Population Modeling of Prairie Dog Contraception as a Management Tool

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Abstract: Recently, wildlife contraception became a reality with the registration of OvoControl for geese and pigeons. A data submission to the Environmental Protection Agency for the registration of GonaCon™ for white-tailed deer is forthcoming. The question that is now facing wildlife managers is if, and how, to implement contraception as part of an overall management plan. Population models offer a method of predicting the long-term efficacy of management actions without investing time and money in expensive field studies. Black-tailed prairie dogs were used as a target species for the purposes of these models. Four different management options were modeled for a 100-year period including no control, lethal control only, fertility control only, or a combination of lethal and fertility control. Yearly culling resulted in a more rapid rate of population decline than yearly contraception. Culled populations (50-90% culling) went extinct more quickly than populations contracepted at the same rate. Populations could be stabilized at their current size with 12.79% yearly culling or 33.25 % yearly contraception. Populations also remained relatively stable over 100 years when 50% of the population was culled initially, followed by 85.8% contraception once every 3 years. These models will help provide a scientific basis for further discussion on the usefulness of wildlife contraceptives, and will help highlight the areas that need further research.

Key Words: contraception, *Cynomys ludovicianus*, population management, population model, prairie dog

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INTRODUCTION

Wildlife contraception is not a new idea, with studies ranging as far back as the 1960s. Only recently has wildlife contraception become a reality with the registration of OvoControl for Canada geese (*Branta canadensis*) and pigeons (*Columba livia*). OvoControl is an avian contraceptive that prevents eggs from hatching when ingested (Avery et al. 2008, Bynum et al. 2007). A data submission to the Environmental Protection Agency for registration of GonaCon™ for use in white-tailed deer (*Odocoileus virginianus*) is forthcoming. GonaCon™ is an injectible immunocontraceptive that prevents the formation of reproductive hormones by inhibiting the action of gonadotropin releasing hormone (Miller et al. 2000). The question now facing wildlife managers is if, and how, to implement contraception as part of an overall management plan.

Population models offer a method of predicting long-term efficacy of management actions without investing time and money in expensive field studies. Often, data on effects of long-term contraception are unavailable because long-term field studies are too costly. Models can offer managers a scientific basis for implementation.

Several authors have published results of population models of wildlife contraception as a practical management tool and as a means to control wildlife populations (Garrott 1995, Haight and Mech 1997, Courchamp and Cornell 2000, Ellis and Elphick 2007). Results of these papers have varied with type of fertility control proposed, species, and whether fertility control was used alone or in combination with lethal control. In addition, only some models incorporated density dependence, stochasticity, or allowed for immigration and emigration. To be of value to wildlife managers, population models must balance realistic complexity against availability of data to parameterize the model. However, models that only incorporate data from specific geographic areas may not be applicable on a broader scale. If models are to be applicable on a broader scale, ranges of demographic parameters taken from all available literature can be used in a stochastic model. If necessary, models can then be further refined using data from a specific area.

Black-tailed prairie dog (*Cynomys ludovicianus*) management in urban settings is a contentious issue. Many people enjoy seeing these highly social, charismatic animals, but resource managers and property owners must deal with habitat degradation. Prairie dogs often occur in natural areas that are adjacent to or surrounded by urban development. Although colonies regulate themselves through dispersal in an open prairie, these small natural areas provide little opportunity for dispersal. As a result, prairie dogs are forced into small areas where they quickly denude the habitat and must disperse to find adequate food. Conflicts may occur when prairie dogs move into adjacent urban areas and begin grazing on landscaping.

Management of prairie dogs in the past has included poisoning, fumigants, barriers, and relocation (Franklin and Garrett 1989, Robinette et al. 1995, Andelt and Hopper 1998). Acceptance of lethal control methods increases when individuals experience damage to property as a result of prairie dog activities (Zinn and Andelt 1999). However, in recent years, lethal control has become less publicly acceptable. Some nonlethal methods, such as barriers and relocation, tend to be expensive, can be ineffective, and are dependent on available sites (Witmer et al. 2008). Contraception may provide an economical and feasible alternative management method.

The question arises as to why contraception should be considered at all when there are already effective tools available. As mentioned in the previous paragraph, public opinion and public policy may be one driving force behind choosing to use a nonlethal control method. Although lethal control can immediately remove prairie dogs from a site, a sink is created that can be quickly recolonized if there are prairie dogs on adjacent properties. In addition, survival and reproductive rates can increase after a population reduction, either through lethal control or natural means such as a plague outbreak (Knowles 1986, Cully 1997).

Our goal is to provide a broadly applicable, realistic conceptual framework for incorporating contraception into a management plan, using the prairie dog as an example. We had 6 objectives for this paper as follows: 1) model the population with no control, 2) model the population when yearly culling is applied at 50, 60, 70, 80, and 90%, 3) model the population when yearly contraception is applied at 50, 60, 70, 80, and 90%, 4) determine the yearly culling rate that results in maintaining the population at its current size over a 100 year period, 5) determine the yearly contraceptive rate that results in maintaining the population at its current size over a 100 year period, and 6) determine what level of contraception would be needed to maintain the population at half its original size if 50% of the population is initially culled followed by contraception once every 3 years.

METHODS

Because emigration occurs primarily within colonies rather than between colonies (Hoogland 1995, 2003), prairie dog populations were modeled as closed populations using an Excel spreadsheet. In addition, mean emigration and immigration rates reported in the literature are nearly equivalent (Tileston and Lechleitner 1966, Garrett and Franklin 1988, Stockrahm and Seabloom 1988). Populations were modeled using logistic (density dependent) growth in a deterministic model. Density dependence was applied only to the pup survival rate, because this was assumed to be one of the most important mechanisms limiting population growth (White 2000).

Three age classes were used: juvenile, yearling, and adult. Juveniles were defined as animals less than 1 year old. Yearlings were defined as animals between 1 to 2 years of age, and adults were defined as animals greater than 2 years of age. Only adults were allowed to breed in the model. Because pups are raised underground initially, litter sizes are hard to determine immediately after birth. Values reported in literature are usually for litter sizes upon emergence; therefore, this is what is used for the models. Based on initial field data obtained at a colony in Colorado, a constant reproductive rate of 2.8 pups/female was used (Yoder, unpubl. data). The census each year was taken after the birth pulse.

The value used for adult survival (0.52) was based on ranges found in existing literature (Garrett et al. 1982; Crosby and Graham 1986; Hoogland 1995, 2003). The definitions of each parameter or symbol and the equations used to calculate each parameter are given in Tables 1 and 2.

The model was based on an initial population of 25 adult females and 25 adult males. Based on field data obtained at a colony in Colorado (Yoder, unpubl.), the initial sex ratio (M:F) was assumed to be 50:50.

Models for culling or contraception tested the effects of 50, 60, 70, 80, or 90% yearly levels of control. Mixed management was modeled as 50% reduction of the population by culling in year 1 combined with contraception applied once every 3 years beginning in year 1. The levels of contraception were varied to determine an approximate percentage of the population that would have to be treated to stabilize the population at close to half its original size. Contraception was assumed to be 100% effective for three years (Yoder, unpubl. data).

Table 1. Parameter/symbol definitions used for all models.

Parameter/Symbol	Definition
$Females_{spr}$	Number of females present in the spring
$Females_{fall}$	Number of females present in the fall
h	Culling rate
H_{pups}	Number of pups culled
H_{fem}	Number of females culled
H_{male}	Number of males culled
$Males_{spr}$	Number of males present in the spring
$Males_{fall}$	Number of males present in the fall
N	Population size
PH_{pups}	Number of pups present post-culling
PH_{fem}	Number of females present post-culling
PH_{male}	Number of males present post-culling
PHN	Population size post-culling
Pups	Number of pups present in a given year
S_{pups}	Density dependent pup survival
t	Year
Yearlings	Number of yearlings present in a given year

Table 2. General equations used to calculate demographic parameters for all models.

Parameter	Equation
$Yearlings_t$	$(Pups_{fall})_{t-1} \times (S_{pups})_{t-1}$
S_{pups}	$1-0.0001 \times N_t$
$(Females_{spr})_t$	$(Females_{fall})_{t-1} \times 0.52$
$(Males_{spr})_t$	$(Males_{fall})_{t-1} \times 0.52$
$Pups_t$	$(Females_{spr})_t \times 2.8$
$(Females_{fall})_t$	$(Females_{spr})_t + (Yearlings_t \times 0.5)$
$(Males_{fall})_t$	$(Males_{spr})_t + (Yearlings_t \times 0.5)$
$(H_{pups})_t$	$Pups_t \times h$
$(H_{fem})_t$	$(Females_{fall})_t \times h$
$(H_{male})_t$	$(Males_{fall})_t \times h$
$(PH_{pups})_t$	$Pups_t-(H_{pups})_t$
$(PH_{fem})_t$	$(Females_{fall})_t-(H_{fem})_t$
$(PH_{male})_t$	$(Males_{fall})_t-(H_{male})_t$
N_t	$Pups_t + (Females_{fall})_t + (Males_{fall})_t$
PHN_t	$(PH_{pups})_t + (PH_{fem})_t + (PH_{male})_t$

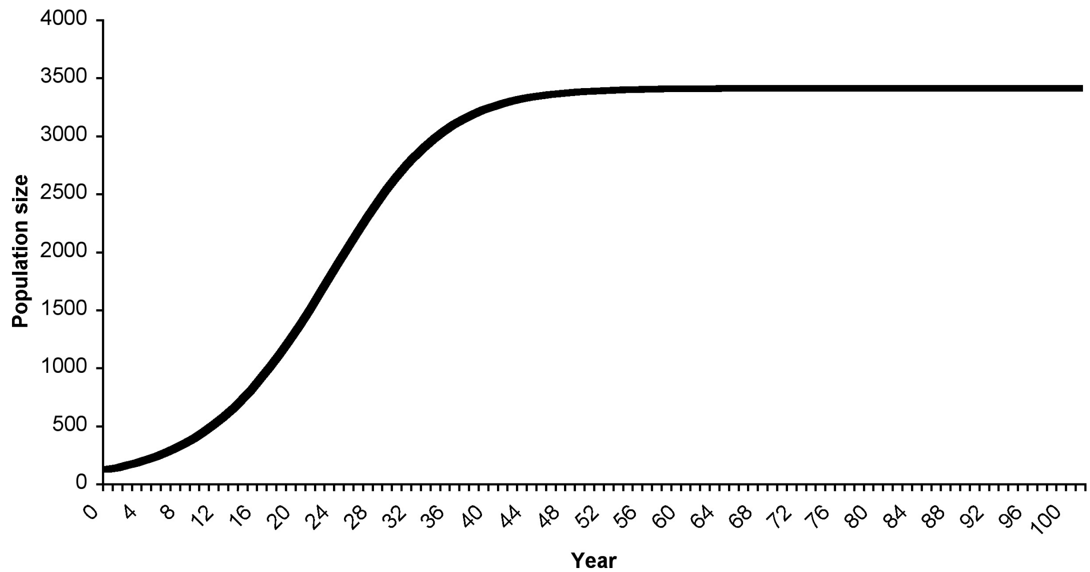

Figure 1. Mean size of a simulated prairie dog population with no control applied over 100 years.

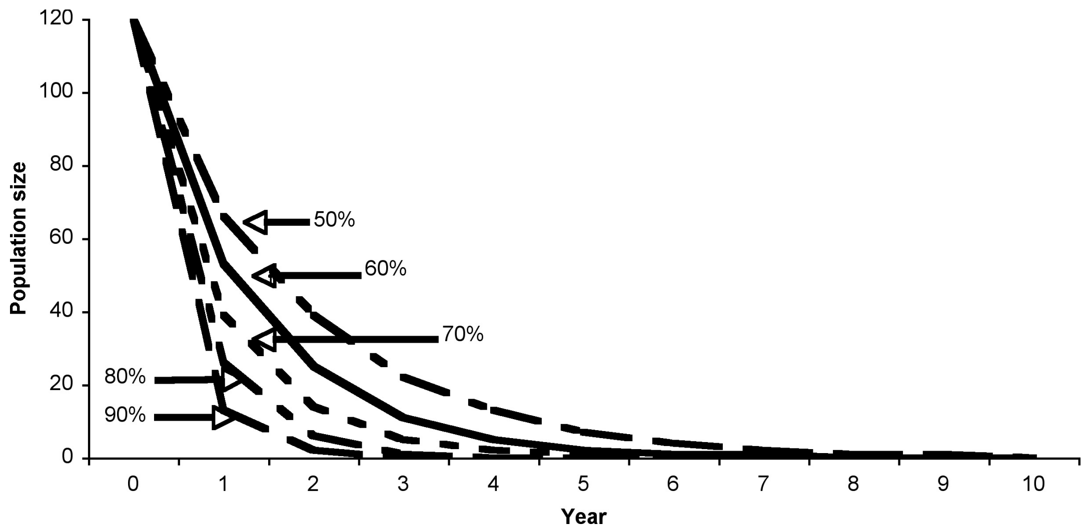

Figure 2. Mean size of simulated prairie dog population subjected to 50-90% yearly culling over 10 years. After 10 years, all populations were extinct.

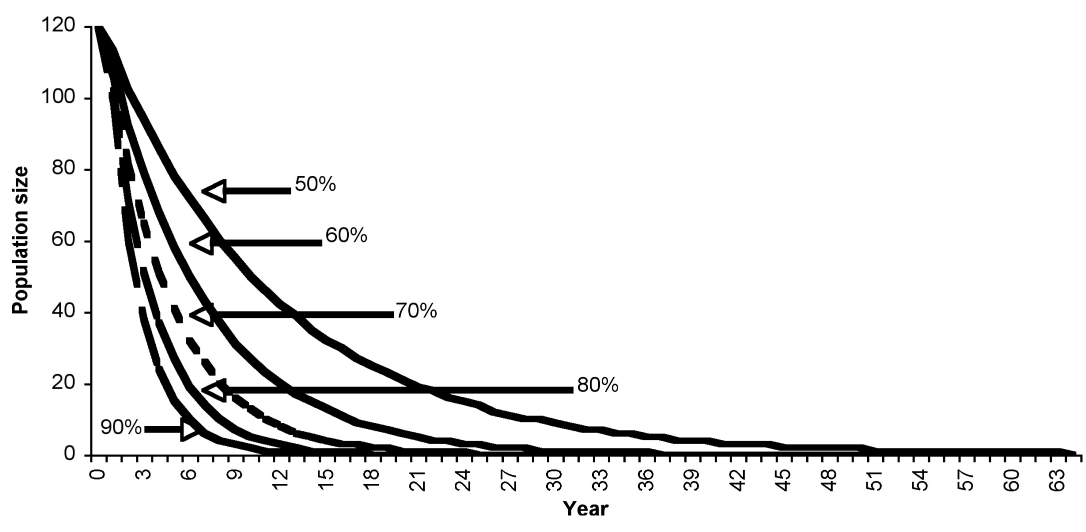

Figure 3. Mean size of simulated prairie dog population subjected to 50-90% yearly contraception over 64 years. After 64 years, all populations were extinct.

Table 3. Mean years to population extinction (zero animals in the population) for simulated populations of black-tailed prairie dogs treated with various percentages of culling or contraception. Initial population consisted of 25 adult females and 25 adult males.

Level of Control	Culling	Contraception
50	11	65
60	8	37
70	6	25
80	4	18
90	3	13

RESULTS

Populations with no control applied to them continued to grow until stabilizing at 3,400 animals after 60 years (Figure 1). Culling 50-90% of the population resulted in a rapid population decline of ≥50% after one year (Figure 2). All populations subjected to 50-90% culling eventually became extinct (had zero animals in the population on average). Contracepting 50-90% of the population resulted in a slower rate of decline than culling (Figure 3). All contracepted populations eventually became extinct, but took much longer to reach extinction than culled populations (Table 3).

Culling 12.79% of the population yearly results in a relatively stable population that ranges between 115 and 121 prairie dogs (Figure 4). Contracepting 33.25% of the population results in a very stable population that only ranges from 119 to 120 animals (Figure 5). Culling 50% of the population in year 1 followed by contracepting 85.8% of the population once every 3 years (beginning in year 1) results in a population that fluctuates between 50 and 69 animals (Figure 6).

DISCUSSION

Yearly culling proved to be more efficient at lowering the population than yearly contraception. According to Hoogland (2001), black-tailed prairie dogs have a slow reproductive rate due to high mortality of pups during the first several months of life. Therefore, lowering the reproductive rate further would not have as large an effect as lowering a high survival rate. Survival rates of yearling and adult females can be as high as 78% (Crosby and Graham 1986; Hoogland 1995, 2003). In addition, culling provides immediate effects, whereas contraception can take several years to produce noticeable population level effects.

Only a small percentage of the population needs to be managed yearly with culling (12.79%) or contraception (33.25%) to maintain current population levels. Differences in the amount of labor required for each of these two methods is likely minimal if an oral contraceptive can be used. If an injectible contraceptive is used, more effort will be required but the goal could likely be achieved with only a few days of trapping.

Assuming an injectible contraceptive is effective for 3 years with a single injection, the population can be maintained close to the current level by applying contraception once every 3 years. However, a much larger percentage of the population (85.8%) needs to be treated in this scenario. In addition, the population fluctuates more than with yearly contraception. An economic analysis is needed to determine the feasibility of a yearly contraceptive program versus a program that only uses contraception once every 3 years.

The type of control managers use will depend on the ultimate management goal. If the goal is to eliminate the population completely, culling will give much quicker results than contraception. However, if the goal is to maintain the population at a level that minimizes damage while still allowing animals to exist, either contraception or a combination of culling and contraception is the best choice. If the population is not already causing significant damage, contraception could be used alone to maintain the population at its current level. However, if the population is causing damage, it may need to be reduced to the desirable level prior to implementing contraception. The acceptable population level will depend on both environmental and social carrying capacities.

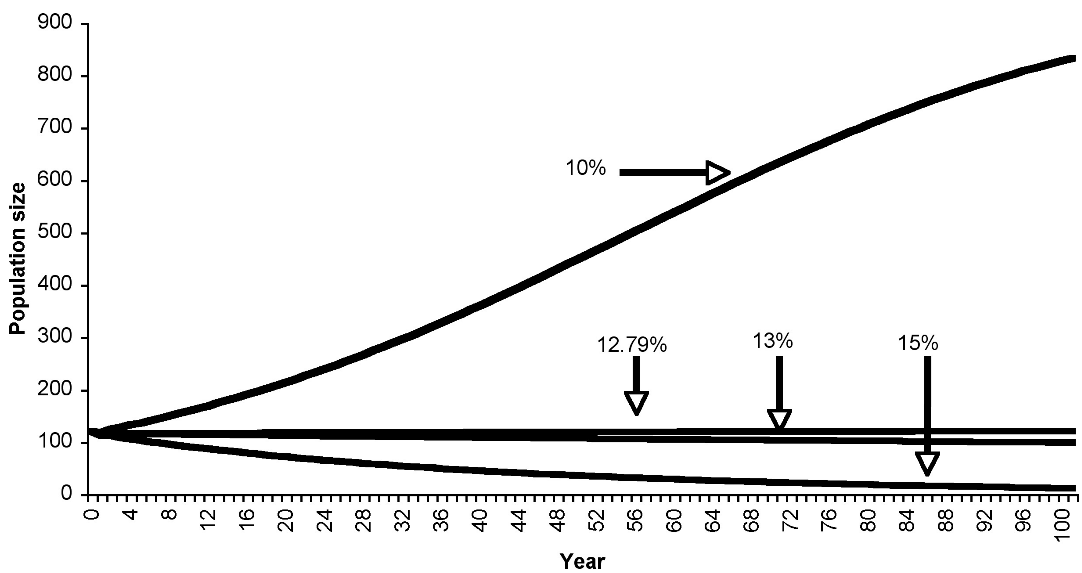

Figure 4. Mean population size of a simulated prairie dog population subjected to 10-15% yearly culling.

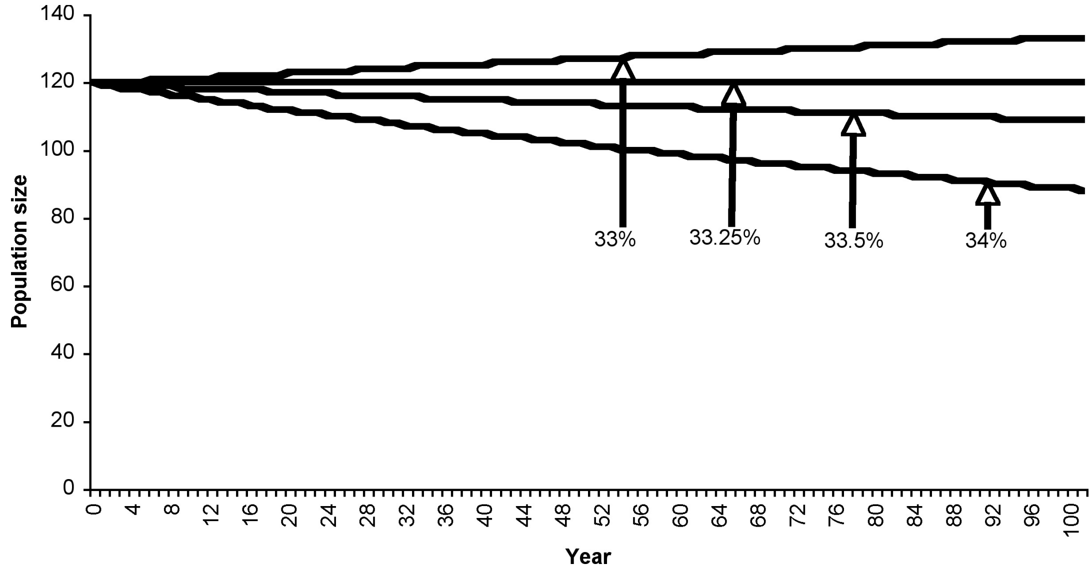

Figure 5. Mean population size of a simulated prairie dog population subjected to 33-34% yearly contraception.

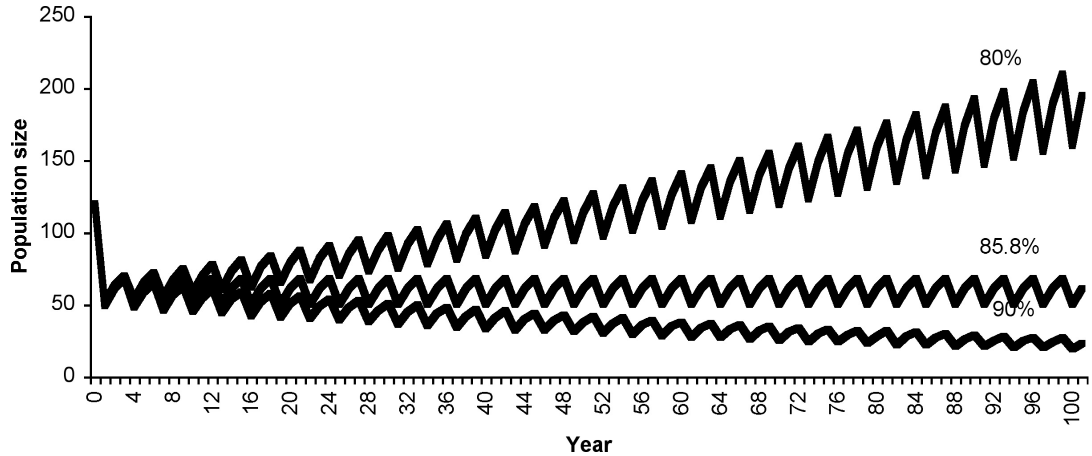

Figure 6. Mean size of simulated prairie dog population subjected to 50% culling in year 1 followed by 80-90% contraception once every 3 years. Contraceptive treatment begins in year 1.

These models provide a framework for wildlife managers to consider the effects of implementing contraception as part of an overall management plan for prairie dogs. Parameters can easily be changed to more accurately assess local populations if needed. The models also highlight the need for further research to provide data so that the models can be refined to more accurately reflect real populations. In particular, more accurate data is needed on immigration and emigration rates as these can have a profound effect on management strategies. Future models should incorporate stochasticity to allow for variability among populations and in the environment. In addition, further work on producing decay curves for the contraceptives considered is needed so that managers can make more informed decisions about how often a population needs to be treated. These models can be used as a starting point for discussion, planning research, and management activities.

LITERATURE CITED

Andelt, W. F., and S. N. Hopper. 1998. Managing prairie dogs. Cooperative Extension Bulletin No. 6.506, Colorado State University, Fort Collins, CO.

Avery, M. L., K. L. Keacher, and E. A. Tillman. 2008. Nicarbazin bait reduces reproduction by pigeons (*Columba livia*). Wildl. Res. 35:80-85.

Bynum, K. S., J. D. Eisemann, G. C. Weaver, C. A. Yoder, K. A. Fagerstone, and L. Miller. 2007. Nicarbazin OvoControl G bait reduces hatchability of eggs laid by resident Canada geese in Oregon. J. Wildl. Manage. 71:135-143.

Courchamp, F., and S. J. Cornell. 2000. Virus-vectored immunocontraception to control feral cats on islands: A mathematical model. J. Appl. Ecol. 37:903-913.

Crosby, L. A., and R. Graham. 1986. Population dynamics and expansion rates of black-tailed prairie dogs. Proc. Vertebr. Pest Conf. 12:112-115.

Cully, J. F. Jr. 1997. Growth and life-history changes in Gunnison's prairie dogs after a plague epizootic. J. Mammal. 78:146-157.

Ellis, M. M., and C. S. Elphick. 2007. Using a stochastic model to examine the ecological, economic and ethical consequences of population control in a charismatic invasive species: Mute swans in North America. J. Appl. Ecol. 44:312-322.

Franklin, W. L., and M. G. Garrett. 1989. Nonlethal control of prairie dog colony expansion with visual barriers. Wildl. Soc. Bull. 17:426-430.

Garrett, M. G., J. L. Hoogland, and W. L. Franklin. 1982. Demographic differences between an old and a new colony of black-tailed prairie dogs (*Cynomys ludovicianus*). Am. Midl. Nat. 108:51-59.

Garrett, M. G., and W. L. Franklin. 1988. Behavioral ecology of dispersal in the black-tailed prairie dog. J. Mammal. 69:236-250.

Garrott, R. A. 1995. Effective management of free-ranging ungulate populations using contraception. Wildl. Soc. Bull. 23:445-452.

Haight, R. G., and L. D. Mech. 1997. Simulation of vasectomy for wolf control. J. Wildl. Manage. 61:1023-1031.

Hoogland, J. L. 1995. The black-tailed prairie dog: Social life of a burrowing mammal. University of Chicago Press, Chicago, IL.

Hoogland, J. L. 2001. Black-tailed, Gunnison's, and Utah prairie dogs reproduce slowly. J. Mammal. 82:917-927.

Hoogland, J. L. 2003. Black-tailed prairie dog. Pp. 232-247 *in*: G. A. Feldhammer, B. C. Thompson, and J. A. Chapman (Eds.), Wild Mammals of North America: Biology, Management, and Conservation. The Johns Hopkins University Press, Baltimore, MD.

Knowles, C. J. 1986. Population recovery of black-tailed prairie dogs following control with zinc phosphide. J. Range Manage. 39:249-251.

Miller, L. A., B. E. Johns, and G. J. Killian. 2000. Immunocontraception of white-tailed deer with GnRH vaccine. Am. J. Reproduct. Immunol. 44:266-274.

Robinette, K. W., W. F. Andelt, and K. P. Burnham. 1995. Effect of group size on survival of relocated prairie dogs. J. Wildl. Manage. 59:867-874.

Stockrahm, D. M. B., and R. W. Seabloom. 1988. Comparative reproductive performance of black-tailed prairie dog populations in North Dakota. J. Mammal. 69:160-164.

Tileston, J. V., and R. R. Lechleitner. 1966. Some comparisons of the black-tailed and white-tailed prairie dogs in north-central Colorado. Am. Midl. Nat. 75:292-316.

White, G. C. 2000. Modeling population dynamics. Pp. 84-107 *in*: S. Demarais and P. R. Krausman (Eds.), Ecology and Management of Large Mammals in North America. Prentice Hall, Upper Saddle River, NJ.

Witmer, G., J. Gionfriddo, and M. Pipas. 2008. Evaluation of physical barriers to prevent prairie dog colony expansion. Human-Wildl. Conflicts 2:206-211.

Zinn, H. C., and W. F. Andelt. 1999. Attitudes of Fort Collins, Colorado, residents toward prairie dogs. Wildl. Soc. Bull. 27:1098-1106.