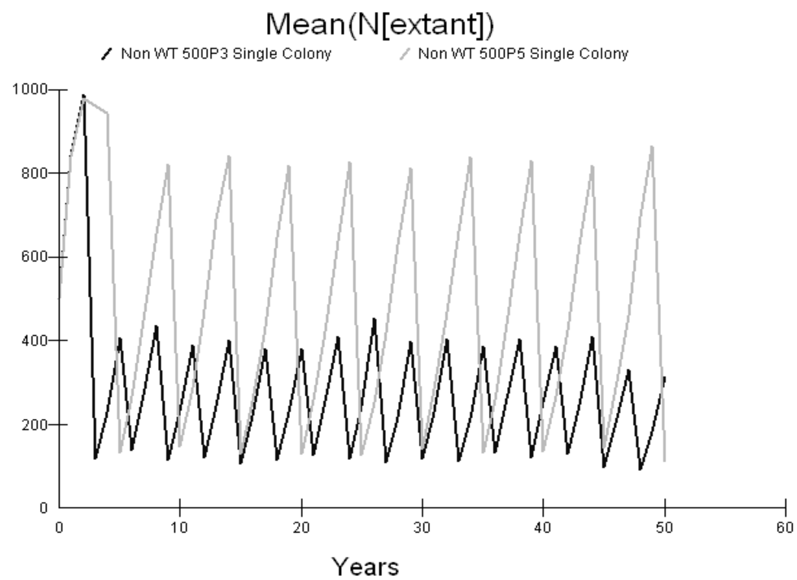
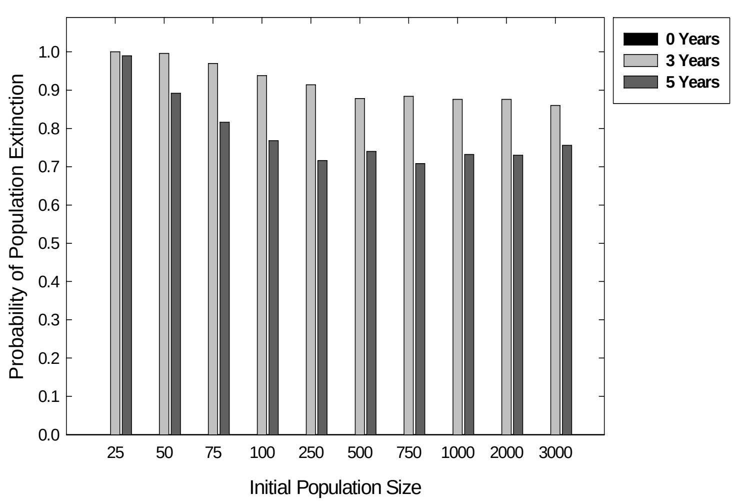


Figure 12. Average extant size of a simulated prairie dog population with a non-enzootic white-tailed demographic profile in the presence of periodic poisoning. The dark line indicates poison application every three years, while the light line indicates application every five years. Poisoning is assumed to 85% effective, resulting in the elimination of 85% of the population during the year of application. Initial population size is 500 individuals. See text for additional information.

Figure 13. Probability of extinction over 50 years for simulated prairie dog populations of different initial size, and exhibiting a non-enzootic white-tailed demographic profile in the presence of periodic poisoning. Light gray bars indicate poison application every three years, while the dark gray bars indicate application every five years. Black bars, indicating no poison application (control), appear absent but merely represent a zero extinction risk in the absence of poison application. See text for additional information.



Additionally, Figure 13 shows that even the largest populations have quite similar extinction risks compared to much smaller populations. This reinforces the field observations of the effectiveness of such agents when applied frequently.

As with other sets of scenarios described here, the results shown in Figures 12 and 13 are for only one of the four demographic profiled constructed at the beginning of this PVA. However, because the non-enzootic white-tailed profile shown here is the most robust demographic performer among the profiles, the remaining profiles will show an even greater level of decline in the presence of periodic poisoning.

Conclusions

We may conclude our analysis of Colorado prairie dog population viability by returning to the original set of questions that provided the foundation for our study.

- *Can we build a series of simulation models with sufficient detail and precision that describe the dynamics of Gunnison's and white-tailed prairie dog populations across Colorado with reasonable accuracy*?

  Our overall demographic analysis, combined with observations from the field, indicates that we are indeed capable of building such models. It is extremely important to remember, however, that reliance on the absolute outcome predicted by any one modeling scenario must always be interpreted with extreme caution due to the inherent uncertainty in model input parameterization. A comparative analysis between models, in which a single factor (or at most two factors) is studied while all other input parameters are held constant, provides a much more robust environment in which alternative management scenarios can be evaluated for their effectiveness in increasing the viability of the target species.

- *What are the primary demographic factors that drive growth of Gunnison's and white-tailed prairie dog populations?*

  Our demographic sensitivity analysis indicates that models of prairie dog population dynamics are most sensitive to rates of juvenile female survival and adult female reproductive success (probability of weaning a litter and mean litter size). If appropriate and/or feasible, research and management efforts could be focused on these aspects of prairie dog biology in order to improve the persistence of selected populations in a conservation management context.

- *How vulnerable are small, fragmented populations of Gunnison's and white-tailed prairie dog in Colorado to extinction under current management conditions? How small must a population become to increase its risk of extinction to an unacceptable level?*

  Current simulations (and field observations) indicate that prairie dog populations, if free from natural or anthropogenic stressors, can show strong demographic dynamics. This greatly reduces the risk of extinction for even the smallest populations on the landscape.

- *What are the predicted impacts of plague on Gunnison's and white-tailed prairie dog populations in Colorado?*

  Plague epidemic events are a major threat to the future survival of prairie dog populations in Colorado, particularly in combination with other stressors present on the landscape. Our models indicate that the frequency of such events is a critical factor in determining the long-term impacts. However, what seems like a relatively modest reduction in the severity of plague epidemics, effected through flea dusting practices, can lead to a dramatic reduction in the long-term impacts of epidemics.

- *What are the predicted impacts of current shooting practices on Gunnison's and white-tailed prairie dog populations in Colorado?*

  Lower rates of shooting-based mortality appear to be sustainable in otherwise demographically robust (i.e., plague-free) prairie dog populations. However, populations appear to become less stable when shooting is practiced during the primary reproductive period when pup production would be compromised.

- *What are the predicted long-term impacts of poisoning practices on Gunnison's and white-tailed prairie dog populations in Colorado?*

  Current poisoning practices greatly reduce the long-term survival of even the largest prairie dog towns. This reduction in viability is, as expected, more acute when poisoning is implemented more frequently.

- *Can we devise reasonable management practices to reduce predicted impacts of these activities on Gunnison's and white-tailed prairie dog populations in Colorado?*

  Overall, results from this analysis suggest that management practices currently proposed for prairie dogs – activities such as flea dusting among prairie dog burrows, seasonal shooting closures, and restrictions in the geographic extent of poison use – can have measurable positive impacts on the long-term viability of prairie dog populations. Careful consideration of extent and scope of selected management options must occur so that conservation of an important prairie resource in Colorado can be achieved within an atmosphere of social, political and cultural acceptance.

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White-Tailed and Gunnison's Prairie Dogs in Colorado Statewide Conservation Planning Workshop

16 – 18 May, 2007
Grand Junction, Colorado

III
Range Condition, Livestock and Predation

Range Condition, Livestock and Predation Working Group Report

Working Group Participants:
T. Wright Dickensen, Moffat County
Brian Holmes, Colorado Division of Wildlife
Ken Morgan, Colorado Division of Wildlife
Amy Seglund, Colorado Division of Wildlife
Jen Burton, University of Illinois (Recorder)
Mark Loye, Mediation Works 2, LLC (Facilitator)

Issue Generation

During our first working group session, the working group used a brainstorming technique to come up with the following issue pertaining to range condition, livestock and predation and their effects on Gunnison's and white-tailed prairie dogs in Colorado:

- Competition for forage between cattle, large wild ungulates and prairie dogs
- Lack of documented information on relationship between grazing and prairie dogs, fire and prairie dogs
- Present good range conditions; prairie dogs can coexist w/present livestock grazing load
- Statewide assessment condemns current agricultural system, including livestock production, and may overestimate threat to prairie dogs
- Polarization between CDOW and agricultural/range folks due to assessment
- Contradiction: prairie dogs do better on private land (where most shooting, poisoning, unregulated grazing occur) than they do on public lands
- There is a two-way relationship between poor range condition and prairie dog populations: prairie dog populations exist in and/or create areas of poor grazing conditions (pastures, range). Which comes first? Also, scale of observation matters: a prairie dog town evaluated without consideration of the larger mosaic might be considered poor range condition
- Natural predator numbers may not have significant influence on prairie dog populations
- Information is lacking on what numbers constitute a healthy prairie dog population. Published measurements of prairie dog population size that have been used as target numbers may be taken from too small a spatial or temporal sample, and therefore may not reflect stable equilibrium values. The relationship between these numbers and range health is unclear.
- The time lag between range management practices and effects of those practices on the surrounding ecosystem results in misconceptions about the current relationship between livestock/agriculture and ecosystem health
- Potential future restriction of grazing [public land] if species gets listed
- Potential impacts of loss of grazing permits – private land overgrazing, development – may have negative impacts on prairie dog conservation
- Scale of observation is critical in assessment of range condition; different conclusions will be drawn based on different scales (habitat mosaic vs. individual pasture area) This creates conflict.
- Because of the pattern of land designation (steeper areas tend to be public, areas with lower slope tend to be private), private land tends to be preferable prairie dog habit and therefore have more prairie dogs.
- Potential for restrictions on private land threatens landowners' ability to protect their investment, including investments they make in conservation.

The group then consolidated these issues into six more descriptive problem statements, and prioritized them on the basis of their global impact to the development of the Gunnison's and white-tailed prairie dog statewide management plan:

1. Uncertainty exists in relation to the following areas: the size of a healthy prairie dog population, the relationship between grazing and prairie dogs, distribution of prairie dogs across different land ownership (i.e. private vs. public land), different habitat types (soil, weather, etc.) and different management styles, the relationship between prairie dogs and fire, predators, plague, and invasive species.
2. The potential for listing of white-tailed and gunnison's prairie dog and related regulations could lead to losses within much of the livestock business. Succeeding land uses could be detrimental to prairie dogs and the related ecosystem function.
3. Polarization between CDOW, agricultural producers, and other environmental groups leads to a gap in current research, and to doubts about conclusions being drawn regarding prairie dog population conditions and the interaction between producers and prairie dogs.
4. The scale of analysis is critical in the assessment of ecosystem condition. Different conclusions about the health and function of range ecosystems will be drawn, depending on the extent of the area surveyed. Analyses that focus on a habitat mosaic are more relevant to conservation than analysis of individual pasture areas.
5. Competition for forage between prairie dogs and ungulates
6. Relationship between predators and prairie dogs (including importance of prairie dogs as prey)

It is important to define "good range condition". The definition is not the same for prairie dogs, sage grouse, and grazers.

The fact of poor range conditions in the immediate vicinity of prairie dog populations makes scale of analysis an extremely important part of this issue.

The economic viability of agriculture is a part of the larger system being discussed.

Research has not kept up w/the pace of change in [grazing] land management. Management today looks at long-term viability of the operation and the ecosystem that supports it.

There is an implied negative interaction [in the assessment] between livestock grazing practices and prairie dog conservation.

Regulatory uncertainty creates the potential for a domino effect: if producers don't have enough time to make required changes in a way that is economically feasible within their industry, those changes may be too costly or too risky to do at all. In such a case, a likely outcome is that the land use would be something other than grazing, such as residential development.

Because of different land/soil types, "one-size fits all"-type regulations are probably not the best approach.

Objectives and Strategies

The following pages list the objectives and strategies designed to directly address those issues developed earlier.

PROBLEM / ISSUE: 1. Uncertainty exists in relation to the following areas: the size of a healthy prairie dog population, the relationship between grazing and prairie dogs, distribution of prairie dogs across different land ownership (i.e. private vs. public land), different habitat types (soil, weather, etc.) and different management styles, the relationship between prairie dogs and fire, predators, plague, and invasive species.						
GOAL / OBJECTIVE: 1.1. Develop a prioritized, collaborative research program for white-tailed and gunnison's prairie dog that addresses key conservation practices, to include the size of healthy prairie dog populations, the relationship between grazing and prairie dogs, distribution across land ownership and different habitat types (soil, weather, etc.), relationship between fire and prairie dogs, the relationship between prairie dogs and invasive species/weeds, the relationship between prairie dogs and predators, and the impacts of plague and drought.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
#1a: Adaptively implement the collaborative monitoring strategy in relation to pd distribution and pop trends across the landscape on a more frequent basis than has been done (currently 3-yr; smaller scale annual). Develop protocols for collection of data on private land.	Amy Seglund (CDOW)	Brian Holmes (BLM) Bruce Norwood (CCA), for private landowners	Begin by 1/08 Reassess 12/2012	$ 750,000 ($150,000 annually)	$, landowner cooperation staffing?	Poor temporal data resolution, resultant poor decisions
#1b: Develop and implement an integrative applied research plan to address data gaps in the relationships between pd pops and invasives / weeds, grazing, and fire.	Amy Seglund (CDOW) Brian Holmes (BLM)	T. Wright Dickensen	Begin by 1/08 Complete and/or reassess by 12/2012	$300,000 ($60,000 annually)	$, agency cooperation	Inadequate data, resultant poor decisions
Develop a BMP handbook for prairie dogs based on above research, to include scale-appropriate assessment tool for range ecosystem health.	Chris Kloster (CDOW)	Brian Holmes (BLM)	Begin 1/2013 Complete by 12/31/2013	$50,000	$, uncertainty regarding research results, completion of research	Lack of coordinated effort, public perception and regulatory decisions based on out-of-date practices
Design and implement an effective strategy to disseminate research purpose and results to stakeholders.	Ken Morgan (CDOW)		Complete by 12/31/07	$1500	Time and availability of organizers/ participants	Misunderstanding, decreased landowner participation, inadequate data

PROBLEM / ISSUE: 2. The potential for listing of white-tailed and Gunnison's prairie dog and related regulations could lead to losses within much of the livestock business. Succeeding land uses could be detrimental to prairie dogs and the related ecosystem function.

GOAL / OBJECTIVE: 2.1. Develop demonstration projects showing the basis of the relationship between current grazing management and healthy prairie dog habitat.

ACTION/STRATEGY	LEAD RESPONSIBLE PARTY(IES)	OTHER RESPONSIBLE PARTIES	TIMELINE*	COST**	Obstacles	Consequences of no action
Create incentives for participation in wt and g pd conservation activities by permitees and lessees on federal land: Extend "safe-harbor"-type assurances to provide protections for to federal permitees and lessees in the event that these spp. are listed, if these parties have undertaken recommended conservation practices. * Commitment required by CDOW, USFWS	T. Wright Dickensen	Amy Seglund (CDOW) Brian Holmes or Al Pfister (USFWS)	Begin 1/08 Complete by 12-31-08	$10,000-50,000	Negotiation of details, legal challenges	Reduced implementation of conservation strategies due to lack of incentive Reduced funding opportunities
Develop and implement demonstration projects in appropriate locations across the ranges of the WT and G pds. These locations should include public and private lands, various habitat types, various spp (sheep, cattle, wild ungulates), integration of pd mgmt practices and working ranch. Lead tours among multi-stakeholder groups	CJ Mucklow (CSU Extension)	Ken Morgan (CDOW) Lars Santana (NRCS)	Start 6-1-08 Begin tours 6/08 Reassess 5/2013	$15,000 annually	Participation $	Continued misunderstanding and distrust

PROBLEM / ISSUE: 3. Polarization between CDOW, agricultural producers, and other environmental groups leads to a gap in current research, and to doubts about conclusions being drawn regarding prairie dog population conditions and the interaction between producers and prairie dogs.						
GOAL / OBJECTIVE: 3.1. Regular communications between those in the livestock industry and FWS, CDOW, and environmental organizations should be instituted to discuss the white-tailed and Gunnison's prairie dog and their relationship to grazing management						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Ongoing update of the Colorado assessment based on the work being done under objectives #1 and 2. This can be distributed through the CCA Research can be reported through CDOW	Amy Seglund (CDOW)	All other research participants - working group (see below)	Begin 1/08 Reassess 12/12	$2000 plus below		Failure of collaboration; research lost
* sub-strategy for above: Create and implement working groups for above, to include groups specific to smaller regional areas. Umbrella group could periodically link these groups together	Amy Seglund and Pam (CDOW), T Wright Dickensen		Assemble by 10-1-07 Reassess by 12-31-12	$5000/yr	Logistics, interest	Lack of buy-in

PROBLEM / ISSUE: 4. The scale of analysis is critical in the assessment of ecosystem condition. Different conclusions about the health and function of range ecosystems will be drawn, depending on the extent of the area surveyed. Analyses that focus on a habitat mosaic are more relevant to conservation than analysis of individual pasture areas						
GOAL / OBJECTIVE: 4.1. Develop scale-appropriate analysis for assessment of ecosystem condition. Refocus on existing protocols and work w/BLM to accomplish this.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Encourage and continue constructive organized dialogue among private landowners, BLM permittees and lessees, CDOW, BLM, and other relevant stakeholders regarding BMPs for WT and G pd and healthy rangeland ecosystems. MEAs should be a primary topic of discussion.	Brian Holmes (BLM)	Amy Seglund (CDOW) T Wright Dickensen (NWRAW)	Start 6-1-07 Ongoing through 2013	Minimal	Logistic	Misunderstandings persist

PROBLEM / ISSUE: 5. Competition for forage between prairie dogs and ungulates						
GOAL / OBJECTIVE: 5.1. Develop an incentive plan for private landowners to maintain appropriate prairie dog populations in priority areas as a part of a functioning agricultural/range business operation						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Develop and implement incentive plan for private landowners and BLM lessees and permittees to develop/maintain pd populations/habitat. Do this by borrowing CSI (Cooperative Sagebrush Initiative) (see Sand Co. Foundation website) strategies and applying them to Gunnison's and shite-tailed prairie dogs. Develop direct and indirect incentive and assurance program for habitat areas deemed to be important for species/ecosystem maintenance. Program needs to be flexible, adaptive, and outcomes-based.	T Wright Dickensen Ken Morgan (CDOW)	Robin Sell (BLM)	Begin 1/08 Completed by 12-31-12	Development: $5000	Agency participation	Missed prairie dog conservation opportunities

Additional notes and discussion on objectives and strategies

Clarification: 80% mortality does not represent a plague epizootic.

Further discussion of assessment language
Concurrence that current range management practices do not pose an immediate threat to prairie dog populations, and that the relationship between current practices and prairie dog populations needs to be further elucidated.

If research efforts concentrate on the landscape [rather than on prairie dog species alone], the opportunity for multiple funding sources increases due to inclusion of multiple species (burrowing owl, _?_ fox (in SE areas)).

FWS will take into consideration that this is a rangewide effort.

Historical data regarding numbers may not be relevant to describing a healthy prairie dog population today.

More data is needed to describe the relationship between invasive species/weeds and prairie dog populations. Weed management is part of BMP. Until specific relationships are discerned between weeds and prairie dogs, the consensus is that weed management is part of range management and should not be separately addressed in the prairie dog plan.

Most of prairie dog populations will be in *low srl st.* (early post-disturbance) areas, because prairie dogs effect changes on the landscape. This is where control of invasive species would start.

It would be good to elevate noxious weeds as a component of the plan. More information is needed, as noted above.

Getting people (recreation, grazing, energy) to invest in public lands will require some assurance that they will see a return on their investment, or at least that the investment is not extremely high-risk. This can be implemented via demonstration projects, but the attitude of the plan should include a statement by CDOW that livestock is not a threat to, and therefore not threatened by, prairie dog conservation.

Large-scale comprehensive efforts are required, but]smaller regional work groups will help achieve cultural buy-in.

Discussion: prairie dogs move into areas after fire. The history of fire suppression, esp. in certain areas, has eliminated some prairie dog habitat. This is further complicated by the fact that areas not recently burned are better sage grouse habitat. There is a need to balance habitat BMPs to consider multiple species.

Regarding strategy for goal #4: it is important to preclude negative impressions of focus areas by implementing dialogue with the people who use that land prior to labeling those areas. It may be helpful to identify more potential focus areas than immediately needed: some people may readily accept this designation, and neighbors in higher-value focus areas may warm up/buy in to the idea over time.

Clarification: Management emphasis areas are areas in which intensive management will be applied if population surveys find #s below a statewide trigger (40% decline). These areas don't come with any preordained "regulatory attachments". If prairie dog populations fall below the trigger, management of these areas would likely include new ideas or experimental methods.

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16 – 18 May, 2007
Grand Junction, Colorado

IV
Agriculture and Poisoning

Agriculture and Poisoning Working Group Report

Working Group Participants:
Cathleen Neelan, North American Mediation Associates (Facilitator)

Issue Generation

Our working group tackled the issues of agriculture and poisoning separately, brainstorming two lists of issues to guide our subsequent discussions.

Agriculture

You can't simultaneously kill and conserve same organism (conservation vs. control) – we recognize need to kill and control in croplands. Why is this a problem for agriculture?

1. Ground disturbance, equipment damage/ breakage, organic farms get run over with prairie dogs, crop loss
2. Fragmentation of habitat and does it still occur
3. Protection of private property rights
4. Fear of disease
5. Tunnel into canals/ ditches- impact water movement
6. Agricultural conversion and potential loss of habitat
7. Agricultural land attracting prairie dogs and how to minimize attractant

Poisoning

1. NW corner of CO not an issue and not widely used in this area.
2. Not done extensively and has limited effectiveness
3. Not as efficient as perceived
4. Other non-target species can be poisoned
5. Use is not always done correctly/ as prescribed (timing, barometric pressure)
6. Where should control be conducted and where should conservation be done (public, private)
7. Public perception of poisoning, burning, drowning, etc prairie dogs
8. Loss of management control because of public perception
9. Historic actions were more effective than current products
10. Un-sanctioned and variable methods of controls employed by private land owners with uncertain results.

These issues were then distilled down to the following problem statements:

Agriculture

1. The co-existence of prairie dogs and agriculture present a challenge each one another. The challenges include: crop damage, equipment damage, disease, fear and often have a negative perception within the populous.
2. Agricultural conversion has resulted in fragmentation with ground disturbances and land management differences on adjacent properties. This conversion has resulted in ecological impacts on prairie dogs and restricted or altered distribution.

Poisoning

1. There have been problems with the proper use of poisons that have limited effectiveness. We don't have sufficient data on the extent of use.
    a. Develop better tracking means for poison use
        i. Compile stock purchased in one year and where it is used
        ii. Correlate with Pdog trends for the year
        iii. Survey those with applicators license, amount used, where used
    b. Better education for proper use and alternatives
    c. Proper management
2. How do we determine where poisons should or should not be used?
    a. Determine where poisons can be used
    b. Develop rationale for explanation of support
    c. Integrate decision with wider variety of stakeholders
    d. How to reduce use of poisons via other alternatives
3. Negative Public perceptions reduce management control options
    a. Minimize public perception when using poisoning
    b. Improve public perception
4. Use of poisons to control prairie dogs may affect associated species.
    a. Minimize affects on associated species
5. Use of poison to control P-dog may result in losses of non-target species.
    a. Minimize effects on non-target species (strategy-find chemicals with least effects on other species)
6. Modeling and information translation

Objectives and Strategies

The following pages list the objectives and strategies designed to directly address those issues developed earlier.

PROBLEM / ISSUE: 1. The co-existence of prairie dogs and agriculture present a challenge each one another. The challenges include: crop damage, equipment damage, disease, fear and often have a negative perception within the populous						
GOAL / OBJECTIVE: 1.1. Minimize the effects of prairie dogs and agriculture on each other						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Research alternative material for barriers for use around croplands. Evaluate effectiveness and cost feasibility	CDOW, universities	CSU-extension, NRCS	Initiate 2008	Graduate student		
Recommend either barriers between habitat and cropland (i.e. landscape, unpalatable grasses, visual barriers) or recommend effective raptor perches near croplands, if feasible as a means of control	CDOW, CSU-extension, USFWS	Counties, private industry (commercial controllers, non-commercial controllers)	Ongoing	n/a	regulations	
Provide landowners with educational materials on alternatives to protect croplands. Create incentives for landowners to keep prairie dog habitat on private land	CDOW, NRCS, USFWS-partners program	Private industry	Initiate 2008	$10K +landowner incentives		
Provide an economic opportunity for harvest of prairie dogs if agriculture is impacted. (Provide crop rotation that includes commercial prairie dog harvest)	CDOW	Private landowners				

PROBLEM / ISSUE: 2. Agricultural conversion has resulted in fragmentation with ground disturbances and land management differences on adjacent properties. This conversion has resulted in ecological impacts on prairie dogs and restricted or altered distribution						
GOAL / OBJECTIVE: 2.1. Strive to minimize the fragmentation caused from agriculture practices (crop rotation) that adversely impact prairie dogs						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Map critical areas and target those areas for agricultures cooperation to minimize impacts	CDOW-GIS					
Develop a recommendation for agriculture practices to work together with prairie dog needs. Create incentives to fund cooperative agreements	CDOW, NRCS					

PROBLEM / ISSUE: 1.There have been problems with the proper use of poisons that have limited effectiveness. We don't have sufficient data on the extent of use.						
GOAL / OBJECTIVE: 1.1. Develop better tracking means for poison use						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Compile stock purchased in one year and where it is used						
Correlate with prairie dog trends for the year						
Survey those with applicators license, amount used, where used						

PROBLEM / ISSUE: 1.There have been problems with the proper use of poisons that have limited effectiveness. We don't have sufficient data on the extent of use.						
GOAL / OBJECTIVE: 1.2. Better education for proper use and alternatives						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action

PROBLEM / ISSUE: 1.There have been problems with the proper use of poisons that have limited effectiveness. We don't have sufficient data on the extent of use.						
GOAL / OBJECTIVE: 1.3. Proper management						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action

PROBLEM / ISSUE: 2. How do we determine where poisons should or should not be used?						
GOAL / OBJECTIVE: 2.1. Determine where uses of poisons are most appropriate						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Develop a decision matrix that more clearly identifies the places (public, private, distance from human habitation, etc) that poison could/should be used to control prairie dogs. Develop explicit rationale to support decisions. Include stakeholders in decision process.	CDOW, USFWS	CO Dept. of Ag, CDPHE, Wildlife Services, stakeholders	Initiate- 2008	.05 FTE	Attitudes	
Recommend maintaining the current limited/restricted use of poisons on public rangelands.	BLM, USFS, CDOW, NPS, USFWS-refuge	Cities, counties	Ongoing	N/A		Jeopardize existence of prairie dogs if we return to large scale poisonings
Provide information on non-lethal removal methods	CDOW, CSU-coop extension,	Wildlife services, CDPHE,	Ongoing	N/A		

PROBLEM / ISSUE: 3. Negative Public perceptions reduce management control options						
GOAL / OBJECTIVE: 3.1. Minimize public perception when using poisoning 3.2. Improve public perception						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action

PROBLEM / ISSUE: 4. Use of poisons to control prairie dogs may affect associated species						
GOAL / OBJECTIVE: 4.1. Minimize impacts to non-target species						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Recommend the use of poisons (i.e. zinc phosphide instead of anticoagulants) that result in the least impact on non-target species	CO Dept. of Ag, Wildlife Services,	Counties, CSU-extension	Ongoing	n/a		
Assemble information and disseminate to those using poisons to minimize impact to non-target species	CSU-extension, wildlife services, CO Dept. of Ag	Counties, CDOW	2008- ongoing	.25 FTE		
Identify susceptible non-target species that can be impacted by poison and improve public awareness	CDOW, USFWS	Stakeholders	2008- ongoing	.05 FTE		
Identify personnel to disseminate information on how to minimize impacts to non-target species. Develop a funding mechanism to continue to improve awareness on minimizing impacts on non-target species	CO Dept of Ag, CDOW, USFWS		2008	.5 FTE		

PROBLEM / ISSUE: 5. Use of poison to control prairie dogs may result in losses of non-target species						
GOAL / OBJECTIVE: 5.1. Minimize effects on non-target species						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Find chemicals with least effects on other species						

White-Tailed and Gunnison's Prairie Dogs in Colorado
Statewide Conservation Planning Workshop

16 – 18 May, 2007
Grand Junction, Colorado

V
Oil and Gas Development

Oil and Gas Development Working Group Report

Working Group Participants:
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Kim Kaal, Colorado Division of Wildlife
Jeff Madison, Rio Blanco County
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Erin Robertson, Center for Native Ecosystems
Liza Rossi, Colorado Division of Wildlife (Recorder)
Rebecca Seal Soileau, Conservation Breeding Specialist Group (Facilitator)

Issue Generation

Our first task was to brainstorm a series of issues that are pertinent to the topic of oil and natural gas development in Colorado and its potential impact on management of Gunnison's and white-tailed prairie dogs throughout the state. Individual issues emerging from this brainstorming session were then clustered into larger categories, and the collapsed list was then prioritized by the group on the basis of their importance for developing an effective management strategy for these prairie dog species in the state. The group finally crafted more descriptive problem statements for each larger issue. The prioritized list of problem statements, including the individual component issues developed in the initial brainstorm, is given below.

1. The understanding of oil and gas activities is insufficient to determine the affects on prairie dog populations and their spatial distributions. Data related to oil and gas impacts on prairie dogs and their ecosystems are insufficient to make robust management decisions. Drilling is occurring at a pace where it will be difficult to wait for research results and effectively conserve the prairie dog ecosystem. A new CO State Law requires the COGCC and CDOW to develop oil and gas best management practices for prairie dogs by July 2008. [13]

   A. There is insufficient data on baseline population trends of species potentially impacted by oil and natural gas development, along with insufficient data on the actual effects of oil and gas development on prairie dogs in associated habitats.
   B. Are best management practices effective for prairie dogs? How do baseline best management practices affect prairie dogs? Are there any best management practices specific for prairie dogs? There is a general lack of data on this issue.
   C. Data gaps exist in our knowledge of the spatial arrangement of oil and gas development and prairie dog population distribution.

2. Oil & Gas development may result in habitat loss, degradation, and loss of connectivity between colonies, partially due to the speed at which it is occurring. [12]

   A. There is a potential for permanent habitat loss resulting from oil and gas development, leading to declines of prairie dog populations.
   B. Habitat fragmentation from development may lead to greater levels of threat among associated prairie dog populations.
   C. Considerable overlap may exist between oil and gas development and prairie dog range, resulting in threats to prairie dog habitat and populations.
   D. Oil and gas development is rapidly increasing across prairie dog range – in both speed and extent.

E. There is a potential future conflict between development and wildlife conservation interests in that some identified species management focus areas are also areas designated for increased oil and gas development.

3. Other associated components of the prairie dog ecosystem may not tolerate certain aspects of oil and gas development activities. Preserving only the prairie dog populations in the ecosystem may not be enough to preserve the functional integrity of the system. [10]

   A. Conserving a prairie dog ecosystem with all of its species components is a huge challenge. For example, Ferruginous Hawks are not as tolerant of disturbance as prairie dogs, thereby potentially leading to more rapid and severe impacts of oil and gas development.
   B. Is there a secondary effect of oil and gas development on other species that rely on prairie dogs for prey?

4. There may be both direct and indirect impacts to prairie dog populations of increased road density and accessibility within prairie dog habitat resulting from oil and gas development. [5]

   A. What is magnitude of direct effects from increased vehicle traffic on prairie dog populations?
   B. What are the indirect effects from increased access/roads/development, such as shooting or OHVs?

5. The federal/private/tribal interface is often complex, leading to difficulties in data sharing and effective communication from the state to tribal interests. [3]

6. There is a concern with imposing regulatory mechanisms on oil and gas development prior to the collection and presentation of defensible data on its impact to local wildlife. [1]

7. There may be a significant economic cost of conservation-based mitigation of oil and gas development, thereby increasing the financial burden to those companies involved in development of the resource. [0]

Data Assembly – Assumptions/Preconceived Notions/Data Gaps

Topics discussed below were brought up by the larger group in a plenary session following the presentation by Amy Seglund (CO Division of Wildlife) on Issues and Management Difficulties.

- Issues surrounding disposal of water used during oil and gas development are not as problematic in Colorado as there are in Wyoming.
  - In most areas, water is being re-injected. However, in the Little Snake Resource Area (BLM), they do have some surface water discharge issues (3 places in Little Snake Resource Area).
  - Although these areas are not necessarily impacting PDs, O&G may expand in the future.
    - Water may be clean, but putting it on alkaline soils may cause problems.
    - Water also causing erosion issues in systems not used to having water.
- Invasive species are an issue in new development areas – *This is a habitat issue, also data gap in how to control weeds, also policy gap in responsibility. Data gap in seed mix quality.*
- Prairie dog densities may be high in oil and gas development areas, but activities may be impacting dependent species.
  - *Data gap for dependent species – burrowing owl, mountain plovers*
  - Documented impacts for Ferruginous Hawks
  - Include other species.
- Uranium mining is an emerging issue. It may be important to move forward on this issue and address it directly in the Draft Plan.

- Gravel mining is also emerging issue – companies are looking for flat areas, similar to good prairie dog habitat, for gravel mining. This needs to be addressed in the Plan as well.
  - Gravel mining is tied to oil and gas development because companies involved in this activity are using lots of materials.
- State Reclamation requirements are in place. The question is if current reclamation requirements are beneficial/adequate for prairie dogs.
- Reclamation requirements are important for phased development and interim staged reclamation – *Data gap is a policy formulation gap* – For interim reclamation, we need to think beyond general seed mixes to include things such as cover requirements. We also need to be thinking about prairie dogs, not just deer and elk. One size does not fit all. Also should not be just thinking about prairie dogs, should manage for overall landscape that supports multiple wildlife species.
- What about pipeline impacts to prairie dogs? Group agreed that pipelines are probably a minimal impact because prairie dogs re-colonize these narrow areas. But what about other species? Pipelines can be positive if reclaimed properly (dozer work and proper timing).
  - Storm water control and erosion control may be a fragmentation issue with pipelines, but can be done properly.
  - The group considered overhead powerlines associated with development and decided that not significant for prairie dogs.
- Rangely Oil Field is an example as a place where prairie dogs exist co-exist with O&G. Possible research area. Although prairie dogs are there, we do not really know if this pop is doing great biologically.
  - Assumption is that if we see prairie dogs, then they are "just fine"
  - *Data gap on effects of anthropogenic changes*
- Audible Impacts – *data gap* – Different types of developments may have different audible impacts.

Objectives and Strategies

For each of the high-priority problem statements detailed above, we developed a set of longer-term objectives, followed by specific strategies intended to help achieve them. These data are presented in tabular form below, with each set of objectives and strategies linked to the associated problem statement.

In order to give a sense of the importance of implementing these objectives, we went through a prioritization process for the full set of nine objectives developed during this workshop. The criterion for prioritization was: **Objectives related to the Statewide Conservation Strategy that will provide for prairie dog population viability in a socially supportive environment.** Overall goal of writing this Statewide Plan is to conserve prairie dogs and their habitat and the overall system. This does not negate the value of considering associated species, but the Plan will focus on prairie dogs as a means of achieving effective conservation action. *[large group discussion]*

PROBLEM / ISSUE: 1. The understanding of oil and gas activities is insufficient to determine the affects to prairie dog populations and spatial distributions. Data related to oil and gas impacts on prairie dogs and their ecosystems are insufficient to make robust management decisions. Drilling is occurring at a pace where it will be difficult to wait for research results and effectively conserve the prairie dog ecosystem.						
GOAL / OBJECTIVE: 1.1 Collect data related to oil and gas development impacts on prairie dogs and their ecosystems.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Design optimal methodologies to document prairie dog population dynamics in active oil and natural gas fields (long term population biology studies).	CDOW, Universities	Industry, BLM, USFS	Design by 2010 (tied to completion of the review team)	.5 FTE		
Promote prairie dog research agenda within Academia and research institutions.	CDOW (Nesler)		By 2010 and ongoing			
Monitor for the effects of oil and natural gas on associated species, per established methodologies and by trained biologists.	CDOW, Industry	BLM, USFS	Initiate by 2010 and ongoing	~$150,000 per year		
Document potential habitat prior to developments. Analysis should include mapping of suitable and occupied habitat, use of GIS to determine spatial distribution of these areas, estimates of local population densities, and evaluation of dispersal potential between suitable habitat patches within each complex.	CDOW, Industry, BLM, USFS (depending on project)		Initiate by 2010 and ongoing	50,000 per field per year		
Develop an MOU and central repository for prairie dog and associated data.	CDOW	BLM, Private Industry, USFS, COGCC	Complete by 2010	.5 FTE		
Provide data to COGCC in order to put prairie dog colony information on Website to share with Industry.	CDOW	COGCC	Start immediately, ongoing			
Identify funding sources necessary to document prairie dog population dynamics in active oil and natural gas fields.	PD Steering committee	NRCS	Complete as Appendix to Plan by Dec 31, 2007			
Explore possibility to share most recent relevant GIS data between agencies and industry.	LPEC	CDOW, COGCC, COGA, IPAMS	Initiate by July 2007			

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GOAL / OBJECTIVE: 1.1 Collect data related to oil and gas development impacts on prairie dogs and their ecosystems.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Assemble interagency review team to review prairie dog research and monitoring methods.	CDOW	BLM, USFS, USFWS, NGOs, DNR, USGS	Complete by 2009			
Evaluate "on-the-ground" effectiveness of oil and natural gas best management practices for prairie dogs and their ecosystems (research).	CDOW		?			
Define high quality prairie dog habitat. Share definitions with partners.	Prairie dog experts	CDOW, USFWS, BLM, USFS	Complete by 2009 and ongoing			
Research appropriate seed mixes and seed application techniques for prairie dog reclamation and site potential with respect to prairie dog productivity.	BLM, NRCS	USFS, Seed supply companies				
Utilize Rangely oil and natural gas field for research data on prairie dog *ecosystem* / oil and natural gas development interactions (High development situation).	CDOW, Academia, Rangely Field Operator		Initiate by 2010 with Field Operator	$100,000 per year		
Research: Audible component of oil and natural gas development affects to prairie dog dynamics. (This could be a component of other research projects)	CDOW, Academia		Complete with other research			
Research is needed regarding anthropogenic (sp.) activity affects to prairie dog dynamics (physiological, social, etc.) (Assumption: Public *sees* prairie dogs so they are "okay").	Academia	CDOW	Complete by 2013			

PROBLEM / ISSUE: 1. The understanding of oil and gas activities is insufficient to determine the affects to prairie dog populations and spatial distributions. Data related to oil and gas impacts on prairie dogs and their ecosystems are insufficient to make robust management decisions. Drilling is occurring at a pace where it will be difficult to wait for research results and effectively conserve the prairie dog ecosystem.						
GOAL / OBJECTIVE: 1.1 Collect data related to oil and gas development impacts on prairie dogs and their ecosystems.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Initiate a systematic regional public perception surveys of prairie dogs. Include a public awareness program. (Appropriate reference: Andelt 1999; Wildlife Society Bulletin & Rich Reading, Denver Zoo)	Academia	CDOW, Private Survey Company	Complete by 2009			
Design and implement research project that compares public perception of prairie dog pop health to actual field health (Potential Area; Rangely Field, Urban / oil and gas interfaces)	Academia	CDOW, Private Survey Company	Following completion of survey.			

PROBLEM / ISSUE: 1. The understanding of oil and gas activities is insufficient to determine the affects to PD populations and spatial distributions. Data related to oil and gas impacts on prairie dogs and their ecosystems are insufficient to make robust management decisions. Drilling is occurring at a pace where it will be difficult to wait for research results and effectively conserve the prairie dog ecosystem.						
GOAL / OBJECTIVE: 1.2 Develop adaptive prairie dog best management practices that utilize the best available information.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Develop prairie dog oil and gas best management practices (after review of other State's BMPs).	CDOW, BLM, USFS, COGCC		Complete by July 2008, per law above			
Review existing Industry oil and gas best management practices and Agency BMPS (e.g Gold Book) and their relevance to prairie dogs and their ecosystems. Include invasive non-native species control BMPs.			Start immediately, Compile by January 2008			
Annually, as more data are available, review oil and gas best management practices.			Annually, beginning 2009			
Require on-the-ground compliance monitoring to insure implementation of best management practices						

PROBLEM / ISSUE: 1. The understanding of oil and gas activities is insufficient to determine the affects to PD populations and spatial distributions. Data related to oil and gas impacts on prairie dogs and their ecosystems are insufficient to make robust management decisions. Drilling is occurring at a pace where it will be difficult to wait for research results and effectively conserve the prairie dog ecosystem.						
GOAL / OBJECTIVE: 1.3 Complete more field surveys to map occupied and potential habitat.						
ACTION/STRATEGY	LEAD RESPONSIBLE PARTY(IES)	OTHER RESPONSIBLE PARTIES	TIMELINE*	COST**	Obstacles	Consequences of no action
Evaluate changes in distribution and population densities at sites prior, during, and after development.	CDOW	BLM, USFS	Ongoing			
Evaluate colonization rates and distribution after wells are removed.	CDOW	BLM, USFS	Ongoing			
Monitor for the effects of O&G on associated species.	CDOW	BLM, USFS	Ongoing			
Refine PD range mapping, including vegetation characteristics.	CDOW	BLM, USFS	Ongoing			
Document potential habitat prior to developments. Analysis should include mapping of suitable and occupied habitat, use of GIS to determine spatial distribution of these areas, estimates of local population densities, and evaluation of dispersal potential between suitable habitat patches within each complex.	CDOW, Industry, BLM, USFS (depending on project)		Initiate by 2010 and ongoing	50,000 per field per year		
Review and compile existing mapping data from agencies and industry.	CDOW, Industry, BLM, USFS (depending on project)					
Review historical research and compile distribution data in maps.	CDOW	Academia, BLM, USFS, USFWS (ferret clearances), Industry				

PROBLEM / ISSUE: 1. The understanding of oil and gas activities is insufficient to determine the affects to PD populations and spatial distributions. Data related to oil and gas impacts on prairie dogs and their ecosystems are insufficient to make robust management decisions. Drilling is occurring at a pace where it will be difficult to wait for research results and effectively conserve the prairie dog ecosystem.						
GOAL / OBJECTIVE: 1.3 Complete more field surveys to map occupied and potential habitat.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Standardize appropriate ecological scale for mapping i.e vegetation community classification.	CDOW	Nature Serve, CNHP, USGS, NRCS				
Following surveys, share relevant prairie dog data. Develop minimum consistent mapping/survey methodology (e.g. UTM location) to facilitate data sharing.	Industry, CDOW,					

PROBLEM / ISSUE: 2. Oil and gas development may result in habitat loss, degradation, and loss of connectivity between colonies, partially due to the speed at which it is occurring.						
GOAL / OBJECTIVE: 2.1 Increase the number of areas where conserving PD ecosystems is the primary objective.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Identify high quality PD habitat with conservation potential and work toward protective management of these areas.						
Develop collaborative agreements between private and public land interfaces for PD conservation areas.						
Develop and fund voluntary economic incentives for private landowners.						
Designate large complexes as special management areas for PDs (e.g. ACEC designation).						

PROBLEM / ISSUE: 2. Oil and gas development may result in habitat loss, degradation, and loss of connectivity between colonies, partially due to the speed at which it is occurring.						
GOAL / OBJECTIVE: 2.2. Minimize habitat loss and degradation through temporal and spatial planning, with components related to connectivity.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Develop realistic rules-of-thumb for traffic densities considering the need for colony connectivity.						
Develop potential mitigation measures (e.g. speed limits, seasonal speed limits) to improve connectivity.						
Plan oil and gas field developments in order to allow for sustainable prairie dog colonies.						
Optimize pad size/pad construction based on topographic features and relationship with prairie dog colonies.						
Develop reclamation requirements to allow for prairie dog movement and recolonization.						
E.g. Reseeding 30 feet inside of level pad area. Implement gradual cut/fill slopes						
Ensure rapid interim reclaim and revegetation.						
Minimize the number of well pad and maximize habitat patch size through co-location and directional drilling, when possible.						
Utilize collector roads to access multiple well sites in order to minimize impacts in prairie dog habitat areas.						

PROBLEM / ISSUE: 2. Oil and gas development may result in habitat loss, degradation, and loss of connectivity between colonies, partially due to the speed at which it is occurring.

GOAL / OBJECTIVE: 2.2. Minimize habitat loss and degradation through temporal and spatial planning, with components related to connectivity.

ACTION/STRATEGY	LEAD RESPONSIBLE PARTY(IES)	OTHER RESPONSIBLE PARTIES	TIMELINE*	COST**	Obstacles	Consequences of no action
Project design of O&G facilities in occupied and suitable habitat should include location of wells and roads outside of these areas, consideration of directional drilling when wells are proposed within suitable and occupied habitat, timing restrictions of vehicle travel to periods when PDs are less active, and regulation of type of vehicle traffic.						
Revision of Land Use Plans to manage leasing and development in prairie dog complexes to address prairie dog management needs and maximize habitat potential to prevent further prairie dog habitat loss.						
Use larger scale planning (i.e. geographic area plans) to adequately address cumulative impacts of oil and gas development.						

PROBLEM / ISSUE: 2. Oil and gas development may result in habitat loss, degradation, and loss of connectivity between colonies, partially due to the speed at which it is occurring.						
GOAL / OBJECTIVE: 2.3. Mitigate impacts in a timely fashion.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Ensure rapid interim reclaim and revegetation.						
Put requirement for rapid interim reclaim and revegetation in COAs.						
Develop phase specific optimal seed mixes for rapid prairie dog habitat reclamation with respect to long term prairie dog productivity and larger prairie dog ecosystem sustainability.						
Develop and require performance based revegetation standards based on site potential.						
Bonding						

PROBLEM / ISSUE: 2. Oil and gas development may result in habitat loss, degradation, and loss of connectivity between colonies, partially due to the speed at which it is occurring.						
GOAL / OBJECTIVE: 2.4. Private and public land managers should be educated in WTPD / GPD issues and concerns for implementation of project mitigations for prairie dog management for short-term and long-term management						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Encourage special status species designation by agencies for prairie dogs (e.g. BLM sensitive and CDOW species of concern).						
Encourage additional participants in the WAFWA Prairie Dog Conservation Team to promote an interdisciplinary environment.						
Evaluate need for short-term interdisciplinary prairie dog management direction workshop.						
Develop long-term interdisciplinary prairie dog management direction workshop based on prairie dog best management practices.						

PROBLEM / ISSUE: 3. Other associated components of the prairie dog ecosystem may not tolerate certain aspects of oil and gas development activities. Preserving only the prairie dog populations in the ecosystem may not be enough to preserve the functional integrity of the system.						
GOAL / OBJECTIVE: 3.1. Management of oil and gas field developments should focus on prairie dog habitat components (veg, soils, perches, burrows, etc) that maintain the functional integrity of the system.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Attempt to preserve large blocks of habitat necessary for prairie dog ecosystem components.						
Investigate opportunities and provide incentives for phased energy development.						
Preserve prairie dog populations/habitat in a context that other species can still use.						

Prioritized List of Objectives

1) Maintain connectivity between colonies to the maximum extent possible. [38]
2) Minimize habitat loss and degradation through temporal and spatial planning. [37]
3) Develop adaptive PD BMPs that utilize the best available information. [36]
4) Conserve the functional integrity of the system in order to sustain all the dependent components. [30]
5) Collect data related to O&G impacts on PDs and their ecosystems. [29]
6) Complete more field surveys to map occupied and potential habitat. [24]
7) Mitigate impacts in a timely fashion. [22]
8) Increase awareness of land manager to PD needs. [19]
9) Increase the number of areas where conserving PD ecosystems is the primary objective. [15]

White-Tailed and Gunnison's Prairie Dogs in Colorado
Statewide Conservation Planning Workshop

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VI
Plague and Drought

Plague and Drought Working Group Report

Working Group Participants:
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Issue Generation

Our working group used a brainstorming technique to generate the following list of issues related to the impacts of plague and drought on prairie dogs in Colorado:

- The issue of plague transmission from other reservoirs (other rodents) is poorly known
- Do mild winters and wet springs increase likelihood of plague? What about warm years followed by warm and moist years? What are the environmental cues that increase the likelihood of plague transmission?
- The general scenario of how plague functions isn't well understood
- Our understanding of plague dynamics in prairie dog colonies is unclear
- What are the specific effects of plague on prairie dogs?
- What can be done to mitigate plague events?
- Prairie dog burrows not as easy to identify
- What is the best unit of management when dealing with plague? Managing fleas rather than prairie dogs or other rodents
- How are outbreaks identified? It is not easy to detect plague in either prairie dogs or fleas
- Monitoring efforts are difficult to design and maintain, and expensive
- Spatial resolution in monitoring schemes (e.g., occupancy monitoring) is not good for plague detection
- What causes plague to become epizootic if it is already present?
- Better understanding of plague will lead to better management
- Plague is more likely to show up in larger colonies, perhaps (not known) because of more contact with more potential carriers
- No data to determine if density is a factor in plague prevalence (largely because it's difficult to determine density in prairie dog colonies)
- No evidence that prairie dogs can or have developed immunity to plague. Plague titers do NOT mean that the individual is immune, only that for some unknown reason it escaped a plague challenge
- Poor understanding of plague immunity in prairie dogs
- Poor understanding of survival of populations in plague events
- Environmental change may influence plague frequency/virulence/transmissible
- Does plague reduce maximum size of colonies and/or fragment colonies and therefore reduce their ecological function in supporting other species?
- Does plague impose an "artificial ceiling" on density of colonies?

- Are population fluctuations that affect structure and density affected by plague in ways that impact ecological function and associated species?
- Plague is also a human disease, so prairie dog management must address potential impacts on human populations
- Does plague cause negative public attitudes towards prairie dogs?

Following the brainstorm session, we consolidated these statements into five issues and then prioritized them based on the importance of resolving the issue for developing the statewide prairie dog conservation plan. Feasibility, cost, and conservation benefit were also briefly considered, but the relevance to the statewide plan was seen as the primary criterion.

1. There is a lack of understanding of the epidemiology and dynamics of plague and its relationship to environmental changes
2. There are currently no effective techniques for large-scale management of plague
3. Our ability to predict and manage plague is hindered by a lack of surveillance and monitoring
4. Population recovery (abundance and local distribution) after epizootics is inconsistent and poorly understood
5. Plague has potentially negative effects on human health and public perception of prairie dogs.

Our overarching theme for the group's discussions is that plague is the largest threat to both species of prairie dogs in Colorado.

Some additional thoughts on this topic:

- CDC involvement would be good, funding would follow. Vaccines would be highly valuable if fully developed (example of raccoon rabies in east). Chris noted that we're "close" to an oral vaccine.
- We did NOT address other diseases (tularemia, west Nile) as there is little or no information, but we recognize that other diseases may impact prairie dog populations.
- Inbreeding could result from reduced population size. (Trudeau, K.M., H.B. Britten and M. Restani. 2000. Sylvatic plague reduces genetic variability in black-tailed prairie dogs. J. Wildl. Dis. 40(2):205-211.)

Objectives and Strategies

The following pages list the objectives and strategies designed to directly address those issues developed earlier.

PROBLEM / ISSUE: 1. There is a lack of understanding of the epidemiology and dynamics of plague and its relationship to environmental changes

GOAL / OBJECTIVE: 1.1. Improve our understanding of the epidemiology and dynamics of plague (L)

ACTION/STRATEGY	LEAD RESPONSIBLE PARTY(IES)	OTHER RESPONSIBLE PARTIES	TIMELINE*	COST**	Obstacles	Consequences of no action
Conduct research to determine whether plague is enzootic in GUPD and WTPD (animal study-individual sampling of host and vectors) a. Intensively monitor a minimum of 10 colonies throughout the range for evidence of exposure to plague (presence of antibodies)	CDOW: Wildlife Health Program (Martin) USGS (Biggins) Universities (Ray)	USFWS NPS BLM CDC USFS WAFWA	3 years	125K annually		
Develop a map/database that tracks the frequency and geographic distribution of plague across the landscape in WTPD and GUPD and populate with historic data (see below) PRODUCT: Map and database, ongoing maintenance	CDOW: Wildlife Conservation (Skiba) Wildlife Health (Martin) and GIS (Eichhoff)	BLM NPS USFS CDPHE County & City Health Depts. WAFWA Other states (MT, WY, UT, NM, AZ)	1 year	5K		
Monitor adjacent/nearby colonies and potential movement corridors to those undergoing outbreaks to determine the timing and mechanisms of movement of plague by sampling potential hosts and carrier species (e.g., coyote) a. Study design (completed in 1 year) b. Issues with landowner buy in c. Budget flexibility needed—rapid response team	CDOW: Wildlife Health (Martin) Wildlife Conservation (Skiba)	CDC CDPHE County and city health depts. WAFWA	3-5 yrs Dependent on appropriate situation developing	30K/yr		

PROBLEM / ISSUE: 1. There is a lack of understanding of the epidemiology and dynamics of plague and its relationship to environmental changes						
GOAL / OBJECTIVE: 1.1. Improve our understanding of the epidemiology and dynamics of plague (L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Analyze data and prepare appropriate reports from all of the above	Universities (Ray)	CDOW USFWS **ALL**	Ongoing	30-70K yr		

PROBLEM / ISSUE: 1. There is a lack of understanding of the epidemiology and dynamics of plague and its relationship to environmental changes

GOAL / OBJECTIVE: 1.2. Improve our understanding of the role of environmental change (human induced, climate) in plague outbreaks (L)

ACTION/STRATEGY	LEAD RESPONSIBLE PARTY(IES)	OTHER RESPONSIBLE PARTIES	TIMELINE*	COST**	Obstacles	Consequences of no action
Monitor (presence/absence)a substantial number of colonies annually to help understand the temporal patterns of plague across the landscape in WTPD and GUPD as influenced by environmental conditions Need to determine percentage of colonies that are impacted by plague with some level of certainty (e.g., 5% at 90% certainty over 5 years; in MT, 300 roughly contiguous colonies in southern Phillips County. 12 years of data yielded some useful patterns).	CDOW: Wildlife Health Program (Martin) Wildlife Conservation (Skiba)	USFWS NPS BLM CDC Universities (CU, CSU, etc), USGS USFS WAFWA	10 + years	300K /year		
Gather adequate information on environmental conditions (precipitation and temperature, etc.) on Management Emphasis Areas for WTPD and GUPD via standard weather stations—daily temperature and precipitation, humidity, soil temperature, soil humidity	CDOW: Wildlife Conservation (Skiba)	BLM USFS NPS USFWS WAFWA	ONGOING	2 wks/yr 15k/yr		
Characterize and map topographic relief, percent water/riparian, percent prairie dog colony, vegetation characteristics, etc, on Management Emphasis Areas a.GAP analysis b.Basinwide vegetation	CDOW: Wildlife Conservation (Skiba) GIS (Eichhoff)		1 year	5K/yr		

PROBLEM / ISSUE: 1. There is a lack of understanding of the epidemiology and dynamics of plague and its relationship to environmental changes						
GOAL / OBJECTIVE: 1.2. Improve our understanding of the role of environmental change (human induced, climate) in plague outbreaks (L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Examine existing historical datasets to elucidate relationships between environmental factors and plague outbreaks in GUPD and WTPD Product: Published report	CDOW: Wildlife Health (Martin) Wildlife Conservation (Skiba)	University (grad student)	2yr	50K		
Conduct research to determine if other small mammal populations increase in or after wet years leading to plague outbreaks in GUPD and WTPD in representative colonies (minimum of 5 for each species) Product: Published report(s)	CDOW: Wildlife Health Program (Martin) Universities (Ray)	USFWS NPS BLM CDC USFS USGS, WAFWA	10 years	10K/year		
Analyze data and prepare appropriate reports from all of the above Product: Published report(s)	Universities (Ray)	CDOW USFWS **ALL**	Ongoing	30-70K yr		

PROBLEM / ISSUE: 2. There are currently no effective techniques for large-scale management of plague						
GOAL / OBJECTIVE: 2.1. Develop effective management techniques to ensure large scale population resilience in the presence plague (L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Complete development and testing of oral vaccine for plague in prairie dogs	USGS Tonie Rocke	WAFWA	Ongoing	Consult with USGS		
Test oral vaccine efficacy in different field situations for both GUPD and WTPD Product: Published report(s)	USGS Tonie Rocke	WAFWA CDOW: Wildlife Health	3-5 yr after vaccine availability	Consult with USGS		
(This is for smaller scale management) Document efficacy of burrow dusting efforts and apply appropriately – some data already exists –Biggins Cost estimate based on limited application(150 acre colony, based on NPS work) Product: Published report(s)	NPS (Curecanti) County Health Depts (Mesa, Steve DeFeyter)	CDC USGS CDOW-State Wildlife Areas	2-3 yrs	5K/yr		
Adaptively apply management techniques developed in Issue 1b (e.g: habitat manipulation) to manage environmental characteristics to manage the spread of plague Products: 1. Interagency coordinated management plan for plague. 2. Acres treated/year and displayed in GIS format Dependent on development of effective techniques and occurrence of plague	CDOW:Wildlife Conservation (Skiba) BLM (Borthwick) NPS (Stahlnecker) NRCS (Marymor)	USFS USFWS-refuges, Partners for Wildlife Private landowners	Ongoing	Unknown, but could be very high—both plan cost and manipulation cost (approx $100/acre)		

PROBLEM / ISSUE: 2. There are currently no effective techniques for large-scale management of plague						
GOAL / OBJECTIVE: 2.1. Develop effective management techniques to ensure large scale population resilience in the presence plague (L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Determine and maintain spatial distribution and size of prairie dog complexes to best result in resilience to plague (what natural distribution is most effective). [This is a preferred long term strategy to deal with plague in prairie dogs] Depends on output from Issue 1. Product: Published report(s) Product: Viable metapopulations of WTPD and GUPD (will determine risk of extinction).	CDOW: Wildlife Conservation (Skiba) Universities (Ray)	BLM USFS USFWS-Refuges, Partner for Wildlife NPS NRCS Private landowners	3-5 yrs to develop, then ongoing	200K		
Implement						
Maintain large numbers of prairie dogs across landscape						

PROBLEM / ISSUE: 3. Our ability to predict and manage plague is hindered by a lack of surveillance and monitoring						
GOAL / OBJECTIVE: 3.1. Develop and implement appropriate surveillance and monitoring strategies to: a. Facilitate further research and analysis of plague dynamics (L) b. Facilitate immediate management of plague outbreaks (L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Review and analyze existing datasets for efficacy of past monitoring and surveillance efforts: Curecanti, CDPHE, CDC, County and City health depts. Product: Published Report(s)	CDOW: Wildlife Health (Martin)	Curecanti, CDPHE, CDC, County and City health depts. WAFWA	1 yr	5K		
Determine spatial and temporal structure of surveillance and monitoring sites needed to provide necessary data Product: Published Report(s)	CDOW: Wildlife Conservation (Skiba) Wildlife Health (Martin) Universities (Ray)	WAFWA	1 yr	15K		
Develop mechanism for dissemination of data to research and management agencies Product: Outreach plan	CDOW: Wildlife Health (Martin)	BLM, USFWS USFS, NPS Other land use agencies WAFWA	1 yr	5K		
Implement monitoring and surveillance efforts in areas targeted for research needs Product: Monitoring and Surveillance plan	CDOW: Wildlife Conservation (Skiba) Universities (Ray)	WAFWA	10 yrs	10k/yr		
Implement monitoring and surveillance efforts for management needs Product: Monitoring and Surveillance plan	CDOW: Wildlife Health (Martin) Wildlife Conservation (Skiba)	BLM, USFWS USFS, CDPHE Other land use agencies, CDC WAFWA, NPS County and city health depts.	Ongoing	50k/yr		

PROBLEM / ISSUE: 4. Population recovery (abundance and local distribution) after epizootics is inconsistent and poorly understood						
GOAL / OBJECTIVE: 4.1. Develop an understanding of population recovery after epizootics (L) 4.2. Determine feasibility and efficacy of, and implement techniques to assist in population recovery (L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Monitor post-outbreak colonies to determine persistence of plague in non-prairie dog hosts	CDOW: Wildlife conservation (Skiba)	All Land mgmt agencies CDPHE County and city health depts	10 yr	20k/yr		
Monitor prairie dog population dynamics and demography to understand post-outbreak recovery	CDOW: Wildlife conservation (Skiba)	All Land mgmt agencies	10 yr	40k/yr		
Sample prairie dogs that survive an epizootic to estimate the proportion of survivors that were exposed to plague (some individuals may escape exposure and some exposed animals will not succumb to plague)	CDOW: Wildlife Health (Martin) Wildlife conservation (Skiba)	County and city health depts. (collection) CDC	5 yrs	5k/yr		
Determine if population reduction caused by plague results in a decrease in heterozygosity in GUPD and WTPD	CDOW: Wildlife conservation (Skiba) Universities (Ray) Wildlife Health (Martin)	BLM, USFS NPS, USFWS - refuges	20 yrs	50k/yr		
Determine if plague leads to a long term reduction in peak population size after recovery	CDOW: Wildlife conservation (Skiba)	BLM, USFS NPS, USFWS – refuges, USGS	50 yr	1.5M		
Determine characteristics of corridors that influence the recovery of post-plague populations	CDOW: Wildlife conservation (Skiba) GIS (Eichhoff) Univeristies (Ray)	BLM, USFS NPS, USFWS – refuges, USGS Private landowners	10 yr	50k/yr		

PROBLEM / ISSUE: 4. Population recovery (abundance and local distribution) after epizootics is inconsistent and poorly understood						
GOAL / OBJECTIVE: 4.1. Develop an understanding of population recovery after epizootics (L) 4.2. Determine feasibility and efficacy of, and implement techniques to assist in population recovery (L)						
Determine if relocation (supplementation) is an effective technique for improving recovery of post-plague populations	CDOW: Wildlife conservation (Skiba) Wildlife Health (Martin)	BLM, USFS NPS, USFWS – refuges USGS, Private landowners	5 yrs	50k/yr		
Implement techniques that are determined to be effective to enhance post-plague recovery	CDOW: Wildlife conservation (Skiba)	BLM, USFS NPS, USFWS – refuges USGS, Private landowners NRCS	Ongoing after development of information	Unknown as techniques unknown--$100/acre for habitat manipulation		

PROBLEM / ISSUE: 5. Plague has potentially negative effects on human health and public perception of prairie dogs.						
GOAL / OBJECTIVE: 5.1. Improve awareness of the value of prairie dogs and the role of prairie dogs in plague dynamics (S and L)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Improve public understanding of the role of prairie dogs in plague epidemiology: • Website • Pamphlets • Radio and TV shows	CDOW: Education	CDOW: Wildlife Health (Martin)	Ongoing	10k/yr		
Improve public understanding of the role of prairie dogs in ecosystems: • Website • Pamphlets • Radio and TV shows	CDOW: Education	CDOW: Wildlife Conservation (Skiba)	Ongoing	10k/yr		

White-Tailed and Gunnison's Prairie Dogs in Colorado Statewide Conservation Planning Workshop

16 – 18 May, 2007
Grand Junction, Colorado

VII
Shooting

Shooting Working Group Report

Working Group Participants:
Richard Borcherdt
Brad Petch, Colorado Division of Wildlife (Recorder)
Bill de Vergie
Scott Wanstedt
Landel Weddle
Jenna Borovansky, CBSG (Facilitator)

Issue Generation

The working group developed the following list of issues pertaining to the biological, social and economic consequences of prairie dog shooting as a method of population control across the state:

- Is there a problem with declining populations of these two species of prairie dogs? Is this beyond the scope of this group?
- Public versus private land should be discussed as far as shooting.
- What is the level of harvest via shooting? What is the impact at the local level and the population level?
- Is behavior is altered under shooting issues. Is this a problem?
- Seasonal closure prevents prairie dog control, leading to damage of local rangelands
- Local communities / counties can get the short end of the stick in statewide processes. How do counties deal with the desires of local communities in the context of the desires of a statewide group?
- What are the impacts of shooting on non-target species?
- Loss of income due to shooting restrictions – head fees charged by ranches, small game license sales, motel income, sales of ammo and expensive rifles and scopes.
- Interaction of plague and shooting – does it pose additional risk to prairie dog population viability?
- Is shooting an effective measure for control of prairie dogs?
- Management difficulties across public vs. private lands.
- What impact does shooting have on the prairie dog populations as a whole?
- What are our data gaps on this issue? Damage by prairie dogs during seasonal closure vs. damage to prairie dog population in the absence of the seasonal closure.
- Social issues of hunting versus non-hunting public.
- Not consuming prairie dogs. Some of the public does not accept this as a legitimate recreational use of wildlife.
- Balancing the opportunity for recreation versus species conservation.
- Is shooting better than poisoning as a means of prairie dog control? What are the relative pros and cons among these two methods?

Further review and discussion among group members led us to create the following five prioritized problem statements:

1. The issue of prairie dog shooting is highly polarized across the general public
2. Shooting may have potential detrimental impacts on prairie dog population dynamics, perhaps leading to longer-term population decline
3. There are socio-economic benefits, as well as potential gains or losses to shooting prairie dogs, thereby strengthening the debate over the topic
4. There is a general lack of reliable information on the current levels of harvest, the specific types of impact to prairie dog populations, and the impacts on non-target species
5. Prairie dogs have detrimental impacts on property, making shooting a desirable method of population control under some circumstances.

Information Assembly and Analysis

The group spent some time reviewing the information presented by CDOW's Amy Seglund on prairie dog biology and potential threats to their long-term viability. The following gives a summary of the issues discussed.

Previously CDOW has not looked at these two prairie dog species separately, but only as it related to black-footed ferret conservation. However, given the recent petition to list one or both of these species, CDOW has started to look at how to manage prairie dogs. We are here because of CDOW's interest in management of these species.

We do not have a lot of information on shooting impacts on these two species of prairie dogs or non-target species.

Is the public vs. private lands issue something for our group to address? After all, we don't have very much information on the ways in which these two hunting practices differ. At present, little hunting appears to take place on private lands in April. Most hunting takes place in May and June. There is some hunting over the summer July-August and maybe a little in September. We really do not know what the effect of the current closure on public lands (March 1 – June 14th) as this is the first year of the closure. Available research (mostly antidotal) suggests that hunting is much less on white-tailed and Gunnison's than on black-tailed prairie dogs. In addition, public lands get more hunting pressure than private lands. There are not the big hunting clubs that specialize in prairie dog hunting on private lands (and sell themselves to landowners as a "help" with prairie dog control) on white-tailed and Gunnison's prairie dogs like there are on black-tailed prairie dogs. However there are some "unofficial" groups of folks who do hunt so there is some of the issue of specialized hunting occurring on WTPD & GPD on private lands.

Analysis of the distribution of white-tailed and Gunnison's prairie dogs indicates that the majority of their habitat is on public land – so is shooting on private land really an issue? A more detailed analysis indicates that about 50% of Gunnison prairie dog habitat is on public land so the issue is more tightly focused with this species.

We next looked at the issue of the effect of the seasonal closure on public lands. Currently, the HIP System is the only one we have for data on this. However this data will be very general and may not give us the data we need to determine the overall effect of the closure. When people hunt on public land they actually spend more time driving than shooting. The next group looking at kill rates on white-tailed and Gunnison's prairie dogs. The group thinks that fifty prairie dogs a day is a high number (although black-tailed prairie dogs can go as high as 150 per day per hunter). The group agrees that 25-50 is the range for most hunters in white-tailed and Gunnison's prairie dog range. We looked at the HIP data and feels that it may be a bit high in terms of harvest numbers. Some concern exists over using these data to figure out the difference between shooting intensity and impact on public and private lands. Can we recommend some sort of voluntary measures on prairie dog harvest?

Objectives and Strategies

The following pages list the objectives and strategies designed to directly address those issues developed earlier.

PROBLEM / ISSUE: 1. The issue of prairie dog shooting is highly polarized across the general public						
GOAL / OBJECTIVE: 1.1. Improve public understanding of the effects of shooting on prairie dog populations 1.2. Improve public understanding of the status and trends of prairie dog populations (numbers & distributions) 1.3. Improve public understanding of current regulatory and management actions						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Create internet educational site (aiming at more urban audiences, primarily non-hunters) that addresses all three goals	CDOW	CSU Extension; Other State Game & Fish Agencies; WAFWA	2 year			
Approach other organizations; shooting & environmental to find out interest in education efforts on prairie dog shooting and populations. Encourage a unified message	CDOW		6 months		Groups may not want to work together	
Launch education efforts via newspapers, brochures, television?	CDOW	Shooting organizations	1 year			
Study of demographic information on public and what different publics feel about prairie dogs and shooting	CDOW		1 year			
Continue to inform hunters on prairie dog regulations in small game brochures	CDOW		ongoing			

PROBLEM / ISSUE: 2. Shooting may have potential detrimental impacts on prairie dog population dynamics, perhaps leading to longer-term population decline						
GOAL / OBJECTIVE: 2.1. Maintain sustainable prairie dog populations while providing for recreational opportunities						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Provide for local management flexibility on a site specific basis. Institute emergency closure if necessary (may have to do public land only) because of plague. Limit harvest if warranted up to closing areas.	CDOW		1 year			
Identify ways to encourage sport shooters to concentrate on private lands where populations are high.	CDOW		1 year	0.5 FTE; 20K for landowner signup		
Evaluate population impacts of closure on prairie dogs (using existing data sources; HIP) to improve available information.	CDOW		2 year	0.25 FTE		
Modify HIP to allow for additional information on prairie dogs . Number of prairie dogs harvested, public versus private land hunting. Hunting days. Location by GMU.	CDOW		2 Year			
Try separate HIP permit for Gunnison and White-tailed prairie dogs. Follow up with a phone survey on harvest information.	CDOW		2 year	10K for phone survey		
Encourage prairie dog hunters to keep logbooks. The logbook would be provided online and provided at CDOW offices. Allow prairie dog hunters to enter logbook information online.	CDOW		2 year			

Initiate a walk-in-access program for prairie dogs. Idea would be to move the areas around from year to year	CDOW		5 year		Lack of good data on when to close an area. Getting word out to the public that an area is closed. Enforcement of closures on private may not be enforceable.	
Encourage hunters to not shoot small colonies	CDOW		2 year		Hunters may not be able to judge what is a 'small colony'	

PROBLEM / ISSUE: 3. There are socio-economic benefits, as well as potential gains or losses to shooting prairie dogs, thereby strengthening the debate over the topic						
GOAL / OBJECTIVE: 3.1. Preserve and enhance the recreational opportunity and resulting economic benefits 3.2. Demonstrate the economic benefit of shooting						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Institute closures only on a temporary (review all closures on a 1 to 5-year cycle) basis using a biological need. Use best available information.	CDOW		1 year			Permanent closures which reduce economic benefits
Investigate opportunities to assist landowners with promoting shooting on their properties (with access fees) as a way to promote landowners being more accepting of prairie dogs on there lands.	CDOW					
See walk in strategy.	CDOW	Counties, tribal, County extensions	2 year			
Add a prairie dog shooting specific element to CDOW economic analysis	CDOW	USFWS	At next update to CDOW economic analysis.	5K		

PROBLEM / ISSUE: 4. There is a general lack of reliable information on the current levels of harvest, the specific types of impact to prairie dog populations, and the impacts on non-target species						
GOAL / OBJECTIVE: 4.1. Collect information to determine impacts of shooting on prairie dogs						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Spatial analysis of impacts of hunting. Where are hunters, where are prairie dog towns (idea that hunters typically do not walk more then ¼ mile to a dog town from a road). Try to identify areas that may be experiencing high take. Field interviews of hunters by DWM's to collect data	CDOW	University, Hunters	1 year	0.5 FTE GIS, 0.5 FTE DWM's		
Model via GIS and PVA impacts of harvest on population. Utilize HIP data and additional data to estimate harvest levels on a geographic basis	CDOW	University	3 year	25K per year 4 years		
Investigate potential behavior changes of prairie dogs based on shooting pressure	CDOW	University	3 year	15K per year 2 years		
Evaluate the potential importance of shooting to predator species	CDOW	University	3 year	15K per year 2 years		
Investigate lead impacts on non-target species. Especially take a look at impacts of various expanding rounds, types of rounds (jacketed vs. non-jacketed)	CDOW	University	5 year	50K a year for 2 years		

PROBLEM / ISSUE: 5. There is a general lack of reliable information on the current levels of harvest, the specific types of impact to prairie dog populations, and the impacts on non-target species						
GOAL / OBJECTIVE: 5.1. Continue to allow shooting as a control method						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Provide exemptions to public land closure on a case by case basis (based on damage claim for example on irrigation ditches, reservoirs, dams on BLM property)	CDOW		1 Year			Damage occurring due to no way to control prairie dogs due to conflicting federal and state regulations
Maintain existing regulatory framework that allows shooting as a control method on private and public lands	CDOW	Department Agriculture	ongoing			

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VIII
Urbanization

Urbanization Working Group Report

Working Group Participants:
Michelle Cowardin, Colorado Division of Wildlife (Recorder)
Eric Rechel, Sierra Club Grand Valley
Pam Schnurr, Colorado Division of Wildlife
Steven Westbay, Town of Gunnison
Larry Cerrillo, Ingenuity Enterprises International (Facilitator)

One of our first tasks was to come up with a more precise define of the word "urbanization" in order to present a more coherent picture of the process and its impacts on prairie dogs. After some discussion, we defined the following terms:

- Urban – An area with more than 1 housing unit per acre
- Suburban – An area with 1 housing unit per 1 – 10 acres
- Rural – An area with 1 housing unit per more than 10 acres

Therefore, urbanization refers to the process of any human infrastructure within a geographic area (density related). Is the word urbanization too restrictive?

Issue Generation

The following list gives our view of the issues related to urbanization and its effects on Gunnison's and white-tailed prairie dogs in Colorado:

- Development could lead to direct destruction of prairie dog burrows
- Increased prairie dog mortality resulting from vehicle collisions
- Lack of awareness and knowledge – positive or negative - (public and research)
- Urban interaction with landowners in yards can result in negative outcomes for prairie dogs
- Livestock pastures can threaten prairie dog colony integrity
- Concern of plague and transfer – validate from a residents viewpoint or not
  - worried and it does not exist
  - worried and it does exit
  - transferred to humans, wild and domestic animals
- Lack of knowledge of environmental impacts caused by urbanization
- Noise can lead to behavior modifications
- Water runoff can impair colony function
- Vibration impacts
- Heat islands from excessive development could cause earlier hibernation, further modifying behavior
- Change in water table can affect local ecosystem function
- Loss of habitat
- Habitat quality
- Habitat Fragmentation
- Urbanization
  - Urban Development (houses, retail, infrastructure, noise)
  - Ranchett
  - Increased predation

    - Domestic animals
    - Increased urban predators (red fox, coyotes, skunks, raccoons)
    - Infrastructure as raptor perches
- Land use management Policy
  - Statutory requirements (incorporated vs. unincorporated areas)
  - Uplands vs. valley bottoms
  - Public vs. private lands

This general list was collapsed and prioritized into the following final list of issues for our group:

1. Housing development and urbanization causes habitat fragmentation and permanent loss of prairie dog habitat.
2. There is a lack of knowledge and understanding in sub/urban areas relating to prairie dog.
3. Sub/urban development results in increased predation and disturbance on prairie dogs by domestic pets.
4. Sub/urban development increases *disturbance on prairie dog from recreational activities*, potentially affecting survival and reproduction of prairie dog colonies.
5. Prairie dog habitat is not typically recognized by land-use planning practices related to development and mitigation of impacts.

<u>A further discussion of the scale of issues</u>
The group realized that smaller parcels – specifically, those no more than 10 acres in size – have a set of issue that are quite different than those affecting larger parcels. Consequently, we have outlined these two sets of issues below.

I. Parcels < 10 acres
- Awareness/Knowledge of urbanization's impacts
  Public education (prairie dog biology, disease)
- Relocation
  Finding a group interesting in participating

II. 10 – 35 acre parcels (40 acres if required for analysis)
- Policy Statutory
  Local government
- Loss of habitat
- Fragmentation
- Awareness/Knowledge
  Public education (prairie dog biology, disease)
- Relocation
  Finding a group interesting in participating
- Predation
  Domestic pets
  'Urban' predators

Objectives and Strategies

The following pages list the objectives and strategies designed to directly address those issues developed earlier.

PROBLEM / ISSUE: 1. Housing development and urbanization causes habitat fragmentation and permanent loss of prairie dog habitat						
GOAL / OBJECTIVE: 1.1. Within existing prairie dog habitat, minimize impact of existing development in relation to habitat loss and fragmentation in rural areas (for parcels between 10 – 40 acres)						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Identify and map movement corridors between existing colonies	CDOW	BLM, local governments	Initiated by 2008 and ongoing	0.25 FTE, $5,000		
Identify and map sustainable colonies within sub/urban areas	CDOW	BLM, local governments	Initiated by 2008 and ongoing	0.25 FTE, $5,000		
Work with willing landowners to maintain prairie dogs through conservation easements, land trade, and other land conservation tools	CDOW	land trusts, local governments, NGO	Initiated by 2009 and ongoing	0.25 FTE		
Identify funding sources for land protection	Land Trusts	NGO's, CDOW	Initiated by 2008 and ongoing	0.1 FTE		

PROBLEM / ISSUE: 1. Housing development and urbanization causes habitat fragmentation and permanent loss of prairie dog habitat						
GOAL / OBJECTIVE: 1.2. Within existing prairie dog range minimize habitat loss and fragmentation from future sub/urban development.						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Identify and map movement corridors between existing colonies	CDOW	BLM, local governments	Initiated by 2008 and ongoing	0.25 FTE, $5,000		
Develop best management practices for site development in prairie dog habitat	CDOW	local governments, NGOs	Initiated by 2009 and on-going	0.25 FTE		
Work with willing landowners to maintain prairie dog through conservation easements, land trade, and other land conservation tools	Land Trusts	NGOs, CDOW, local government	Initiated by 2009 and on-going	0.25 FTE		
Work with local governments to develop comprehensive plans and regulatory standards for prairie dog sustainability (see policy strategy)	CDOW	Local governments, NGOs	Initiated by 2009 and on-going	0.5 FTE		

PROBLEM / ISSUE: 1. Housing development and urbanization causes habitat fragmentation and permanent loss of prairie dog habitat						
GOAL / OBJECTIVE: 1.3. Evaluate relocation options within sub/urban areas						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Identify colonies that need to be relocated	NGOs	CDOW, local governments	Initiated by 2008 and ongoing	0.1 FTE, $1000		
Identify and regulate groups to conduct relocation efforts	CDOW		Initiated by 2008 and ongoing	0.1 FTE		
Identify sending and receiving areas for relocation efforts	BLM, USFS	CDOW, NGOs, local governments	Initiated by 2008 and ongoing	0.25 FTE		
Conduct relocation activities of prairie dogs	NGOs		Initiated by 2008 and ongoing	0.3 FTE, $3000		
Evaluate current relocation efforts and study techniques to improve relocation success	CDOW	NGOs	Initiated by 2009 and on-going	0.5 FTE, $1000		

PROBLEM / ISSUE: 2. There is a lack of knowledge and understanding in sub/urban areas relating to prairie dogs						
GOAL / OBJECTIVE: 2.1. Create public outreach materials to increase knowledge and understanding of prairie dogs in the sub/urban landscape						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Develop informational materials regarding prairie dogs in sub/urban landscapes	CDOW	local governments, NGOs	Initiate by 2009 and ongoing	0.1 FTE, $5000		
Develop and implement ongoing outreach program for homeowners regarding prairie dog biology and disease issues and importance to the ecosystem	CDOW	NGOs, local governments	Initiate by 2009 and ongoing	0.1 FTE, $5000		
Prepare, distribute and present informational materials about prairie dog to land-use planners, developers, landowners, realtors, utility companies, relevant agencies and housing residents	CDOW	County Extension Office, local governments	Initiate by 2009 and ongoing	0.1FTE, $5000		

PROBLEM / ISSUE: 2. There is a lack of knowledge and understanding in sub/urban areas relating to prairie dogs						
GOAL / OBJECTIVE: 2.2. Encourage research efforts to develop a better understanding of how prairie dogs interface with sub/urban areas						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Work with institutions to identify research needs	CDOW	Universities, BLM, FWS, NGOs	Initiate by 2009 and ongoing	0.1FTE		
Where feasible, support and identify research projects and funding sources	CDOW	FWS, BLM, Universities	Initiate by 2009 and on-going	0.1 FTE		

PROBLEM / ISSUE: 3. Sub/urban development results in increased predation and disturbance on prairie dogs by domestic pets						
GOAL / OBJECTIVE: 3.1. Reduce predation to pdogs that are associated with sub/urban development						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Encourage enforcement and existence of animal control regulations (leash law).						
Educate landowners on the effects of domestic pets on prairie dog behavior and survival						
Implement relocation efforts if appropriate and feasible						

PROBLEM / ISSUE: 4. Sub/urban development increases *disturbance on prairie dogs from recreational activities*, potentially affecting survival and reproduction of prairie dog colonies						
GOAL / OBJECTIVE: 4.1. Reduce disturbance to prairie dogs from recreational activities						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Plan recreational activity areas that minimize disturbance to prairie dog colonies						
Recommend closure areas to recreational activities on public property (town, county, etc) that have prairie dog activity						

PROBLEM / ISSUE: 5. Prairie dog habitat is not typically recognized by land-use planning practices related to development and mitigation of impacts						
GOAL / OBJECTIVE: 5.1. Work with local governments to amend the Comprehensive Plan to address prairie dog issues						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Educate planners and policy makers						
Provide mapped areas of prairie dog habitat and colonies	CDOW					
Encourage biologist and land managers to work with planners to address prairie dog and development issues						

PROBLEM / ISSUE: 5. Prairie dog habitat is not typically recognized by land-use planning practices related to development and mitigation of impacts						
GOAL / OBJECTIVE: 5.2. Amend local land development codes to address prairie dog issues						
ACTION/STRATEGY	**LEAD RESPONSIBLE PARTY(IES)**	**OTHER RESPONSIBLE PARTIES**	**TIMELINE***	**COST****	Obstacles	Consequences of no action
Provide best management practices and mapped areas for prairie dog management to local government						
Consider overlay zones for habitat protection						
Encourage local governments to use land conservation methods (transfer of development rights, conservation easements)						

White-Tailed and Gunnison's Prairie Dogs in Colorado
Statewide Conservation Planning Workshop

16 – 18 May, 2007
Grand Junction, Colorado

IX
Appendix

Appendix 1

Population Viability Analysis and Simulation Modeling

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Introduction

Thousands of species and populations of animals and plants around the world are threatened with extinction within the coming decades. For the vast majority of these groups of organisms, this threat is the direct result of human activity. The particular types of activity, and the ways in which they impact wildlife populations, are often complex in both cause and consequence; as a result, the techniques we must use to analyze their effects often seem to be complex as well. But scientists in the field of conservation biology have developed extremely useful tools for this purpose that have dramatically improved our ability to conserve the planet's biodiversity.

Conservation biologists involved in recovery planning for a given threatened species usually try to develop a detailed understanding of the processes that put the species at risk, and will then identify the most effective methods to reduce that risk through active management of the species itself and/or the habitat in which it lives. In order to design such a program, we must engage in some sort of predictive process: we must gather information on the detailed characteristics of proposed alternative management strategies and somehow predict how the threatened species will respond in the future. A strategy that is predicted to reduce the risk by the greatest amount – and typically does so with the least amount of financial and/or sociological burden – is chosen as a central feature of the recovery plan.

But how does one predict the future? Is it realistically possible to perform such a feat in our fast-paced world of incredibly rapid and often unpredictable technological, cultural, and biological growth? How are such predictions best used in wildlife conservation? The answers to these questions emerge from an understanding of what has been called "the flagship industry" of conservation biology: Population Viability Analysis, or PVA. And most methods for conducting PVA are merely extensions of tools we all use in our everyday lives.

The Basics of PVA

To appreciate the science and application of PVA to wildlife conservation, we first must learn a little bit about population biology. Biologists will usually describe the performance of a population by describing its demography, or simply the numerical depiction of the rates of birth and death in a group of animals or plants from one year to the next. Simply speaking, if the birth rate exceeds the death rate, a population is expected to increase in size over time. If the reverse is true, our population will decline. The overall rate of population growth is therefore a rather good descriptor of its relative security: positive population growth suggests some level of demographic health, while negative growth indicates that some external process is interfering with the normal population function and pushing it into an unstable state.

This relatively simple picture is, however, made a lot more complicated by an inescapable fact: wildlife population demographic rates fluctuate unpredictably over time. So if we observe that 50% of our total population of adult females produces offspring in a given year, it is almost certain that more or less than 50% of our adult females will reproduce in the following year. And the same can be said for most all other demographic rates: survival of offspring and adults, the numbers of offspring born, and the offspring sex ratio will almost always change from one year to the next in a way that usually defies precise prediction. These variable rates then conspire to make a population's growth rate also change unpredictably from year to year. When wildlife populations are very large – if we consider seemingly endless herds of wildebeest on the savannahs of Africa, for example – this random annual fluctuation in population growth is of little to no consequence for the future health and stability of the population. However, theoretical and practical study of population biology has taught us that populations that are already small in size, often defined in terms of tens to a few hundred individuals, are affected by these fluctuations to a much greater extent – and the long-term impact of these fluctuations is always negative. Therefore, a wildlife population that has been reduced in numbers will become even smaller through this fundamental principle of wildlife biology. Furthermore, our understanding of this process provides an important backdrop to considerations of the impact of human activities that may, on the surface, appear relatively benign to larger and more stable wildlife populations. This self-reinforcing feedback loop, first coined the "extinction vortex" in the mid-1980's, is the cornerstone principle underlying our understanding of the dynamics of wildlife population extinction.

Once wildlife biologists have gone out into the field and collected data on a population's demography and used these data to calculate its current rate of growth (and how this rate may change over time), we now have at our disposal an extremely valuable source of information that can be used to predict the *future* rates of population growth or decline under conditions that may not be so favorable to the wildlife population of interest. For example, consider a population of primates living in a section of largely undisturbed Amazon rain forest that is now opened up to development by logging interests. If this development is to go ahead as planned, what will be the impact of this activity on the animals themselves, and the trees on which they depend for food and shelter? And what kinds of alternative development strategies might reduce the risk of primate population decline and extinction? To try to answer this question, we need two additional sets of information: 1) a comprehensive description of the proposed forest development plan (how will it occur, where will it be most intense, for what period of time, etc.) and 2) a detailed understanding of how the proposed activity will impact the primate population's demography (which animals will be most affected, how strongly will they be affected, will animals die outright more frequently or simply fail to reproduce as often, etc.). With this information in hand, we have a vital component in place to begin our PVA.

Next, we need a predictive tool – a sort of crystal ball, if you will, that helps us look into the future. After intensive study over nearly three decades, conservation biologists have settled on the use of computer simulation models as their preferred PVA tool. In general, models are simply any simplified representation of a real system. We use models in all aspects of our lives; for example, road maps are in fact relatively simple (and hopefully very accurate!) 2-dimensional representations of complex 3-dimensional landscapes we use almost every day to get us where we need to go. In addition to making predictions about the future, models are very helpful for us to: (1) extract important trends from complex processes, (2) allow comparisons among different types of systems, and (3) facilitate analysis of processes acting on a system.

Recent advances in computer technology have allowed us to create very complex models of the demographic processes that define wildlife population growth. But at their core, these models attempt to replicate simple biological functions shared by most all wildlife species: individuals are born, some grow to adulthood, most of those that survive mate with individuals of the opposite sex and then give birth to one or more offspring, and they die from any of a wide variety of causes. Each species may have its own special set of circumstances – sea turtles may live to be 150 years old and lay 600 eggs in a single event, while a chimpanzee may give birth to just a single offspring every 4-5 years until the age of 45 – but the fundamental biology is the same. These essential elements of a species' biology can be incorporated into a computer program, and when combined with the basic rules for living and the general characteristics of the population's surrounding habitat, a model is created that can project the demographic behavior of our real observed population for a specified period of time into the future. What's more, these models can explicitly incorporate random fluctuations in rates of birth and death discussed earlier. As a result, the models can be much more realistic in their treatment of the forces that influence population dynamics, and in particular how human activities can interact with these intrinsic forces to put otherwise relatively stable wildlife populations at risk.

Many different software packages exist for the purposes of conducting a PVA. Perhaps the most widely-used of these packages is *VORTEX*, developed by the IUCN Conservation Breeding Specialist Group (CBSG) for use in both applied and educational environments. *VORTEX* has been used by CBSG and other conservation biologists for more than 15 years and has proved to be a very useful tool for helping make more informed decisions in the field of wildlife population management.

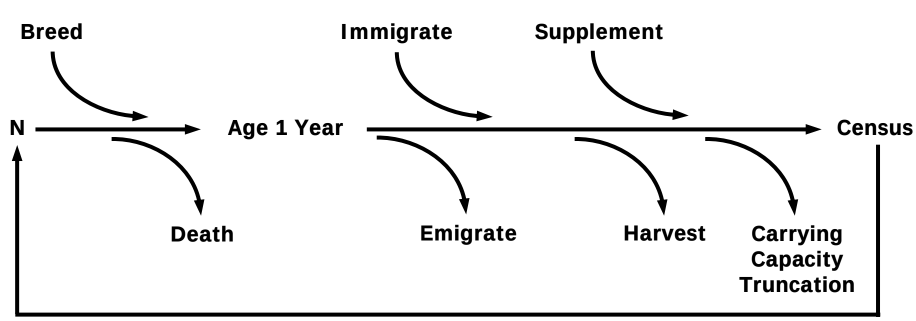
The *VORTEX* Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX Simulation Model Timeline



Events listed above the timeline increase N, while events listed below the timeline decrease N.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. (See figure above.) Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

Further information on *VORTEX* is available in Lacy (2000) and Miller and Lacy (2003).

Strengths and Limitations of the PVA Approach

When considering the applicability of PVA to a specific issue, it is vitally important to understand those tasks to which PVA is well-suited as well as to understand what the technique is not well-designed to deliver. With this enhanced understanding will also come a more informed public that is better prepared to critically evaluate the results of a PVA and how they are applied to the practical conservation measures proposed for a given species or population.

The dynamics of population extinction are often quite complicated, with numerous processes impact the dynamics in complex and interacting ways. Moreover, we have already come to appreciate the ways in which demographic rates fluctuate unpredictably in wildlife populations, and the data needed to provide estimates of these rates and their annual variability are themselves often uncertain, i.e., subject to observational bias or simple lack of detailed study over relatively longer periods of time. As a result, the elegant mental models or the detailed mathematical equations of even the most gifted conservation biologist are inadequate for capturing the detailed nuances of interacting factors that determine the fate of a wildlife population threatened by human activity. In contrast, simulation models can include as many factors that influence population dynamics as the modeler and the end-user of the model wish to assess. Detailed interactions between processes can also be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes.

PVA models have also been shown to stimulate meaningful discussion among field biologists in the subjects of species biology, methods of data collection and analysis, and the assumptions that underlie the analysis of these data in preparation for their use in model construction. By making the models and their underlying data, algorithms and assumptions explicit to all who learn from them, these discussions become a critical component in the social process of achieving a shared understanding of a threatened species' current status and the biological justification for identifying a particular management strategy as the most effective for species conservation. This additional benefit is most easily recognized when PVA is used in an interactive workshop-type setting, such as the Population and Habitat Viability Assessment (PHVA) workshop designed and implemented by CBSG.

Perhaps the greatest strength of the PVA approach to conservation decision-making is related to what many of its detractors see as its greatest weakness. Because of the inherent uncertainty now known to exist in the long-term demography of wildlife populations (particularly those that are small in size), and because of the difficulties in obtaining precise estimates of demographic rates through extended periods of time collecting data in the field, accurate predictions of the future performance of a threatened wildlife population are effectively impossible to make. Even the most respected PVA practitioner must honestly admit that an accurate prediction of the number of mountain gorillas that will roam the forests on the slopes of the eastern Africa's Virunga Volcanoes in the year 2075, or the number of polar bears that will swim the warming waters above the Arctic Circle when our great-grandchildren grow old, is beyond their reach. But this type of difficulty, recognized across diverse fields of study from climatology to gambling, is nothing new: in fact, the Nobel Prize-winning physicist Niels Bohr once said "Prediction is very difficult, especially when it's about the future." Instead of lamenting this inevitable quirk of the physical world as a fatal flaw in the practice of PVA, we must embrace it and instead use our very cloudy crystal ball for another purpose: to make **relative**, rather than **absolute**, predictions of wildlife population viability in the face of human pressure.

The process of generating relative predictions using the PVA approach is often referred to as sensitivity analysis. In this manner, we can make much more robust predictions about the relative response of a simulated wildlife population to alternate perturbations to its demography. For example, a PVA practitioner may not be able to make accurate predictions about how many individuals of a given species may persist in 50 years in the presence of intense human hunting pressure, but that practitioner can speak with considerably greater confidence about the relative merits of a male-biased hunting strategy compared to the much more severe demographic impact typically imposed by a hunting strategy that prefers females. This type of comparative approach was used very effectively in a PVA for highly threatened populations of tree kangaroos (*Dendrolagus* sp.) living in Papua New Guinea, where adult females are hunted preferentially over their male counterparts. Comparative models showing the strong impacts of such a hunting strategy were part of an important process of conservation planning that led, within a few short weeks after a participatory workshop including a number of local hunters (Bonaccorso et al., 1998), to the signing of a long-term hunting moratorium for the most critically endangered species in the country, the tenkile or Scott's tree kangaroo (*Dendrolagus scottae*).

PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models often underestimate the threats facing the population, or the total risk these threats collectively impose on the population of interest. To address this limitation, conservation biologists must try to engage a diverse body of experts with knowledge spanning many different fields in an attempt to broaden our understanding of the consequences of interaction between humans and wildlife.

Additionally, models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (2003) for more details).

Finally, it is also important to understand that a PVA model by itself does not define the goals of conservation planning of a given species. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used.

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