Colby College
Digital Commons @ Colby

Honors Theses | Student Research

2008

Separating People and Wildlife: Zoning as a Conservation Strategy for Large Carnivores

Courtney L. Larson
Colby College

Follow this and additional works at: https://digitalcommons.colby.edu/honorstheses

Part of the Environmental Sciences Commons

Colby College theses are protected by copyright. They may be viewed or downloaded from this site for the purposes of research and scholarship. Reproduction or distribution for commercial purposes is prohibited without written permission of the author.

Recommended Citation
Larson, Courtney L., "Separating People and Wildlife: Zoning as a Conservation Strategy for Large Carnivores" (2008). *Honors Theses.* Paper 245.
https://digitalcommons.colby.edu/honorstheses/245

This Honors Thesis (Open Access) is brought to you for free and open access by the Student Research at Digital Commons @ Colby. It has been accepted for inclusion in Honors Theses by an authorized administrator of Digital Commons @ Colby.

Separating People and Wildlife:
Zoning as a Conservation Strategy for Large Carnivores

Courtney L. Larson
Environmental Studies Program
Colby College
Waterville, Maine

May 2008

A thesis submitted to the faculty of the Environmental Studies Program in partial fulfillment of the graduation requirements for the Degree of Bachelor of Arts with honors in Environmental Studies

Philip J. Nyhus, Mentor	F. Russell Cole, Reader	David H. Firmage, Reader

Copyright © 2008 by the Environmental Studies Program, Colby College. All rights reserved.

ABSTRACT

Large carnivores are some of the world's most difficult species to conserve because of their large spatial requirements, low population density, and high potential for conflict with humans. However, large carnivores are valuable for ecological, cultural, and ethical reasons. Carnivore management can take a wide variety of forms, including translocation, sterilization, livestock compensation programs, regulated hunting, improved livestock husbandry practices, and zoning, among others. The objective of this thesis was to conduct a comparative analysis of examples of zoning from around the world to examine whether it is an effective carnivore management strategy.

Analysis of twelve case studies showed that zoning systems vary widely based on the characteristics of the target species and location-specific factors. However, four broad categories of zoning were identified: density driven, core area, game species, and pest species zoning. Furthermore, several factors stood out as important in the success or failure of zoning systems: space availability, level of conflict with humans, relative abundance of the species, public support for the zoning system, and the economic and political context of the location. It seems that zoning has the potential to be a successful management tool for large carnivore species if these factors are taken into account during the management planning process.

ACKNOWLEDGEMENTS

I would like to thank Philip Nyhus, my advisor, for encouraging me to write a senior honors thesis in the first place and for all his advice and support throughout the year. I would also like to acknowledge F. Russell Cole and David Firmage for reading a nearly completed draft and offering helpful comments and suggestions. Thank you to Beth Kopp and the Environmental Studies Program for providing assistance and support throughout the year. I also greatly appreciate having the use of a much-needed research space for the duration of this project. Finally, I would like to thank the experts from around the world who took the time to fill out my survey or answer my questions – this project was greatly enriched by their opinions and perspectives.

TABLE OF CONTENTS

INTRODUCTION

At its most basic, zoning is a spatial separation of land uses. It was originally developed for use in urban planning, in which it separates land uses seen as incompatible, such as residential and industrial areas (Linnell et al. 2005). In conservation, the most common application of zoning is in protected area design. In the early 1970s, the UNESCO Man and the Biosphere Program developed a now well-known system of protected area zoning. The biosphere reserve zoning method involves three zones: the core zone, the buffer zone, and the transition zone, which allow differentiated levels of human impact in each zone (Nyhus and Adams 1995). This system is now used in 531 biosphere reserves around the world (UNESCO 2008), and many other protected areas have zoning systems similar to the biosphere reserves.

Although protected areas can aid greatly in wildlife conservation, they rarely cover enough area to maintain a viable population of species – such as large carnivores – that have large spatial requirements (Linnell 2005; Linnell et al. 2005). In most cases, protected areas alone are not adequate for long-term conservation of these species. This problem has led to the creation of zoning schemes that are focused on the conservation and management of a single species on an appropriately large scale. The defining feature of this type of zoning is geographical differentiation of management strategies. These zoning systems, which I refer to as single-species zoning systems, seek to concentrate wildlife populations into areas where they can be conserved, while minimizing their spread into areas where they are not accepted by humans (for example, areas with large human populations). In contrast, protected area zoning manages the human uses that are allowed in different areas of protected areas and does not deal specifically with wildlife. This thesis focuses only on single-species zoning strategies; protected area zoning is beyond its scope.

Unlike protected area zoning, single-species zoning (hereafter: zoning) is not well understood. Although zoning is often referred to in passing as a carnivore conservation strategy, comparative and/or analytical studies on its efficacy and applicability are practically nonexistent. In this paper I look comparatively at zoning systems from around the world to address the broad, central question: is zoning an effective method for the conservation of carnivores?

To explore this question, I organized both my research and this paper around the following set of more specific questions. I first asked: how has zoning been used in the past, and how is it being used today? After gaining an understanding of the variety of zoning systems that have been tried, I then asked: which of these zoning systems worked? More importantly, why were they successful or unsuccessful? What factors are the most important in designing and implementing a successful zoning system? The main analysis of this thesis takes the form of a categorization of the primary types of zoning and the influential factors that cause them to be more or less successful. I deal only with zoning systems for large carnivore species because most of the zoning literature is focused on large carnivores and because they are fairly unique in their spatial and dietary needs. I now begin with a brief overview of the importance and challenge of conserving large carnivores and the variety of management strategies that are currently used for this purpose.

The Importance of Large Carnivores

Large carnivores pose a unique conservation challenge because of their large body size, large home range, low population density, and frequent conflict with humans and their livestock. They are often reclusive and dangerous to humans, making them difficult to study and census (Gittleman et al. 2001). These characteristics have resulted in dwindling numbers of many of the world's large carnivore species due to persistent human persecution and habitat loss (Breitenmoser 1998; Dinerstein et al. 2007). Many large carnivore species remain in peril of extinction or local extinction, including the Iberian lynx, the African wild dog, and the snow leopard (IUCN 2007). However, others have recently been recovering in numbers and distribution, both through natural recolonization, such as the wolf in central Europe and the brown bear in Norway, and through planned reintroductions, such as the wolf in the Western United States and the lynx in Switzerland (Sagor et al. 1997; Breitenmoser 1998).

Ecologically, carnivores have been shown to play an important role in regulating populations of prey species and maintaining healthy, diverse ecosystems. In the absence of carnivore species, ecosystems often experience trophic cascades and eventually, degradation of biodiversity (Terborgh et al. 2001). Top carnivores are sometimes pointed to as keystone species, which are species that have disproportional importance in the ecological balance and organization of their communities (Mills et al. 1993). Additionally, some carnivore species have specialized habitat requirements and narrow geographic ranges, which make them useful as indicator species of intact ecosystems (Gittleman et al. 2001).

Given the large home ranges of large carnivore species, they can also serve as umbrella species (Gittleman et al. 2001). By conserving a large carnivore population, many other species are also conserved because their habitats are contained within the collective home range of the carnivores. Sergio et al. (2006) found that areas containing top raptor species had significantly higher numbers of both threatened and non-threatened species than randomly chosen areas. This suggests that some carnivore species could be used as effective flagship species in addition to the roles mentioned above. A flagship species is a charismatic animal with broad appeal to the public that can be used to raise funds for and educate people about biodiversity conservation.

However, in some cases large carnivores are not particularly useful as keystone, umbrella, flagship, or indicator species. For example, Linnell et al. (2000) argue convincingly that large carnivores in Scandinavia are not good flagship species because of their high levels of conflict with humans, which has led to a negative public perception of these species. Furthermore, some large carnivore species, such as the wolf, may survive quite well in degraded ecosystems, seriously limiting their utility as indicator or umbrella species (Mech 1995).

Even if some carnivores are not useful in one of these roles, there is still ample reason to prevent their extinction. Ethical, biocentric arguments state that every species has intrinsic value, and this should be enough to motivate their conservation (Naess and Sessions 1995). Large carnivores have deep cultural and symbolic value in many parts of the world. For example, in the United States wolves are often seen as a representation of wilderness and harmony with nature (Mech 1995). David Quammen (2003) writes that “the alpha predators, and the responses they evoke, have transcended the physical dimension of sheer mortal struggle, finding their way also into mythology, art, epic literature, and religion.” Losing the large carnivores would also mean losing part of human culture and heritage.

Why Manage Large Carnivores?

The conservation of carnivores is controversial for many reasons. Humans and large carnivores have some of the same basic needs, such as large amounts of space and a protein-rich diet (Treves and Karanth 2003). This inevitably brings humans and large carnivores into conflict, which can take several different forms. Conflicts include direct threat to human or carnivore life, competition for food resources, or spatial incompatibility. These conflicts have led to the widespread elimination or reduction of carnivore populations in many places around the world. Large carnivores not only need conservation, but also management that minimizes conflict with humans. Without such management programs, large carnivore conservation is likely to be so unpopular that it simply is not feasible.

Although some large carnivore species are more dangerous to humans than others, nearly all are capable of causing harm to humans. In an extreme example, man-eating tigers have been present for over three centuries in the Sundarban region of India, and an estimated one percent of these tigers are "dedicated man-eaters," that actively seek out human prey (McDougal 1987). Deaths and injuries resulting from attacks on humans are clearly a strong argument for management of large carnivores. Additionally, the effects of carnivore attacks – retaliatory killings, fear, and increased political pressure for elimination – only compound the need for careful management (Nyhus and Tilson 2009).

The most common conflict between humans and large carnivores is probably over livestock (Thirgood et al. 2005). Ungulate species make up a large percentage of the diet of many large carnivore species, and domesticated ungulates present an especially easy target for predation. This is often a problem in areas where carnivores have recently recolonized or been reintroduced. In these areas, people have grown accustomed to the absence of large predators and as a result, some of the traditional husbandry practices to guard against carnivores have been discarded (Breitenmoser 1998).

The economic losses resulting from carnivore predation on livestock can be very high for those who live in areas with large concentrations of predators. For example, some ranchers in Bhutan reported livestock losses to leopards, tigers, Himalayan black bears, and dholes that would cost 84% of their annual income to replace (Wang and Macdonald 2006). Beside the economic loss for the livestock owners, livestock depredation can also have a negative impact on the carnivore species if the livestock owners kill them in retaliation. The problem of livestock depredation has resulted in the widespread use of compensation and/or livestock insurance programs, preventative fencing, guard dogs, and other methods in an effort to prevent retaliatory killing (Woodroffe et al. 2005). However, some of these methods have proved more successful than others.

A third type of human-carnivore conflict is competition for game species. Hunting is a widespread practice among humans. For example, in the United States approximately one out of seven males between ages 16 and 65 is a hunter (Berger 2005). Hunters are often accustomed to elevated prey density as a result of the absence of large carnivore species and will often vehemently protest carnivore conservation or reintroduction (Breitenmoser et al. 2005). This was one of the more controversial aspects of the reintroduction of the wolf to Yellowstone National Park (Phillips et al. 2004).

Finally, spatial competition makes up the last category of human-carnivore conflict. Most large carnivores need vast amounts of space because of their body size, dietary needs, low density, and dispersal distances (Linnell et al. 2001b). Humans also require large areas because of their large population and high demand for space. Although some types of land uses, such as the timber or ecotourism industries, may be compatible with large carnivores, other land uses, such as sheep farming or human settlement, simply cannot coexist with them (Linnell et al. 2005). Humans are not willing to allow large carnivores to live in areas of high human population density because of the danger they pose, and carnivores would not survive well in these areas anyway because of habitat alteration. Across the world, people have set aside some areas of land as protected areas, in which habitat is relatively unaltered, for the purpose of biodiversity conservation. Although this may be sufficient protection for species with small home ranges, large carnivores usually need land beyond the boundaries of these areas in order to maintain viable population sizes. This means that the conservation of carnivores will depend on the ability of humans and carnivores to coexist in multi-use landscapes (Linnell et al. 2005).

Managing Large Carnivores

Strategies for the management of large carnivores fall into two broad categories: reactive and preventative (Treves and Karanth 2003). The first category consists of strategies that modify the behavior of either carnivores or humans to minimize or mitigate existing conflicts. Modifications to carnivore behavior include using lethal control to remove problem individuals, translocation, and sterilization, whereas human behavior can be modified through education campaigns, compensation for carnivore-caused damages, and improved husbandry practices.

All of these strategies have certain advantages and disadvantages. For example, removing problem individuals can prove unmanageable because of the difficulty of identifying and locating target individuals. However, in many cases it reduces the hostility of rural people toward carnivores because it is direct, visible action to reduce livestock predation (Treves and Naughton-Treves 2005). Similarly, although compensation systems are used widely around the world in an attempt to prevent retaliatory killing of large carnivores that prey on livestock, they can be ineffective unless the compensation system is quick, fair, and efficient (Nyhus et al. 2003).

The second category, preventative strategies, includes management techniques designed to avert human-wildlife conflicts before they happen. Strategies such as physical barriers and culling programs fall into this category. Physical barriers, such as fences or trenches, are a relatively simple method to reduce conflict, although they have varying success depending on the type of carnivore that is being excluded and the type of fence used (Breitenmoser et al. 2005). Culling programs are a type of lethal control that seeks to maintain the carnivore population density at a low enough level so that conflict will be minimized, although there is some doubt about whether culling programs are actually effective in keeping the population at a targeted level (Treves and Naughton-Treves 2005).

Zoning

Zoning is also a preventative strategy, but it differs from those described above in that it attempts to achieve, on a basic level, a spatial separation of humans and carnivores. The theory behind zoning is that by reducing the number of encounters between humans and carnivores, it minimizes livestock depredation and carnivore attacks on humans (Linnell et al. 1996). Although the concept seems logically sound, experts disagree on its effectiveness in practice, and there are few studies that can be used to defend either side.

The research on zoning that does exist falls into two broad categories: general description of the theory of zoning, and description of specific cases of zoned management in practice. There are very few studies in the first category: Linnell et al. (2005) is the only published piece that focuses solely on single-species zoning. Treves and Karanth (2003) list and briefly describe zoning as a method of managing large carnivores, but they emphasize that further research is necessary to better understand the efficacy and applicability of zoning.

In the second category, there are many more sources. Some of the more well-documented examples of zoning include the gray wolf in Minnesota and Wisconsin, United States (United States Fish and Wildlife Service 1992; Mech 1995; Wisconsin Department of Natural Resources 1999; Minnesota Department of Natural Resources 2001), the dingo in Australia (Allen and Sparkes 2001; Fleming et al. 2001), and the European brown bear in Slovenia (Adamic 1997; Ministry of the Environment and Spatial Planning 2002; Krystufek and Griffiths 2003). However, many of the publications that describe examples of zoning only discuss the management plan at the time of its implementation, and do not provide information on the outcome of the zoning strategy. There are virtually no studies that approach zoning from a comparative or analytical perspective; this study attempts to address this gap in knowledge.

The goals of this study, outlined above, are threefold: to determine the types of zoning systems that have been used to manage large carnivores world-wide, assess their success or failure, and identify key factors that make zoning more or less likely to succeed. The results of this thesis and similar studies have practical implications for large carnivore conservation around the world, as wildlife managers strive to find solutions to the continuing conflict between humans and carnivores.

METHODS

Single-species zoning schemes are being used around the world to manage many different species, using a variety of approaches. In gathering information, I define zoning somewhat broadly to include the full range of possible examples. For the purpose of this study, I consider zoning to be any system of management of large carnivores that involves spatial delineation of areas (zones) between which the density of carnivores, acceptance of carnivores, or specific management techniques used for carnivores is varied. I define large carnivores as terrestrial members of the Order Carnivora that are known to prey on large, common livestock species such as sheep, goats, or cattle.

I conducted an extensive literature search to find examples of zoned management of large carnivores in both the published literature and in reports and other unpublished sources. I used the databases Web of Knowledge, Academic Search Premier, and Google Scholar for published material, and Google Scholar and a variety of conservation websites, both governmental and nongovernmental, to find unpublished sources. In the literature search, I looked for specific examples of zoning to be used as case studies as well as descriptions of zoning theory and methodology.

I also created a survey, which I sent to carnivore experts and wildlife management practitioners from around the world to gain information and insight that was not available in the literature. The survey included 11 questions, which were designed to assess the opinions of zoning held by the respondents and the reasons behind them (see Appendix A for the survey questions). Six of these questions were quantitative and asked respondents to choose an answer on a scale of 1-5. I then asked for a qualitative explanation for these answers.

When possible, I followed up the survey with questions geared specifically toward the knowledge and experience of the respondents.

I organized the information from both the literature search and the survey into case studies, defined by species and location. For each case study, I recorded data on the biological characteristics of the species, its International Union for the Conservation of Nature (IUCN) status, its estimated population size in the location, basic demographic and economic information of the country or region, and the extent of human-wildlife conflict. I also collected information on the zoning strategy or strategies that had been used in each case study location, including the time span of implementation, who manages the carnivore species, the number of zones, what the zones control, whether there is compensation for damages caused by carnivores, and whether lethal control and hunting are used as part of the management strategy. When possible, I also assessed the outcome of the management strategy. From these case studies, I developed a set of categories that help describe and compare different zoning strategies. Finally, based on the outcomes of the zoning strategies examined in the case studies, I determined some of the most important factors that contribute to the success or failure of zoning systems.

RESULTS AND DISCUSSION

In this section, I give an overview of the information gleaned from both the survey and the literature search. I provide a brief description of each of the twelve case studies (see Table 2), taking care to note the goal and the outcome of each zoning strategy. For each case study, I then evaluate whether the strategy was successful, somewhat successful, unsuccessful, or indeterminate.

I then delve into the analysis and implications of the data. First, I use the case studies to develop a new classification of zoning systems. Subsequently, I discuss the factors that have the most influence over the outcome of a zoning system. Finally, I conclude with a summary of my key findings and the broader implications of this study.

Literature Search Results

In the literature search, I found six documents that discussed zoning as a conservation strategy (only one in detail), which helped provide perspective to the different goals and applications of zoning strategies. Thirty-eight papers, book chapters, action plans, and other documents described a specific zoned management strategy in enough detail to include in one of the case studies. Countless papers and species action plans mentioned zoning in passing, usually as something to research or consider for future inclusion in a management plan. The Large Carnivore Initiative for Europe's five large carnivore action plans are good examples – one of their guiding principles is "the principle of management of large carnivores through a system of zoning," but since the action plans apply to all of Europe, they do not contain specifics on how this would be accomplished (Boitani 2000; Breitenemoser et al. 2000; Delibes et al. 2000; Landa et al. 2000; Swenson et al. 2000). This could indicate that while policymakers and carnivore researchers are aware of zoning, it is only beginning to be used as a widespread strategy for carnivore management.

Survey Results

The survey was less successful than I initially hoped, but still useful. Twelve people responded to my queries, but many included comments without completing the actual survey.

I received only 6 completed surveys out of a total of 23 sent, and I do not believe anyone forwarded the survey to their colleagues as I requested in the e-mail. Although the number of completed surveys was clearly too small for quantitative analysis, the most valuable outcome of the correspondence was the more in-depth discussions I was able to have with the respondents who were willing to answer more targeted questions than those appearing on the survey. Table 1 lists the experts who contributed a completed survey and/or responses to specific questions through e-mail. These answers were valuable in determining what types of data should be collected to analyze the case studies and helped me gain an understanding of what zoning systems are like in practice.

The most interesting and important outcome of the survey was the realization that the experts do not agree about the utility of zoning as a conservation strategy. Opinions differed greatly (Table 1). Some, such as L. David Mech (who is arguably the world's foremost expert on wolves) gave zoning the highest rating on every question, but Petra Kaczensky thought it was essentially useless, giving it the lowest rating on the majority of the questions. Urs Breitenmoser claimed to be "famous in Europe to be anti-zoning," and was instrumental in preventing lynx from being managed with a zoning system in Switzerland. Adrian Wydeven and Boris Krystufek both expressed support for zoning systems used in their home countries, the United States (Wisconsin) and Slovenia, respectively.

Table 1. Experts who contributed input – either through the survey or through e-mail correspondence – with their affiliation and overall opinion of zoning as a method for large carnivore management.

Name	Affiliation	Opinion of zoning
Boris Krystufek	Professor of Zoology at University of Ljubljana, Slovenia	Positive
John Linnell	Norwegian Institute for Nature Research	Positive
L. David Mech	Senior Research Scientist, U.S. Geological Survey, and renowned wolf expert	Positive
Adrian Wydeven	Mammal Ecologist/Wolf Manager for Wisconsin Department of Natural Resources	Positive
Miha Adamic	Associate Professor of Wildlife Ecology at University of Ljubljana, Slovenia	Neutral
Lisa Naughton	Associate Professor of Geography at University of Wisconsin-Madison, Research Fellow for Conservation International	Neutral
Adrian Treves	Assistant Professor of Environmental Studies at University of Wisconsin, Madison, USA, and leading scholar of human-wildlife conflict	Neutral
Urs Breitenmoser	Chair of the IUCN Cat Specialist Group	Negative
Petra Kaczensky	Wildlife Biologist at Salzburg Zoo, Austria	Negative

The survey respondents also cited a variety of factors that make zoning systems more likely to succeed. These included flexibility of rules, human tolerance of carnivores, clarity of rules, scale or size of the zones, the ability to remove problem individuals, public acceptance of zoning, having a long-term strategy, and land use patterns. However, some of the respondents disagreed with each other in terms of what factors were important in a specific location. For example, Petra Kaczensky wrote that the small size of countries in central Europe makes effective zoning impossible, but Boris Krystufek of Slovenia thought zoning worked well in his small country. Similarly, Adrian Wydeven wrote that the flexibility of the Wisconsin wolf management system made it effective, while Adrian Treves, referring to the same management system, wrote that “in practice, there is no difference,” between the zones. This level of disagreement among the experts, about both the effectiveness of zoning and the factors that influence specific zoning systems, shows that more research is necessary to resolve these disparities.

Case Studies

The twelve case studies discussed in this paper were drawn from the results of both the literature search and the correspondence with experts. Case studies were only selected if they adhered to the definition of zoning described above and if clear documentation of the management strategy in place was found. The case studies, listed below in Table 2, include examples of nine different carnivore species and represent nine countries from five different continents. A brief description of each case study is provided below to highlight the diversity of purposes and methods among them. At the beginning of each description, I include a one-sentence statement of both the goal of the zoning strategy and its outcome to date.

Table 2. Species name (both common and scientific), location, and important reference sources for each case study.

Species	Location	Main Sources
Gray wolf (*Canis lupus*)	Minnesota, United States	United States Fish and Wildlife Service (1992), Mech (1995)
Gray wolf (*Canis lupus*)	Wisconsin, United States	Wisconsin Department of Natural Resources (1999)
Gray wolf (*Canis lupus*)	Finland	Wabakken et al. (2001), Ministry of Agriculture and Forestry (2005)
Dingo (*Canis lupus dingo*)	South Australia, Australia	Allen and Sparkes (2001), Fleming et al. (2001)
African wild dog (*Lycaon pictus*)	South Africa	Mills and Gorman (1997), Mills et al. (1998), Lindsey et al. (2005)
Eurasian Lynx (*Lynx lynx*)	Sweden	Linnell et al. (2001a), Swenson and Andren (2005)
Bengal Tiger (*Panthera tigris tigris*)	India	Thapar (1999), Karanth et al. (1999), Damodaran (2007)
Cougar (*Puma concolor*)	Alberta, Canada	Fish and Wildlife Division (1992), Ross et al. (1996)
Brown bear (*Ursus arctos*)	Norway	Sagor et al. (1997), Zedrosser et al. (2001), Swenson and Andren (2005)
Brown bear (*Ursus arctos*)	Slovenia	Adamic (1997), Ministry of the Environment and Spatial Planning (2002), Krystufek and Griffiths (2003)
Grizzly bear (*Ursus arctos horribilis*)	Greater Yellowstone Area, United States	United States Fish and Wildlife Service (1993), Interagency Conservation Strategy Team (2007)
Wolverine (*Gulo gulo*)	Norway	Landa et al. (1998), Landa et al. (1999), Landa et al. (2000)

Case Study 1. The Gray Wolf in Minnesota, United States

Goal: 1,251-1,400 wolves in the state (United States Fish and Wildlife Service 1992).
Outcome: 3,020 wolves in 2004 (Erb and Benson 2004).

After widespread extermination of the gray wolf, by the middle of the twentieth century Minnesota was the only state in the continental United States inhabited by wolves. In 1978, when the Minnesota wolf population numbered approximately 1,235 individuals, it was listed as "threatened" under the U.S. Endangered Species Act (Fuller et al. 1992). A recovery plan was drawn up for the Eastern timber wolf, which included the Minnesota population as well as the newly reestablished Wisconsin and Michigan populations (United States Fish and Wildlife Service 1992).

The goal for the Minnesota wolves was to maintain a stable or increasing population, ideally between 1,251 and 1,400 individuals (United States Fish and Wildlife Service 1992). To accomplish this, the recovery plan set up five zones within Minnesota, with a population goal for each zone. The zones were differentiated by the severity of the response to livestock depredation and the amount of protection afforded wolf habitat. These policies were intended to result in different wolf densities among the zones. In Zone 1, the most strictly protected region, no wolves could be killed. Wolves depredating on livestock would be translocated. In Zones 2 and 3, wolves seen attacking livestock could be killed by government officials. Zones 1, 2, and 3 are frequently described as the "essential areas" in which habitat should be actively improved. In Zone 4, which contains more agriculture, wolves could be shot by government officials at any time within one-half mile of a previous depredation site. Finally, in Zone 5, which should contain no wolves, government officials could shoot wolves within 5 miles of a previous livestock depredation (United States Fish and Wildlife Service 1992).

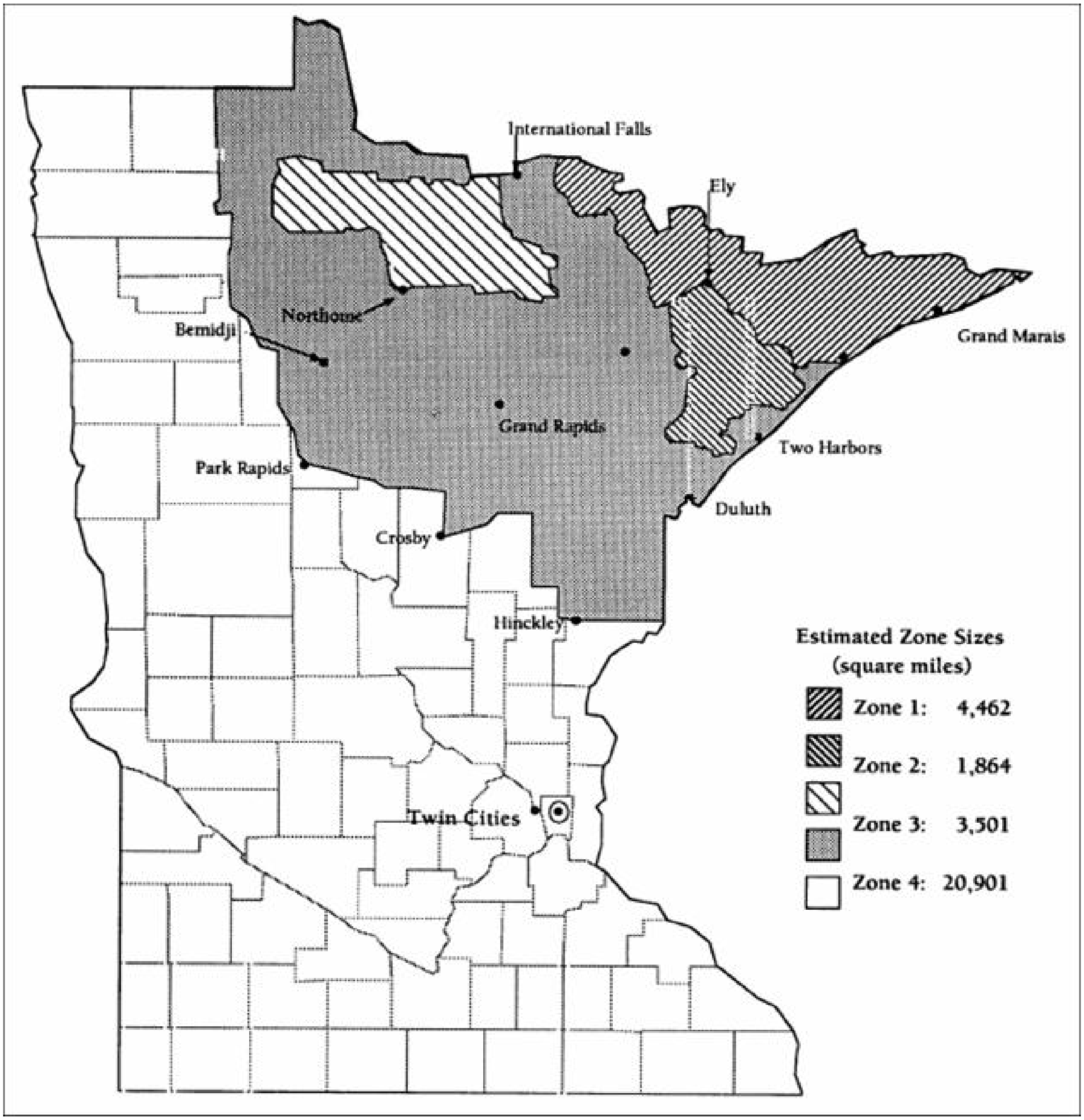

Figure 1. Minnesota wolf zones under federal management, 1978-2007. Source: United States Fish and Wildlife Service (1992).

By 1998, the Minnesota wolf population had increased to 2,450, and on January 29, 2007 it was delisted from the Endangered Species Act (United States Fish and Wildlife Service 2007). The management of wolves in now in the hands of the state government, which uses a simplified version of the federal zoning system; federal Zones 1-4 are now a single zone, Zone A, and federal Zone 5 became Zone B (Minnesota Department of Natural Resources 2001). The only difference between these two zones is in how depredation on livestock is dealt with. In Zone A, there must be an immediate threat of depredation to kill wolves, but in Zone B, wolves can be killed at any time within one mile of land on which livestock or domestic animals are kept. Unlike the federal plan, under state management the killing of wolves is not limited to government officials; landowners are also empowered to kill wolves if they have been trained and possess a permit (Minnesota Department of Natural Resources 2001).

Case Study 2. The Gray Wolf in Wisconsin, United States

Goal: 350 wolves outside of Native American Reservations (Wisconsin Department of Natural Resources 1999).

Outcome: 428 wolves outside of Native American Reservations in 2007 (Wydeven 2008).

Wisconsin wolf management began with the 1978 Eastern timber wolf federal recovery plan, as mentioned above. However, zoned management, which is described in the 1999 Wisconsin Wolf Management Plan, did not go into effect until 2007, when the Minnesota and Wisconsin populations were delisted from the federal Endangered Species list (United States Fish and Wildlife Service 2007). The system involves four zones, which – like the zoning plan in Minnesota – are differentiated by the response to livestock depredation in each zone.

Zones 1 and 2 are the most strictly protected zones and are essentially the same, except they are spatially separated. To allow dispersal between these zones, wolves will not be controlled in Zone 3 unless they cause problems. In Zone 4, wolves are controlled (killed or relocated) if they show no fear in approaching humans, livestock, or pets (Wisconsin Department of Natural Resources 1999). Although the wolf population increased under federal management, the effectiveness of the zoning system and its impact on the Wisconsin wolf population remains to be seen, since it was implemented just last year.

Case Study 3. The Gray Wolf in Finland

Goal: Maintain population of at least 150-200 wolves, evenly distributed between east and west Finland (Ministry of Agriculture and Forestry 2005).

Outcome: 185-200 wolves in 2004 (Ministry of Agriculture and Forestry 2005), distribution unclear.

Wolves have been hunted since at least the late 1800s in Finland, and for much of the twentieth century population numbers were quite low. A 1978 estimate put the Finnish population at 80 individuals; however, the population was never in serious danger because of its connection to the Russian wolf population, which has always numbered well over 10,000. However, in 2005 the Finnish government drew up a management plan with the goal of maintaining a total population of 150-200 wolves (Ministry of Agriculture and Forestry 2005). Although the management plan does not describe very specific management actions, a basic zoning concept makes up the core of the plan.

The management plan divides the country into three zones, or population management regions. Although currently there are no numeric population goals for each region, the need for such goals is scheduled to be discussed in 2010, five years after the implementation of the current management plan. The first zone, the reindeer herding area in northern Finland, is an area of relatively high wolf-human conflict as a result of depredation on semi-domestic reindeer. Therefore, hunting of wolves is allowed during a specified season and lethal control is used by government officials to control wolves that kill livestock.

The overall goal for this region is to maintain or slightly decrease the current wolf population, while still allowing passage of wolves to Norway, Sweden, and Russia (Ministry of Agriculture and Forestry 2005).

The eastern Finland region is the current main wolf area. Since this zone is saturated with wolves, there is no need to increase the wolf population in this area. Lethal control of wolves that kill livestock is allowed, and if the population increases, it may be culled in the future. The third region, western Finland, has suitable habitat for an expanding wolf population, but relatively high levels of human development. The goal for the region is to increase the wolf population and range, but use lethal control by government officials on wolves that attack livestock (Ministry of Agriculture and Forestry 2005).

Case Study 4. The Dingo in South Australia, Australia

Goal: Minimize conflict by eradicating dingoes south of the fence, allow to persist north of fence (Fleming et al. 2001).
Outcome: Unclear due to a lack of population data.

The dingo differs from all of the species listed above because it is still regarded primarily as a pest species in Australia. The primary goal of management is to limit the amount of damage caused by dingoes, although recently some interest in conservation has emerged (Fleming et al. 2006). The current legal status of the dingo varies from state to state. South Australia is the only state that uses a zoning system, although it is not referred to in such terms in the management documents.

Dingoes in Australia were historically controlled through a variety of means, including bounty hunting, poisoned baits, and exclusion fencing. The dingo barrier fence was built in 1945 and stretched 5,631 km in length until it was shortened in 1981 (Allen and

Sparkes 2001). The fence is still the cornerstone of dingo management policy in South Australia. South of the fence is the main sheep-producing area of the state, and landowners are required by state law to lethally control dingoes found within the fence. North of the fence, there is a 35 km buffer zone in which poisoned baits are allowed. Beyond the buffer zone, dingoes are considered a wildlife species, and the baiting, trapping, and shooting of dingoes are prohibited (Fleming et al. 2001). This area produces predominantly cattle, which means that conflict between livestock and dingoes is minimal since they rarely prey on cattle (Allen and Sparkes 2001).

Case Study 5. The African Wild Dog in South Africa

Goal: Conserve a viable population (Woodroffe et al. 1997).
Outcome: 177-434 wild dogs in 2005 (Lindsey et al. 2005), but mostly confined to Kruger National Park with little chance of interbreeding with other populations (Mills et al. 1998).

The African wild dog is threatened throughout its range – it currently is found in only 14 of the 39 countries that made up its historic distribution (Macdonald and Sillero-Zubiri 2004). South Africa is home to one of the most stable populations, comprised of about 350-400 individuals (Woodroffe et al. 1997). Although the legal status of the wild dog in South Africa is "specially protected," in practice this is not the case, as ranchers frequently illegally kill wild dogs found on their land (Linnell et al. 1996).

South Africa does not have a national wild dog management plan, and therefore it does not have an official zoning policy. However, a *de facto* system of zoned management has emerged (Linnell et al. 1996). The gigantic Kruger National Park (22,000 km^2) is home to the majority of the wild dogs in the country, although there are some smaller populations in other national parks and game reserves (Woodroffe et al. 1997). Beyond the borders of these parks, livestock ranches are common, and carnivores of all kinds dispersing from the parks are usually killed to prevent livestock depredation (Linnell et al. 1996). This can be considered a zoning system involving two drastically different zones: adequate protection in large nature reserves such as Kruger National Park, and elimination elsewhere. This is a model of zoning that is relatively common for endangered species because habitat degradation frequently forces these species into the last remaining patches of suitable habitat.

Case Study 6. The Eurasian Lynx in Sweden

Goal: Maintain approximately 1500 lynx, mostly outside of the reindeer husbandry area (Swenson and Andren 2005).
Outcome: Unclear due to lack of updated population data and distribution information.

Swedish lynx make up part of a viable population shared between Sweden and Norway, numbering approximately 1,400-1,800 in 2001 (Liberg and Andren 2004). Lynx have long been a game species in both countries. Most of the livestock depredations occur in the reindeer husbandry areas in northern Sweden. The compensation system for damages resulting from lynx predation on livestock is somewhat unusual as it is based solely on the number of lynx present in a given area, rather than the actual number of depredation events (Swenson and Andren 2005).

According to a 2000 management plan, the goal for Swedish lynx management is to maintain a population of approximately 1500 lynx, but the majority of them should live outside of the reindeer husbandry area. To achieve this goal, the hunting quotas in the north were increased to reduce the population, while those in southern Sweden were decreased to encourage range expansion (Swenson and Andren 2005). This system represents an informal zoning system because the lynx population is being manipulated through hunting to reduce the density in the north while increasing the range in the south.

Case Study 7. The Bengal Tiger in India

Goal: Conserve a viable population.
Outcome: 1,411 tigers as of 2008 (compared to 1,872 at beginning of management plan), highly fragmented populations (Damodaran 2007; Jhala et al. 2008).

Maintaining a viable tiger population was the impetus for the founding of India's most ambitious conservation program, Project Tiger, in 1973. The goal was to preserve tigers by setting up a series of tiger reserves, in which habitat would be protected and human-tiger conflicts minimized (Damodaran 2007). In each reserve, a core area was established, in which all human activity was prohibited. Low-impact human use could occur in the buffer area surrounding the core (Sahgal and Scarlott 2009). Although this system is similar to protected area zoning, it differs in that the reserves are targeted to protect one species (the tiger) rather than to protect biodiversity in general.

Initially, Project Tiger was quite successful. The original 9 reserves grew to 27 reserves by 2001, and the country's tiger population increased from 1,827 in 1972 to 3,750 in 1993 (Damodaran 2007). The unique aspect about tiger management in India is the use of human resettlement as part of the process, which has led Linnell et al. (1996) to characterize India's tiger reserves as examples of "extreme zoning." While it has not been used in all the tiger reserves, in some parks people have expressed a willingness to resettle outside of the park boundaries. For example, resettlement out of Nagarahole National Park has resulted in a reduction of retaliatory killings of tigers, diminished poaching pressure, and less habitat conversion (Karanth et al. 1999).

However, by 1997 India's tiger population was declining steadily. The 2008 tiger population estimate is 1,411, which is smaller than the population at the beginning of the Project Tiger program (Jhala et al. 2008). Problems contributing to the decline include poaching and wood cutting, mining, livestock grazing, and other human activities in the core areas of the parks (Sahgal and Scarlott 2009). Thapar (1999) states that 23,000 km^2 of a total 33,000 km^2 in Project Tiger reserves face either "possible disaster" or an "uncertain future." In 2005, it was revealed that tigers were extinct from Sariska Tiger Reserve as a result of insidious poaching (Sahgal and Scarlott 2009).

However, steps are being taken to improve the status of the tiger in India. In November 2007, a committee was formed to investigate the effects of the Forest Rights Act of 2006, which allows forest dwelling families to claim land, including protected area land. A Wildlife Crime Control Bureau was also created to attempt to stem the flow of poaching (Sahgal and Scarlott 2009). Although there is much work to be done to improve the status of the tiger, it appears that Indian policy may be headed in the right direction.

Case Study 8. The Cougar in Alberta, Canada

Goal: Maintain a population of 600 cougars and a sustainable hunting program (Fish and Wildlife Division 1992).

Outcome: Population of 685 cougars in 1992 (Fish and Wildlife Division 1992) and hunting was sustainable as of 1996 (Ross et al. 1996), but no updated reports since then.

Cougars are abundant enough to be classified as a game species in Alberta. The level of human-wildlife conflict is relatively low because the main agricultural area is in the southeastern portion of the province, while the cougar's range is limited to the western side (Linnell et al. 1996). In 1992 a provincial management plan was created with the stated goals of maintaining the current estimated population of 685 cougars and using regulated hunting to ensure an evenly distributed take (Fish and Wildlife Division 1992).

The plan broke the cougar range into eleven Cougar Management Areas. Quotas for each zone were based on conservative population estimates because of the difficulty of obtaining an accurate cougar population count (Fish and Wildlife Division 1992). Ross, Jalkotzy et al. (1996) report that the new harvest management practices implemented after the 1992 management plan have resulted in a 62% increase in the cougar harvest without harming the population because it distributed the hunting effort evenly between the management areas.

Case Study 9. The Brown Bear in Norway

Goal: Allow no more than 8-10 adult females to establish themselves in the five core zones (Swenson and Andren 2005).

Outcome: 18-34 bears in Norway in 2001 (Swenson and Andren 2005), unacceptably high livestock depredation – 25 times more sheep are killed per bear than in the rest of Europe (Zimmermann et al. 2003).

Brown bears were essentially exterminated in Norway because of the bounty system in place until 1973, at which point they became a protected species. However, due to migrations from neighboring Sweden, the Norwegian bear population rose to about 18-34 as of 2001 (Zedrosser et al. 2001). In 1992 the Norwegian government created a bear management plan that set up five core zones along the border with Sweden, with the goal of maintaining 8-10 adult females in each zone (Swenson and Andren 2005). There is not an available English translation of this plan, but descriptions of its provisions refer vaguely to “alternative conflict-reducing measures” used inside the core areas and lethal control used outside of them (Zimmermann et al. 2003).

The main problem with carnivore management in Norway is that there is an extremely high level of conflict with livestock. The rate of livestock loss due to bear depredation was found to be 24 times higher than the rate in the French Pyrenees, which had the second-highest rate of livestock loss due to bears (Kaczensky 1999). The reason for this is that the dominant livestock husbandry practice in Norway is free-ranging, unguarded sheep, which are highly vulnerable to attacks from carnivores. There is no incentive for farmers to change their husbandry practices, since sheep farming is subsidized and livestock losses due to carnivore depredations are fully compensated. Unlike in Sweden, there is no requirement to use preventative measures such as fences or guard dogs in order to receive compensation (Swenson and Andren 2005). Unless sheep husbandry is changed or prohibited, at least within the core conservation areas, it seems unlikely that the current system will allow for the reestablishment of bear populations without continuing high rates of conflict (Sagor et al. 1997).

Case Study 10. The Brown Bear in Slovenia

Goal: Before 2002 – maintain viable population. After 2002 – maintain viable population, allow bears to colonize Italy through corridor in Alps (Ministry of the Environment and Spatial Planning 2002).

Outcome: Relatively successful management until 2002, then unacceptably high levels of conflict, especially in the corridor area (Krystufek and Griffiths 2003).

Brown bears were first protected in Slovenia in 1966, when the Bear Core Conservation Area (BCCA) was formed in the southern part of the country (Simonic 2003). Within the BCCA, there was regulated hunting of bears, damage compensation, and supplemental feeding of bears at designated sites to keep them from wandering out of the core area. Outside of the BCCA area, bears could be freely hunted, with the exception of females with cubs (Adamic 1997). The theory behind this system was to allow bears to establish a core population in the BCCA, where conflict was minimal, and most dispersing bears would be killed by hunters, keeping damage low outside the BCCA. This system worked fairly well, as visits to the feeding station provided a way to measure the size of the bear population, which was taken into account when setting the hunting quota for the BCCA (Krystufek 2008).

However, in 2002, bear management changed dramatically as Slovenia prepared to join the European Union. Bears transitioned from a game species to a protected species, and international pressure to allow bear migration from the Slovenian Alps to the Italian and Austrian Alps resulted in a completely new zoned management strategy. The four zones consisted of a core area (identical to the BCCA), a transitional or buffer area, two corridors to the Alps, and an outer area. In the core area, regulated hunting and supplemental feeding occur. The transitional and corridor areas allow for very limited hunting, and in the outer area, no hunting was allowed, although problem bears could be killed with a special permit (Simonic 2003). The new system was largely a failure because the habitat in the corridor area was not very suitable for bears, and the number of depredations on livestock skyrocketed in both the transitional and corridor areas (Krystufek et al. 2003).

Case Study 11. The Grizzly Bear in the Greater Yellowstone Area, United States

Goal: Minimum of 158 bears (United States Fish and Wildlife Service 1993).
Outcome: 365 bears in 2001 (Interagency Conservation Strategy Team 2007).

The grizzly bear was categorized as threatened under the U.S. Endangered Species Act in 1975. The Greater Yellowstone Recovery Area manages one of several distinct grizzly bear populations in the Western United States. The first recovery plan was written in 1982 by the United States Fish and Wildlife Service, and has since been revised in 1993 (United States Fish and Wildlife Service 1993). Like the other recovery areas, the Greater Yellowstone Area (GYA) was divided into small bear management units. Each of these units was categorized as one of five different management situations, which control the level of human development that is allowed.

Areas designated as Management Situation 1 have high grizzly bear concentrations that are necessary for the survival of the species. Land uses that cannot be made compatible with grizzly bears will be prohibited. Management Situation 2, in somewhat vague language, attempts to balance land uses for grizzly bears and for humans, stating that “managers would accommodate demonstrated grizzly populations… but not to the extent of exclusion of other uses” (United States Fish and Wildlife Service 1993). In Management Situation 3, grizzly bears are uncommon and their presence is discouraged, using both lethal control and relocation. Finally, Management Situations 4 and 5 refer to areas that are not currently inhabited by grizzly bears, with Situation 4 referring to areas that are potentially suitable for grizzly bears and Situation 5 designated to areas that are not likely to become inhabited by grizzly bears. In these areas there are no restrictions on development or habitat maintenance (United States Fish and Wildlife Service 1993).

In March 2007, the GYA population of grizzly bears was removed from the Endangered Species Act. The new management plan eliminates the Management Situations and makes the entire GYA recovery zone of the 1993 plan into the Prime Conservation Area to facilitate grizzly bears extending their range beyond the borders of the former recovery zone (Interagency Conservation Strategy Team 2007).

Case Study 12. The Wolverine in Norway

Goal: Maintain viable population in the north and establish a viable population in the south, mostly confined to the core area (Swenson and Andren 2005).
Outcome: High depredation rate led to removal of wolverine core area in 2001 (Linnell et al. 2005).

The wolverine was essentially exterminated in Norway by the time it received legal protection in northern Norway in 1973 and southern Norway in 1982. However, a small population remained in the far north on the border with Sweden (Landa et al. 1999), which has recolonized some of its historic range after being granted protection. In 1994, three wolverine core conservation areas were established in Norway. As soon as 1997, two of the core areas were abolished, leaving in place only the southernmost core area. The core conservation area protects wolverines from hunting, although they can be hunted up to the border of the conservation zone (Landa et al. 1998).

Despite the relatively small populations of 209 wolverines in northern Norway and 62 wolverines in southern Norway (2000 estimates), hunting is allowed in both areas (Swenson and Andren 2005). There has been some criticism of the high quotas for the wolverine, especially in the southern part of the country, in which the quota was set at 22% of the total population during 2000-2002. Corresponding to the high quotas, there has been a recent decline in the wolverine population in Norway (Swenson and Andren 2005).

The high rate of hunting is largely a response to the high livestock depredation rate that plagues Norway because of their free-ranging sheep practices, as discussed above. Although wolverines are not allowed to be hunted in the core conservation area, grazing of sheep occurs in this protected zone, leading to a high level of conflict. Landa et al. (1999) have found that lethal control measures on “problem” wolverines, which are allowed in the core conservation area, have only a short-term impact on the level of livestock depredation.

Pressure from the livestock owners due to the high level of predation by wolverines led to the removal of the one remaining wolverine core area in 2001 (Linnell et al. 2005). In this case, it is the high rate of livestock depredation that prevents effective carnivore management.

Evaluation of Case Studies

I defined the "success" of a case study zoning system as meeting the goal stated in a species management plan for each case. When a management document was not available (or was not written in English) I relied on secondary sources that summarized the management plan. I defined zoning systems as unsuccessful if the stated management goal is not being met, or if it is not being met without unacceptable side effects, such as very high rates of livestock depredation. Zoning systems were labeled "indeterminate" if there was not enough information to determine the success or failure of a zoning system, or if the system began very recently and therefore has not been evaluated. Table 3 shows the twelve case studies and the current level of success of their zoning systems.

Three of the twelve case studies achieved success – wolf management in Minnesota, grizzly bear management in the Greater Yellowstone Area, and brown bear management in Slovenia (although only before 2002 – after this point, it was unsuccessful). An additional three were partially successful. Four were unable to be evaluated because of a lack of data after the implementation of the zoning system. Of the three unsuccessful zoning systems, two were located in Norway.

Table 3. Evaluation of the case studies based on the stated goal of the zoned management plan. Outcomes were categorized as successful, somewhat successful, unsuccessful, or indeterminate. Explanatory comments are provided for case studies not deemed successful.

Case Study	Evaluation	Comments
Brown bear, Slovenia (before 2002)	Successful	–
Grizzly bear, GYA	Successful	–
Wolf, Minnesota	Successful	–
African wild dog, S. Africa	Somewhat successful	Population in Kruger National Park is probably viable, but others are fragmented
Tiger, India	Somewhat successful	Population increase at first, then decrease; populations are scattered and fragmented
Wolf, Finland	Somewhat successful/Indeterminate	Population increased, but distribution indeterminate
Cougar, Alberta	Indeterminate	Successful until at least 1996, but no population estimates or reports on hunting since then
Dingo, S. Australia	Indeterminate	Population estimates, livestock depredation rate unknown
Lynx, Sweden	Indeterminate	No available updates since zoning was implemented in 2000
Wolf, Wisconsin	Indeterminate	Zoning implemented in 2007
Brown bear, Norway	Unsuccessful	Unacceptably high livestock depredation
Brown bear, Slovenia (after 2002)	Unsuccessful	High livestock depredation, corridor did not work
Wolverine, Norway	Unsuccessful	Removal of core area because of high livestock depredation

Types of Zoning

The case studies highlight the diverse ways that zoning has been used to manage large carnivore species in locations around the world. Each individual case is somewhat different based on ecological, social, political, and economic factors specific to each location and species. However, if every case is considered to be completely unique, it is difficult to make generalizations about the factors influencing the outcomes of the zoning systems. At the beginning of this paper, I posed the question: how has single-species zoning been used in the past, and how is it being used today? Although the individual case studies are part of the answer to this question, it would be more useful to be able to discuss zoning strategies by category rather than individually.

Using my twelve case studies and additional zoning literature, I propose that there are four main forms of single-species zoning: density-driven, core area, game species, and pest species zoning strategies (Table 4). This categorization is based largely on the goals and methods of the zoning strategy, but also the relative level of abundance or endangerment faced by the species in question. Each of the twelve case studies can be placed into one or more of these categories, and I predict that other examples of single-species zoning could be placed into these categories as well.

Density-Driven Zoning

This type of zoning is characterized primarily by its goal of regulating the density of large carnivores in different management zones. In the zones most suitable for carnivores, such as areas with relatively intact habitat and low human population density, management techniques favor the establishment of carnivore populations. This could mean using translocation of problem animals instead of lethal control, requiring livestock owners to use preventative fencing of their animals, or prohibiting land uses seen as incompatible with large carnivores, such as sheep farming. In areas in which carnivores are less desirable, such as agricultural areas or cities, management techniques would discourage the establishment of carnivore populations, using such tactics as regulated hunting, population culls, or lethal control.

Several of the case studies illustrate density-driven zoning, including wolves in Minnesota, Wisconsin, and Finland, grizzly bears in Yellowstone, and lynx in Sweden. These four cases illustrate the diversity within density-driven zoning systems. Some are more detailed than others, both in the stated goal and in the steps taken to achieve the goal. The management of wolves in Minnesota involves highly specific guidelines for each zone, which outline a target population and specific protocols for managing human-wolf conflict. Wisconsin has a similarly detailed list of allowed and prohibited management actions for each wolf zone, but no zone-specific population goals. Grizzly bear management does not have population goals for different zones, but it does have a system of prioritized land uses within the bear management zones.

Finnish wolf and Swedish lynx management is fairly informal. Management plans for both of these cases state that populations should be maintained at the current level in some areas, and increased or decreased in others because of issues of conflict with human activities, namely reindeer husbandry. The methods for increasing or decreasing the population are left somewhat vague, which may allow increased local flexibility.

Advantages of a density-driven zoning system include the ability to finely regulate where large carnivores appear and do not appear. These systems, provided that they are made well-known, offer predictability to the public about where large carnivores will be, which may influence land use choices. However, this type of system, if crafted in the degree of detail of the Minnesota and Wisconsin wolf plans, requires a considerable amount of research and monitoring to keep track of the population levels in each zone, as well as habitat suitability and levels of human-carnivore conflict in each zone. They may also be difficult to enforce, especially on the borders of zones. For example, a sheep rancher just inside the boundary of a more strictly protected zone may resent the tighter restrictions imposed on him than on his neighbors. A boundary drawn on a map does not necessarily mean that conditions are noticeably different on either side – carnivores and humans alike will not always respect artificial borders (Wydeven 2008).

Core Area Zoning

Core area zoning is a common management strategy that is based on a very simple concept: afford carnivores a high level of protection inside one or more core areas and offer less or no protection outside of them. The core area can, and frequently does, correspond to an existing protected area, but this is not necessary. The ecological theory behind this concept is based in source-sink population dynamics: the carnivore population inside the core area will be maintained approximately at the carrying capacity, which will result in dispersal to surrounding areas, where control of carnivores will keep them from establishing a permanent population (Krystufek and Griffiths 2003). Assuming the core area is large enough to maintain a viable population or is connected to another population, this is a conceptually simple way to keep a viable population confined to an area where conflict will be low.

The cases of the brown bear in Slovenia and Norway, African wild dogs in South Africa, and tigers in India all illustrate this type of zoning. Slovenia (before the changes in management in 2002) was a good model – the core area was connected to the Dinaric brown bear population that stretches southeast to Greece, meaning that there were enough individuals to maintain good genetic diversity. There was relatively little conflict with humans and livestock within the core zone because it was a mostly cattle-producing region rather than the sheep-producing region it is today, and on average bears kill far more sheep than cattle (Krystufek and Griffiths 2003). Krystufek (2003) writes that the system of core area zoning worked efficiently "without anyone having precise knowledge of the parameters involved," meaning that in-depth population monitoring was not necessary in this system. In Norway, however, there is a high level of conflict between brown bears and sheep farmers even inside the core areas, which limits the effectiveness of zoning because sheep producers are unwilling to tolerate the current high rates of livestock depredation (Swenson and Andren 2005).

African wild dogs in South Africa and tigers in India present a slightly different variety of core area zoning. Although both species are legally protected by the government, these carnivores are only truly protected inside national reserves or parks. Where parks are very large, this system seems to function, but the high likelihood of death for dispersing individuals means that smaller populations are likely to become inbred due to a lack of gene flow between populations.

The advantage of core area zoning is that it can work even when the size of the carnivore population is not well known, as shown by the case of brown bears in Slovenia. It is a simple management plan to implement, and it allows the public to have a clear idea of where carnivores will be present. However, its success depends on the core area having a low level of human-carnivore conflict and being large enough to support a viable carnivore population. The main disadvantage of this type of zoning is that there are not many places that fit this description. To make core area zoning work in countries that lack large areas with low conflict levels, human land uses may need to be changed and metapopulation dynamics may depend on translocation of individual animals by humans to function properly (see Mills et al. (1998) and Lindsey et al. (2005) for a description of this concept at work in wild dog conservation in South Africa).

Game Species Zoning

Game species zoning is only used on species that are abundant enough to sustain some level of public hunting. The goals are to sustain viable carnivore populations while keeping human-carnivore conflict at a manageable level and allowing the continuation of a recreational activity that often has deep cultural roots. It involves zones that are each given a quota that can be manipulated from year to year to increase, maintain, or decrease the carnivore population in specific zones. This type of zoning is currently being used on cougars in Alberta and wolverines in Norway.

Alberta is an example of relatively successful game species zoning. The province is fortunate to have a naturally low level of human-carnivore conflict because of the spatial separation of the major agricultural area and the cougar's natural range. Quota-limited hunting has allowed the provincial government to effectively distribute the hunting take between hunting zones and control the proportions of males and females taken (Ross et al. 1996). In Norway, the wolverine harvest is more controversial. Due to the high level of human-carnivore conflict in Norway, it is politically difficult to limit hunting of the wolverine and other carnivores. This has led to an unsustainably high wolverine quota, especially in the southern Norway management region (Swenson and Andren 2005).

Advantages to game species zoning include public participation in large carnivore management and the provision of recreational opportunities. Studies have shown that people feel less antagonism toward large carnivores if they are allowed to hunt them (Treves and Karanth 2003). It is also a low-cost strategy that is relatively easy to implement, and the harvest numbers can be used to help estimate population size. However, there must be a fairly good estimate of the population size to set reasonable quotas. In the Norwegian case, the level of conflict makes it difficult to lower the quota to a more sustainable level of hunting. Furthermore, some researchers have shown that regulated harvests of carnivores only reduces human-carnivore conflict in the short term, because recolonization will replace those lost to hunting (Treves and Karanth 2003). Therefore, game species zoning is probably not the best approach if conflict mitigation is one of the main goals of the management system.

Pest Species Zoning

Pest species zoning is related to game species zoning in that lethal forms of control are used to regulate abundant carnivore populations. However, the species that are subject to pest species zoning are not traditionally hunted. These species have historically been regarded as an impediment to agriculture and have often been the subject of government-sponsored eradication campaigns. The goal of current pest species management is first to control damages caused by the species in question, and then to conserve a viable population.

Pest species zoning is harsher than game species zoning in that regulated hunting usually seeks to remove a small portion of individuals every year, while pest species zoning often aims to eliminate every individual from selected zones.

The only one of the twelve case studies that fits into this category is dingo management in Australia. In many areas of the country, landowners are required by law to kill dingoes found on their property, using a variety of acceptable means (Fleming et al. 2001). Dingoes are tolerated only in areas where they do not cause high levels of damage, which results in a system of dingo presence in cattle raising areas and dingo absence in sheep raising areas. The initiative to conserve dingoes is a somewhat recent development, begun partly because high rates of hybridization with domestic dogs are causing the number of remaining pure dingoes to decline rapidly (Corbett 1995).

The advantages to pest species zoning include the relative ease of management, since landowners are directly involved in population control. However, widespread eradication is obviously damaging to the population of any species, and care must be taken to designate some areas in which the species is allowed to persist. These areas should have low human-carnivore conflict potential to minimize the injustice of forcing some people to tolerate carnivores while others are encouraged to kill them freely. Another disadvantage is that planned eradication of a species is likely to create controversy, especially from animal rights activists.

Table 4. Description of the four types of zoning. Advantages and disadvantages of each type are listed, as well as the case studies that exemplify each type of zoning.

Type of zoning	Description	Advantages	Disadvantages	Case studies
Density-driven	Regulates density of carnivores within each zone	Allows control over where carnivores occur, provides predictability	Large research and monitoring effort, difficult to enforce	Wolf, Minnesota Wolf, Wisconsin Wolf, Finland Grizzly bear, GYA[a] Brown bear, Slovenia
Core area	High level of protection inside core, little to no protection outside	Does not require complete knowledge of population size, simple conceptually, provides predictability	Core must have low human-carnivore conflict, must support viable population	Brown bear, Slovenia Brown bear, Norway African wild dog, S. Africa Tiger, India
Game species	Assigns hunting quotas to zones to maintain or adjust population levels	Public participation in management, recreational opportunities, low cost, harvest numbers help monitor population size	Reliable estimate of population size is needed to set sustainable hunting quotas, may not reduce human-carnivore conflict in the long run	Cougar, Alberta Wolverine, Norway
Pest species	Eradication in selected zones, some protection in others	Relatively easy management, conceptually simple	Can result in dangerously small population, controversial	Dingo, South Australia

[a]Greater Yellowstone Area

Analysis of Key Factors

Space

One of the most difficult aspects of large carnivore conservation is the need for large amounts of space in order to reduce conflicts with people and their property. Nearly all of the experts I corresponded with identified space as a key factor in a successful zoning system. The respondents that placed the most emphasis on scale were those who did their research in small countries, specifically Switzerland, Austria, and Slovenia (Breitenmoser 2008; Kaczensky 2008). A researcher of human-carnivore conflict in central Europe wrote that except for some areas in Scandinavia, zoning cannot be used effectively in Europe because of the small size of the countries and the high density of human settlement (Kaczensky 2008).

The problem of space is expressed well by Linnell (2005), who emphasizes that the scale of zoning systems must correspond to the ecological scale of the species being managed. For large carnivores, important ecological data to consider includes home range size, population density, and dispersal distance of the species in question. Home range size and carnivore population density data help determine how many individuals can live in a certain protected area or management zone, especially when compared to the minimum viable population (MVP) of the species. For example, Wilson (2004) studied the feasibility of reintroducing the wolf, lynx, or brown bear to the United Kingdom using population density and MVP to determine if there was enough available space to support populations of these species.

In Table 5 (below), I present an analysis similar to that of Wilson. For 7 of the 12 case studies, I was able to collect data on both the size of the “core” area and the average population density of the species (for the other five case studies, one or both of these pieces of information was unavailable). The core area was defined as the management zone(s) that provided the highest degree of protection. In some cases this meant more than one zone; for example, in Minnesota zones 1, 2, and 3 are all designated as critical wolf habitat. From these data, I calculated the size of the theoretical population that could inhabit this core area at average population density and, where possible, compared that number to the estimated MVP.

Table 5. Theoretical carnivore population size within the core area for the case studies in which the necessary information was available. This was calculated using the size of the core area or most protected zone (in km^2) and the average population density of the species per square kilometer. The estimated minimum viable population (MVP) is presented when possible for comparison.

Case Study	Size of "core" area	Avg. pop. density	Theoretical pop. size	MVP
Wolf, Minnesota	77,700	2.3-3.8	1,787-2,953	200
Wolf, Wisconsin	47,614	2.5	1,190	200
Wolf, Finland	79,469	0.1-1	79-795	150
Brown bear, Slovenia	3,480	10-20	348-696	1,000
Grizzly bear, GYA	23,854	1.1	262	50
African wild dog, S. Africa	22,000	.-3.5	44-770	100
Cougar, Alberta	89,236	2-5.9	1,785-5,265	–
Wolverine, Norway	13,505	.28-.38	38-51	–

The goal of this analysis is not to predict the population size of these carnivore species within the core areas, but rather to assess whether or not the amount of space in the core zones is sufficient to maintain a viable population. This information is important because in many zoning systems, few individuals will be able to survive outside of the core area because of persecution, unsuitable habitat, or low prey density. This is particularly true for the type of zoning I described as core area zoning. If there is not sufficient space within the core zone, carnivores will either have to survive in less optimal areas where conflict with humans will likely be higher, or face inbreeding and other small population problems.

In considering this analysis, it is important to remember its limitations. First, this model assumes that the population within the core area will either be the only population in the state or country, or it will be isolated from other populations. Although this is true in the case of the Norwegian wolverine population (Landa et al. 1999), many of the core areas do have connectivity with other populations. For example, in Slovenia, the bear core conservation area is adjacent to the bear population of neighboring Croatia, which is home to an estimated 389-620 bears (Huber et al. 2003). Wolves can also disperse easily between Minnesota and Wisconsin – this is how Wisconsin's wolf population was re-established in the first place (Wydeven et al. 1995).

Furthermore, it is important to bear in mind that the calculated theoretical population size takes only two factors into account: available area and species population density. In reality, the size of a population depends on many more factors. Although the core areas used in the analysis are the areas with the highest level of protection within the state or country, this does not mean that there will be no persecution (legal or illegal) of the species or that the habitat is uniformly suitable throughout the core area. The theoretical population size essentially represents the maximum possible population that could inhabit the given core area, assuming the given population density.

Despite these caveats, this analysis can still be of use in examining the effect of core area size on the theoretical maximum population. Many of the core areas in the case studies I examined are large enough to support a population that exceeds the minimum viable population, such as those of Minnesota, Wisconsin, Greater Yellowstone, and Alberta. Some of the theoretical populations vary widely because of the range of reported population densities, such as the wolf population in Finland and the wild dog population in South Africa, making it unclear whether or not the theoretical population meets the MVP. It seems that based on this estimation, the theoretical wolverine population in Norway faces a high risk of local extinction because its small size makes it vulnerable to stochastic variation.

In most zoning systems, if the most highly protected area cannot support a population at or above the level of the MVP, the system is unlikely to be successful. Since the core zones normally occur in the areas with the best available habitat and the lowest conflict potential, the expectation of maintaining a sizable population outside of the core area will probably not be met. This makes clear the significance of the scale of the zoning system.

Human-Carnivore Conflict

Another key factor in the success or failure of a zoning system is the level of human-carnivore conflict. As described above, conflicts with large carnivores can take many forms, the primary ones being competition for game species, livestock depredation, and human injury or death. These conflicts often result in retaliatory killings of carnivores and a lack of public support for carnivore conservation initiatives (Treves et al. 2006). In most of the twelve case studies analyzed in this study, livestock depredation is the most pervasive conflict between humans and carnivores.

In this section, I address the question: does human-carnivore conflict influence the success or failure of zoning systems? Table 6 (below) shows the result of this analysis. I used three determinants of the level of human-carnivore conflict – human population density, the level of danger to humans, and the livestock depredation rate – and compared these variables to the outcome of the zoning system for each of the twelve case studies. The level of danger to humans was classified as high if there have been documented cases of man-killing, medium if there have been documented cases of aggression toward humans, and low if no aggressive encounters with humans have been reported. Livestock depredation rate was difficult to compare between cases because it was reported differently – sometimes raw numbers of livestock killed, sometimes amounts of money paid in compensation, sometimes percentages of livestock killed by all the carnivore species in the area, and sometimes other methods. Therefore, I placed them into rough categories rather than attempting to compare different types of data. I used compensation payment data and rates of livestock kills and compensation claims to place the case studies into categories of high, medium, or low livestock depredation rates.

Woodroffe (2000) found that human population density was a good predictor of declining or very small carnivore populations because of the high level of conflict that results from frequent encounters between humans and carnivores. However, Linnell et al. (2001b) argue that although low human densities are preferable, conservation of large carnivores can be achieved in areas of high human density if the management strategy is effective. The results of this analysis support the latter hypothesis; it seems that human population density did not have an important influence on the success of zoning systems in these twelve cases. One of the successful zoning schemes had a very low human population density (grizzly bear management in the Greater Yellowstone Area), but the other two successful cases had medium to high human population densities. Slovenian management of brown bears before 2002 was successful, and was accomplished at the high human density of 95.1 people per

Table 6. Effect of human-carnivore conflict on the success of zoning systems. The independent variable is the outcome of the zoning system, and the dependent variables are human population density (per km^2), the level of danger to humans posed by the carnivore species, and the livestock depredation rate caused by the carnivore species.

Case Study	Outcome of zoning system	Human pop. density[a]	Danger to humans	Livestock depredation
Grizzly bear, GYA[b]	Successful	2.0	High	Low
Brown bear, Slovenia (pre-2002)	Successful	95.1	Medium	Low
Wolf, Minnesota	Successful	22.2	Medium	Low
African wild dog, S. Africa	Somewhat successful	36.4	Low	Medium
Tiger, India	Somewhat successful	328.6	High	High
Wolf, Finland	Somewhat successful/ Indeterminate	15.5	Low	Medium
Cougar, Alberta	Indeterminate	5.0	Medium	Low
Lynx, Sweden	Indeterminate	20.0	Low	Low
Wolf, Wisconsin	Indeterminate	31.7	Medium	Low
Dingo, S. Australia	Indeterminate	1.6	Low	High
Brown bear, Norway	Unsuccessful	14.2	Medium	High
Wolverine, Norway	Unsuccessful	14.2	Low	High
Brown bear, Slovenia (post-2002)	Unsuccessful	99.2	Medium	Medium

[a] Population data from Statistics Canada (2005), Australian Bureau of Statistics (2006), United States Census Bureau (2005), and the United States Central Intelligence Agency (2005).
[b] Greater Yellowstone Area

km^2. Furthermore, several of the case studies with high population densities had at least somewhat successful zoning systems, such as tiger management in India and African wild dog management in South Africa.

The level of danger to humans does not seem to play much of a role in the outcome of zoning systems. Some highly dangerous and moderately dangerous species (such as the grizzly bear, brown bear, and wolf) were conserved effectively, meaning that the direct threat to human life did not play a significant enough role to prevent the conservation of the species.

The livestock depredation data show that all three of the successful zoning systems had low livestock depredation rates. Meanwhile, two of the unsuccessful systems had high livestock depredation, and the third (brown bears in Slovenia, after 2002) had recently increased from low to medium livestock depredation. This is clear evidence that it is difficult to effectively manage species that have frequent conflicts with humans, a finding that is supported by the work of many other researchers (Karanth and Madhusudan 2002; Treves and Karanth 2003; Swenson and Andren 2005). L. David Mech, in his response to the survey, wrote that zoning only works when carnivores can be zoned out of areas with high levels of conflict (Mech 2008).

The exceptionally high rate of livestock depredation in Norway has been the subject of much discussion (Linnell et al. 1996; Kaczensky 1999; Landa et al. 1999; Andersen et al. 2003). Most blame Norwegian husbandry practices, which, during the long absence of large carnivores, have evolved to allow livestock to roam untended for most of the summer months (Kaczensky 1999). Furthermore, the program of compensation for livestock depredation does not require the livestock owner to have any preventative measures in place, such as fencing or guard dogs (Swenson and Andren 2005). It seems that in order for Norwegian zoning systems to work in the future, livestock husbandry practices will have to be modified.

Threat Level

Depending on the population size of the species, some management tools are more appropriate than others (Linnell et al. 2005). For instance, control of problem individuals might take the form of lethal control if the population is large, or translocation if the population is small. Table 7 shows the IUCN status of each case study species, as well as their legal status and population size in the case study location.

Table 7. Threat level and population size of case study species

Case Study	IUCN Status[a]	Legal status in state/country[b]	Population estimate (year)[b]
African wild dog, S. Africa	Endangered	Protected	177-434 (2005)
Tiger, India	Endangered	Protected	1,411 (2008)
Dingo, S. Australia	Vulnerable	Actively persecuted/no protection	No data
Wolverine, Norway	Vulnerable	Protected game species	360 (2007)
Cougar, Alberta	Near Threatened	Protected game species	682 (1992)
Lynx, Sweden	Near Threatened	Protected game species	1,600 (2000)
Brown bear, Norway	Least concern	Protected	18-34 (2001)
Brown bear, Slovenia	Least concern	Protected game species until 2002, then protected	400-450 (2000)
Grizzly bear, GYA	Least concern	Protected	365 (2001)
Wolf, Finland	Least concern	Protected	185-200 (2004)
Wolf, Minnesota	Least concern	Protected until 2007, then monitored	3,020 (2004)
Wolf, Wisconsin	Least concern	Protected	428 (2007)

[a] Data from the IUCN (2007)
[b] Data sources used for case study information are listed in Table 2.

Only four out of the twelve case study species are listed as either endangered or vulnerable, while six of the species are listed as "least concern" by the IUCN (IUCN 2007). This may seem contrary to the expectations, stated earlier in this paper, that large carnivore species are difficult to conserve because of large space requirements and high conflict potential. However, many of the world's most endangered large carnivores, including the Iberian lynx, the Ethiopian wolf, and the snow leopard, to name a few examples, are not included among the case studies because there is no documentation of a zoning system in place to manage these species. However, it is likely that they are subject to *de facto* zoning in which they are restricted to protected areas or habitat patches simply because they cannot survive anywhere else, similar to the African wild dog case study.

It seems that perhaps zoning is not the best management strategy for highly endangered species. Zoning is closely tied to the use of lethal control (eleven of the twelve case studies include provisions for lethal control in their stated management strategy), which can be highly controversial for very rare species of which every individual is important (Treves and Naughton-Treves 2005). Additionally, endangered species are likely to already be confined to the remaining patches of habitat in some kind of *de facto* zoning system, which would limit the possibility of a new zoning system being able to adjust their distribution. Both of the endangered species investigated in this paper, the African wild dog and the tiger, are managed in some areas with core area zoning somewhat by default because the carnivores are already restricted to the habitat patches that are only to be found in protected areas.

Public Acceptance of Zoning

Even if a large carnivore zoning system has plenty of space, a low rate of conflict with humans, and the species is not highly endangered, it would not necessarily be successful. There are many other site-specific factors that help determine the outcome of a zoning system or any carnivore conservation plan. One of the most important of these is the attitude of the public toward both carnivores and the current management program.

Public attitudes toward carnivores directly affect support for carnivore conservation and willingness to tolerate some level of damage resulting from carnivores (Kaczensky et al. 2004). Those who live nearest to carnivores and are most likely to suffer the associated damage tend to have the most strongly negative opinions, while urban populations tend to favor the recovery or maintenance of carnivore populations. This can cause carnivore management issues to also become environmental justice issues in which a rural minority has limited control over their physical and economic well-being (Linnell et al. 2005).

Public understanding of the carnivore management system and inclusion in its planning stages can greatly improve attitudes toward carnivores. For example, Kaczensky et al. (2004) found that approximately half of the Slovenians they surveyed did not know of the existence of a livestock compensation program. Furthermore, despite the positive attitude toward bears held by most people, approximately 55% of the respondents indicated that bears should be exterminated from areas where they come into conflict with sheep, which would mean removing them from most of their current range. The authors attribute this discrepancy to a lack of knowledge of the complexity of brown bear management (Kaczensky et al. 2004).

Thiel and Valen (1995) describe a method for including public input in carnivore management plans based on their experience with wolves in Wisconsin. The process encouraged public commentary on the draft recovery plan through nine public forums and a series of public comment periods, which were advertised through mass mailings, newspaper articles, and radio and television announcements throughout the state. The recovery plan committee also met with affected parties such as hunters, landowners, and advocacy groups. The entire process resulted in 225 total responses, which were then incorporated into the final wolf recovery plan (Thiel and Valen 1995). These methods could be imitated in other locations to include the public in carnivore management planning.

Economic and Political Factors

The status of carnivores depends greatly on location specific characteristics of many kinds, including cultural, historical, social, economic, and political factors (Clark et al. 1996). In this section, I will briefly highlight some of the economic and political factors that affect the case studies. However, this is by no means a comprehensive list of all the economic and political factors that can influence zoning systems.

In a brief glance at the list of case studies, one may notice that nearly all of them are from Western, developed nations: three from the United States, one from Canada, five from Europe, and one from Australia. The two remaining case studies, India and South Africa, have both had organizational and monetary problems with their large carnivore management systems. India has had ongoing problems with enforcement of park boundaries and lack of political will to conserve tigers, especially when the alternative is development projects (Thapar 1999; Sahgal and Scarlott 2009). South Africa never had a formal management strategy for its African wild dog population; they have become zoned into the national parks by default. Although African wild dogs are legally protected within South Africa, there is little enforcement of this law, and illegal killing of wild dogs is common and even occurs inside the parks (Woodroffe et al. 1997).

Although the zoning systems in the developed countries are certainly not perfect, they generally have better organization and planning and better enforcement of rules. This is probably because the developed countries are able to allocate more funds toward wildlife management and because they have more (and better-funded) non-governmental organizations that assist the government with all stages of management, especially research. It is also a matter of priorities; at least in the short term, developing countries tend to prioritize development over conservation, particularly if encouraged to do so by the World Bank and other international organizations (Sahgal and Scarlott 2009).

In both developed and developing countries, economic incentives related to land use can either help reduce or greatly increase the level of human-carnivore conflict. Two examples help illustrate this point: the compensation systems of Norway and Sweden, and recent sheep grazing policies in Slovenia. In Sweden, in order to receive compensation for livestock killed by carnivores, livestock owners must be able to prove that they are using livestock husbandry techniques aimed at fending off carnivores, such as fencing and guard dogs. Every farmer is provided with funds to install electric fencing. In Norway, since compensation will be paid regardless of the husbandry techniques used, there is no incentive to spend the extra money to put preventative measures in place, and therefore most farmers do not use preventative measures (Swenson and Andren 2005).

In Slovenia, until recently there was little sheep farming within the bear core conservation area, since these two land uses are essentially incompatible (Sagor et al. 1997;

Zimmermann et al. 2003). However, in 1991 the Slovenian government began to encourage and subsidize sheep production within the core area, which was not very profitable because of the area's mountainous terrain, causing sheep production costs to be 20-25% higher than outside the core area. Not surprisingly, bear depredations on sheep increased dramatically (Krystufek and Griffiths 2003). These two examples show that economic incentives and subsidies that do not consider the effect on large carnivore populations can increase the level of conflict, even if they are designed to reduce it.

Finally, international agreements can play an important role in the management of large carnivore species on a national or sub-national level. The importance of these agreements is most pronounced in Europe, where most of the nations are members of the European Union and therefore subject to its laws. The Habitats Directive, under European Community Law, places each species into an Annex, which determines the level of protection it must be afforded in each country that is home to that species. Similarly, the Bern Convention lists species in Appendices, and prohibits certain actions (such as hunting) for the more vulnerable species. The Bern Convention also requires each nation to draft a management plan for each of its terrestrial large carnivore species (Ministry of Agriculture and Forestry 2005).

The Finnish wolf management plan is a direct result of the Bern Convention. In the Finnish case, the Habitats Directive and the Bern Convention, which both list wolves as strictly protected species, mandated that Finland ban the hunting of wolves, which had been part of Finnish culture for centuries (Ministry of Agriculture and Forestry 2005). Although Finland was able to obtain derogations from both of these agreements to continue wolf hunting, this is an example of how well-intentioned international agreements can interfere with management on a national or sub-national level.

The Slovenian brown bear case study provides another example of the impact of international agreements. Brown bear management was quite successful until 2002, when the zoning strategy changed completely, largely to allow bears to migrate into the Italian and Austrian Alps through a corridor in the northeast part of the country. However, the corridor failed – few bears have traveled across the border because the habitat near the border is not suitable for brown bears, while the increased presence of bears in the rest of the corridor has resulted in high depredation rates (Ministry of the Environment and Spatial Planning 2002; Krystufek et al. 2003). Krystufek (2003) refers to the corridor as an "unavoidable price of Slovenia's approach towards integration into the European Community." Although he does not elaborate, it seems clear that the creation of the corridor was based on gaining political favor with the European Union and with Italy and Austria rather than on sound biological and ecological research.

CONCLUSION

In this study, I conducted a comparative analysis of single-species zoning for a range of species across many countries and continents, using information drawn from both an extensive literature search and a survey of carnivore experts and wildlife management practitioners. I used twelve case studies as a means of examining and comparing zoning systems in practice. Of these twelve case studies, I deemed three successful – grizzly bear management in the greater Yellowstone area, wolf management in Minnesota, and brown bear management in Slovenia (before 2002). Three were unsuccessful – brown bear management in Norway, wolverine management in Norway, and brown bear management in Slovenia (after 2002). The rest of the cases were either partially successful or the outcome could not be determined with the available data.

The first part of my analysis was to determine what kinds of zoning have been used and the characteristic features of those zoning systems in order to facilitate comparison between them. Based on the case studies, I proposed a categorization of four types of zoning: density-driven, core area, game species, and pest species zoning. Each of these types has a distinct goal, methodology, and advantages and disadvantages. Density-driven zoning seeks to regulate the density of carnivores in geographically separated zones, using differentiated controls to achieve this goal. Core area zoning is marked by a binary zoning system – a core area in which the carnivore species is protected, and an area outside the core in which protection is weaker or nonexistent. Game species zoning deals with large carnivore species that are abundant enough to be hunted, and uses hunting quotas to regulate, maintain, and/or adjust the size of the population in each zone. Finally, pest species zoning uses lethal control to eliminate carnivores from some areas to minimize conflict, while allowing them to persist in other areas.

In the second part of the analysis, I identified five key factors that influence the success of zoning systems: space, human-carnivore conflict, threat level of the species, public acceptance of zoning, and location-specific economic and political factors. Although all of these factors are significant, space (the most widely cited factor by survey respondents) seems to be the factor on which everything else depends. Without a certain threshold of space on which a carnivore population can survive, there is no hope for conservation of the species, regardless of the other factors. Conflict, the other most important factor, is created by a lack of space, which causes humans and carnivores to interact competitively.

Furthermore, space is a factor that is very difficult to change. Conflict can be reduced through improved husbandry practices. Threat level can be lessened though reducing conflict, enforcing boundaries, and other measures. Education programs, compensation systems, and public participation in the management planning process can all improve public opinion of carnivores and the way they are managed. And although some economic and political factors are difficult to change (such as the economic development of a country), inefficient subsidies and economic incentives can be removed and some political policies can be changed. Space cannot be created, and reclaiming land for conservation from agriculture, development, or other human uses can be very controversial, although human resettlement has occurred in India and some other countries. Finally, space is a resource that will become increasingly difficult to allocate in the future, as populations continue to rise in the developing world and climate change alters the distribution of suitable habitat for all wildlife species.

Zoning can be used as a large carnivore conservation strategy in a broad range of contexts. In this study, I have shown that some existing zoning schemes have been more effective than others. The most effective zoning strategies are those that contain enough space to conserve viable populations of carnivores while keeping the rate of human-carnivore conflict low. They manage species that are abundant enough to use lethal control when necessary without endangering the viability of the population. Finally, successful zoning strategies have broad public acceptance and support, and are not hobbled by inefficient economic incentives and subsidies or international regulations that problematically override national and sub-national level control.

Although zoning is a relatively new and under-studied strategy in the conservation toolbox, it has the potential to become a widely used conservation policy for two main reasons. First, it is one of the few mitigation strategies for human-wildlife conflict that is preventative rather than reactive; large carnivores and incompatible human land uses simply do not overlap (at least in theory). Second, it is adaptable to a wide variety of situations. The 4 types of zoning identified in this paper and the 12 case studies on which they are based illustrate the range of goals that can be accomplished using zoning – anything from strict conservation to regulated harvest to partial eradiation, using a variety of methods that are appropriate to the local context.

This is not to say that zoning works every time. Some locations are inevitably less suited to zoned management than others, such as developing countries with highly endangered carnivore populations and high rates of human-carnivore conflict. Unfortunately, this is the reality in many areas. Future research on zoning could focus on its applicability to this situation, which would be very useful in the future of carnivore conservation.

Zoning is referred to frequently in the carnivore management literature, but there have been no systematic evaluations of zoning in practice. This study is an attempt to fill this void with an analysis of zoning that is useful in understanding current zoning systems and in planning future zoning strategies. However, this is only a beginning; there is still much investigation of zoning that should be done. Because of its considerable flexibility and adaptability, the limits of the applicability of zoning have not yet been reached and are unlikely to be reached in the near future. Although it could possibly be used for other species as well, zoning has the potential to become a widely used and highly effective tool in large carnivore conservation. Since large carnivores are some of the world's most difficult species to conserve, designing and implementing successful zoning systems would be a considerable accomplishment for the conservation of global biodiversity and for the peaceful coexistence of humans and wildlife.

LITERATURE CITED

Adamic, M. 1997. The Expanding Brown Bear Population of Slovenia: A Chance for Bear Recovery in the Southeastern Alps. International Conference on Bear Research and Management **9**:25-29.

Allen, L. R., and E. C. Sparkes. 2001. The Effect of Dingo Control on Sheep and Beef Cattle in Queensland. Journal of Applied Ecology **38**:76-87.

Andersen, R., J. D. C. Linnell, H. Hustad, and S. M. Brainerd, editors. 2003. Large Predators and Human Communities in Norway: A Guide to Coexistence for the 21st Century. NINA Temahefte 25.

Australian Bureau of Statistics. 2006. Census 2006. http://www.abs.gov.

Berger, J. 2005. Hunting by Carnivores and Humans: Does Functional Redundancy Occur and Does it Matter? Pages 315-341 in J. C. Ray, K. H. Redford, R. S. Steneck, and J. Berger, editors. Large Carnivores and the Conservation of Biodiversity. Island Press, Washington, D.C.

Boitani, L. 2000. Action Plan for the Conservation of the Wolves (*Canis lupus*) in Europe. Council of Europe Publishing, Nature and Environment 113.

Breitenmoser, U., C. Breitenmoser-Wursten, H. Okarma, T. Kaphegyi, U. Kaphegyi-Wallmann, and U. M. Muller 2000. Action Plan for the Conservation of the Eurasian Lynx (*Lynx lynx*) in Europe. Council of Europe Publishing, Nature and Environment 112.

Breitenmoser, U. 1998. Large Predators in the Alps: The Fall and Rise of Man's Competitors. Biological Conservation **83**:279-289.

Breitenmoser, U. 2008. Personal communication. 25 March 2008.

Breitenmoser, U., C. Angst, J.-M. Landry, C. Breitenmoser-Wursten, J. D. C. Linnell, and J.-M. Weber. 2005. Non-Lethal Techniques for Reducing Depredation. Pages 49-71 in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Central Intelligence Agency. 2005. The World Factbook. http://www.umsl.edu/services/govdocs/wofact2005.

Clark, T. W., P. Curlee, and R. P. Reading. 1996. Crafting Effective Solutions to the Large Carnivore Conservation Problem. Conservation Biology **10**:940-948.

Corbett, L. 1995. The Dingo in Australia and Asia. Cornell University Press, Ithaca.

Damodaran, A. 2007. The Project Tiger Crisis in India: Moving Away from the Policy and Economics of Selectivity. Environmental Values **16**:61-77.

Delibes, M., A. Rodriguez, and P. Ferreras 2000. Action Plan for the Conservation of the Iberian Lynx (*Lynx pardinus*) in Europe Council of Europe Publishing, Nature and Environment 111.

Dinerstein, E., C. Loucks, E. Wikramanayake, J. Ginsberg, E. Sanderson, J. Seidensticker, J. Forrest, G. Bryja, A. Heydlauff, S. Klenzendorf, P. Leimgruber, J. Mills, T. G. O'Brian, M. Shresthra, R. Simons, and M. Songer. 2007. The Fate of Wild Tigers. BioScience **57**:508-514.

Erb, J., and S. Benson 2004. Distribution and Abundance of Wolves in Minnesota, 2003-04. Accessed 20 March 2008 from http://files.dnr.state.mn.us/natural_resources/animals/mammals/wolves/2004_wolfsurvey_report.pdf.

Fish and Wildlife Division 1992. Management Plan for Cougar in Alberta, Edmonton, Alberta.

Fleming, P., L. Corbett, R. Harden, and P. Thomson 2001. Managing the Impacts of Dingoes and Other Wild Dogs. Bureau of Rural Sciences, Canberra.

Fleming, P. J. S., L. R. Allen, S. J. Lapidge, A. Robley, G. R. Saunders, and P. C. Thomson. 2006. A Strategic Approach to Mitigating the Impacts of Wild Canids: Proposed Activities of the Invasive Animals Cooperative Research Centre. Australian Journal of Experimental Agriculture **46**:753-762.

Fuller, T. K., W. E. Berg, G. L. Radde, M. S. Lenarz, and G. B. Joselyn. 1992. A History and Current Estimate of Wolf Distribution and Numbers in Minnesota. Wildlife Society Bulletin **20**.

Gittleman, J. L., S. M. Funk, D. W. Macdonald, and R. K. Wayne. 2001. Why 'Carnivore Conservation'? Pages 1-7 in J. L. Gittleman, S. M. Funk, D. Macdonald, and R. K. Wayne, editors. Carnivore Conservation. Cambridge University Press, Cambridge.

Huber, D., A. Frkovic, Z. Stahan, J. Kusak, and A. Majic. 2003. Present Status and Management of Large Carnivores in Croatia. Pages 207-227 in B. Krystufek, B. Flajsman, and H. I. Griffiths, editors. A Large European Carnivore in a Shrinking World. Ecological Forum of the Liberal Democracy of Slovenia, Ljubljana.

Interagency Conservation Strategy Team 2007. Final Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Area.

IUCN 2007. 2007 IUCN Red List of Threatened Species. http://www.iucnredlist.org.

Jhala, Y. V., R. Gopal, and Q. Qureshi, editors. 2008. Status of the Tigers, Co-Predators, and Prey in India. National Tiger Conservation Authority, Government of India, and Wildlife Institute of India, New Delhi.

Kaczensky, P. 1999. Large Carnivore Depredation on Livestock in Europe. Ursus **11**:59-72.

Kaczensky, P. 2008. Personal Communication. 3 March 2008.

Kaczensky, P., M. Blazic, and H. Gossow. 2004. Public Attitudes Towards Brown Bears (*Ursus arctos*) in Slovenia. Biological Conservation **118**:661-674.

Karanth, K. U., and M. D. Madhusudan. 2002. Mitigating Human-Wildlife Conflicts in Southern Asia in J. Terborgh, C. V. Schaik, L. Davenport, and M. Rao, editors. Making Parks Work: Strategies for Preserving Tropical Nature. Island Press, Washington.

Karanth, K. U., M. Sunquist, and K. M. Chinnappa. 1999. Long-Term Monitoring of Tigers: Lessons from Nagarahole in J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes. Cambridge University Press, New York.

Krystufek, B. 2008. Personal communication. 15 March 2008.

Krystufek, B., B. Flajsman, and H. I. Griffiths, editors. 2003. Living With Bears: A Large European Carnivore in A Shrinking World. Ecological Forum of the Liberal Democracy of Slovenia, Ljubljana.

Krystufek, B., and H. I. Griffiths. 2003. Anatomy of a Human-Brown Bear Conflict: Case Study from Slovenia in 1999-2000. Pages 127-153 in B. Krystufek, B. Flajsman, and H. I. Griffiths, editors. Living With Bears: A Large European Carnivore in a Shrinking World. Ecological Forum of the Liberal Democracy of Slovenia, Ljubljana.

Landa, A., K. Gudvangen, J. E. Swenson, and E. Roskaft. 1999. Factors Associated with Wolverine *Gulo gulo* Predation on Domestic Sheep. Journal of Applied Ecology **36**:963-973.

Landa, A., M. Linden, and I. Kojola 2000. Action Plan for the Conservation of Wolverines (*Gulo gulo*) in Europe. Council of Europe Publishing, Nature and Environment 115.

Landa, A., O. Strand, J. D. C. Linnell, and T. Skogland. 1998. Home-Range Size and Altitude Selection for Arctic Foxes and Wolverines in an Alpine Environment. Canadian Journal of Zoology **76**:448-457.

Liberg, O., and H. Andren. 2004. Sweden in M. von Arx, C. Breitenmoser-Wursten, F. Zimmermann, and U. Breitenmoser, editors. Status and Conservation of the Eurasian Lynx (*Lynx lynx*) in Europe in 2001. KORA Bericht No. 19.

Lindsey, P. A., R. Alexander, J. T. Du Toit, and M. G. L. Mills. 2005. The Cost Efficiency of Wild Dog Conservation in South Africa. Conservation Biology **19**:1205-1214.

Linnell, J. D. C. 2005. Spatial Aspects of Managing Natural Resources and Conserving Biodiversity: Integrating the Global and the Local. Norwegian Institute for Nature Research, Trondheim.

Linnell, J. D. C., R. Andersen, T. Kvam, H. Andren, O. Liberg, J. Odden, and P. F. Moa. 2001a. Home Range Size and Choice of Management Strategy for Lynx in Scandinavia. Environmental Management **27**:869-879.

Linnell, J. D. C., E. B. Nilsen, U. S. Lande, I. Herfindal, J. Odden, K. Skogen, R. Andersen, and U. Breitenemoser. 2005. Zoning as a Means of Mitigating Conflicts with Large Carnivores: Principles and Reality. Pages 162-175 in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Predators: Conflict or Coexistence? Cambridge University Press, New York.

Linnell, J. D. C., M. E. Smith, J. Odden, P. Kaczensky, and J. E. Swenson. 1996. Carnivores and Sheep Farming in Norway 4. Strategies for the Reduction of Carnivore-Livestock Conflicts: a Review. NINA Oppdragsmelding **443**:1-116.

Linnell, J. D. C., J. E. Swenson, and R. Andersen. 2000. Conservation of Biodiversity in Scandinavian Boreal Forests: Large Carnivores as Flagships, Umbrellas, Indicators, or Keystones? Biodiversity and Conservation **9**:857-868.

Linnell, J. D. C., J. E. Swenson, and R. Andersen. 2001b. Predators and People: Conservation of Large Carnivores is Possible at High Human Densities if Management Policy is Favourable. Animal Conservation **4**.

Macdonald, D. W., and C. Sillero-Zubiri. 2004. Wild Canids - An Introduction and Dramatis Personae in D. W. Macdonald, and C. Sillero-Zubiri, editors. The Biology and Conservation of Wild Canids. Oxford University Press, New York.

McDougal, C. 1987. The Man-Eating Tiger in Geographical and Historical Perspective. Pages 435-448 in R. L. Tilson, and U. S. Seal, editors. Tigers of the World: The Biology, Biopolitics, Management, and Conservation of an Endangered Species. Noyes Publications, Park Ridge.

Mech, L. D. 1995. The Challenge and Opportunity of Recovering Wolf Populations. Conservation Biology **9**:270-278.

Mech, L. D. 2008. Personal communication. 6 March 2008.

Mills, L. S., M. E. Soule, and D. F. Doak. 1993. The Keystone-Species Concept in Ecology and Conservation. BioScience **43**:219-224.

Mills, M. G. L., S. Ellis, R. Woodroffe, A. Maddock, P. Stander, A. Pole, G. Rasmussen, P. Fletcher, M. Bruford, D. Wildt, D. Macdonald, and U. Seal, editors. 1998. Population and Habitat Viability Assessment African Wild Dog (*Lycaon pictus*) in Southern Africa. Final Workshop Report. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley, Minnesota.

Mills, M. G. L., and M. L. Gorman. 1997. Factors Affecting the Density and Distribution of Wild Dogs in the Kruger National Park. Conservation Biology **11**:1397-1406.

Ministry of Agriculture and Forestry 2005. Management Plan for the Wolf Population in Finland. Accessed 10 February 2008 from http://www.lcie.org/Docs/Action%20Plans/Finnish%20wolf%20plan%20E.pdf.

Ministry of the Environment and Spatial Planning 2002. Brown Bear (*Ursus arctos*) Management Strategy in Slovenia. Accessed Feb 2, 2008 from http://www.mop.gov.si/fileadmin/mop.gov.si/pageuploads/podrocja/okolje/pdf/strategy_brown_bear_2002.pdf.

Minnesota Department of Natural Resources 2001. Minnesota Wolf Management Plan. Minnesota Department of Natural Resources (Division of Wildlife) in consultation with the Minnesota Department of Agriculture.

Naess, A., and G. Sessions. 1995. Platform Principles of the Deep Ecology Movement in A. Drengson, and Y. Inoue, editors. The Deep Ecology Movement: An Introductory Anthology. North Atlantic Books, Berkeley.

Nyhus, P., and M. S. Adams 1995. Biosphere Reserves of the World: Principles and Practice. Unpublished.

Nyhus, P., H. Fischer, F. Madden, and S. Osofsky. 2003. Taking the Bite out of Wildlife Damage: The Challenges of Wildlife Compensation Schemes. Conservation in Practice **4**:37-40.

Nyhus, P. J., and R. Tilson. 2009. *Panthera tigris* vs *Homo sapiens*: Conflict, Coexistence, or Extinction in R. Tilson, and P. J. Nyhus, editors. Tigers of the World: The Biology, Politics, and Conservation of *Panthera tigris*. William Andrews, in press.

Phillips, M. K., E. E. Bangs, L. D. Mech, B. T. Kelly, and B. B. Fazio. 2004. Grey Wolves - Yellowstone. Pages 297-310 in D. W. Macdonald, and C. Sillero-Zubiri, editors. The Biology and Conservation of Wild Canids. Oxford University Press, New York.

Quammen, D. 2003. Monster of God: The Man-Eating Predator in the Jungles of History and the Mind. W. W. Norton and Company, New York.

Ross, P. I., M. G. Jalkotzy, and J. R. Gunson. 1996. The Quota System of Cougar Harvest Management in Alberta. Wildlife Society Bulletin **24**:490-494.

Sagor, J. T., J. E. Swenson, and E. Roskaft. 1997. Compatibility of Brown Bear *Ursus arctos* and Free-Ranging Sheep in Norway. Biological Conservation **81**:91-95.

Sahgal, B., and J. Scarlott. 2009. This Heaven and this Earth: Will India Keep its Promise to *Panthera tigris*? in R. Tilson, and P. J. Nyhus, editors. Tigers of the World: The Biology, Politics, and Conservation of *Panthera tigris*. William Andrews (in press).

Sergio, F., I. Newton, L. Marchesi, and P. Pedrini. 2006. Ecologically Justified Charisma: Preservation of Top Predators Delivers Biodiversity Conservation. Journal of Applied Ecology **43**:1049-1055.

Simonic, A. 2003. Conservation Strategy for the Brown Bear in Slovenia. Pages 295-321 in B. Krystufek, B. Flajsman, and H. I. Griffiths, editors. Living with Bears: A Large European Carnivore in a Shrinking World. Ecological Forum of the Liberal Democracy of Slovenia, Ljubljana.

Statistics Canada. 2005. Population Counts, Land Area, and Population Density. www12.statcan.ca.

Swenson, J. E., and H. Andren. 2005. A Tale of Two Countries: Large Carnivore Depredation and Compensation Schemes in Sweden and Norway. Pages 323-339 in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Predators: Conflict or Coexistence? Cambridge University Press, New York.

Swenson, J. E., N. Gerstl, B. Dahle, and A. Zedrosser 2000. Action Plan for the Conservation of the Brown Bear (*Ursus arctos*) in Europe Council of Europe Publishing, Nature and Environment 114.

Terborgh, J., L. Lopez, P. Nuñez V, M. Rao, G. Shahabuddin, G. Orihuela, M. Riveros, R. Ascanio, G. H. Adler, T. D. Lambert, and L. Balbas. 2001. Ecological Meltdown in Predator-Free Forest Fragments. Science **294**:1923-1927.

Thapar, V. 1999. The Tragedy of the Indian Tiger: Starting from Scratch in J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the Tiger: Tiger Conservation in Human-Dominated Landscapes. Cambridge University Press, New York.

Thiel, R. P., and T. Valen. 1995. Developing a State Timber Wolf Recovery Plan with Public Input: The Wisconsin Experience. Pages 169-176 in L. N. Carbyn, R. P. Thiel, and D. R. Seip, editors. Ecology and Conservation of Wolves in a Changing World. Canadian Circumpolar Institute, Alberta.

Thirgood, S., R. Woodroffe, and A. Rabinowitz. 2005. The Impact of Human-Wildlife Conflict on Human Lives and Livelihoods. Pages 13-26 in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Treves, A., and K. U. Karanth. 2003. Human-Carnivore Conflict and Perspectives on Carnivore Management Worldwide. Conservation Biology **17**:1491-1499.

Treves, A., and L. Naughton-Treves. 2005. Evaluating Lethal Control in the Management of Human-Wildlife Conflict. Pages 86-106 in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Treves, A., R. B. Wallace, L. Naughton-Treves, and A. Morales. 2006. Co-Managing Human-Wildlife Conflicts: A Review. Human Dimensions of Wildlife **11**:1-14.

UNESCO. 2008. Biosphere Reserves: Reconciling the Conservation of Biodiversity with Economic Development. http://www.unesco.org/mab/BRs.shtml.

United States Census Bureau. 2005. 2005 American Community Survey. http://factfinder.census.gov.

United States Fish and Wildlife Service 1992. Recovery Plan for the Eastern Timber Wolf, Twin Cities, Minnesota.

United States Fish and Wildlife Service 1993. Grizzly Bear Recovery Plan, Missoula, Montana.

United States Fish and Wildlife Service. 2007. Interior Department Announces Delisting of Western Great Lakes Wolves; Proposed Delisting of Northern Rocky Mountain Wolves. <http://www.fws.gov/news/NewsReleases/showNews.cfm?newsId=6F1726CD-952D-6E23-9A79F5D44DBC2637>.

Wabakken, P., H. Sand, O. Liberg, and A. Bjarvall. 2001. The Recovery, Distribution, and Population Dynamics of Wolves on the Scandinavian Peninsula, 1978-1998. Canadian Journal of Zoology **79**:710-725.

Wang, S. W., and D. W. Macdonald. 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. Biological Conservation **129**:558-565.

Wilson, C. J. 2004. Could we Live with Reintroduced Large Carnivores in the UK? Mammal Review **34**:211-232.

Wisconsin Department of Natural Resources 1999. Wisconsin Wolf Management Plan. WDNR, Madison.

Woodroffe, R. 2000. Predators and People: Using Human Densities to Interpret Declines of Large Carnivores. Animal Conservation **3**:165-173.

Woodroffe, R., J. Ginsberg, D. Macdonald, and IUCN/SSC Canid Specialist Group 1997. The African Wild Dog: Status Survey and Conservation Action Plan. IUCN, Gland, Switzerland.

Woodroffe, R., S. Thirgood, and A. Rabinowitz. 2005. The Future of Coexistence: Resolving Human-Wildlife Conflicts in a Changing World in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. People and Wildlife: Conflict or Coexistence? Cambridge University Press, New York.

Wydeven, A. P. 2008. Personal Communication. 18 March 2008.

Wydeven, A. P., R. N. Schultz, and R. P. Thiel. 1995. Monitoring of a Recovering Gray Wolf Population in Wisconsin, 1979-1991. Pages 147-156 in L. N. Carbyn, S. H. Fritts, and D. R. Seip, editors. Ecology and Conservation of Wolves in a Changing World. Canadian Circumpolar Institute, Alberta.

Zedrosser, A., B. Dahle, J. E. Swenson, and N. Gerstl. 2001. Status and Management of the Brown Bear in Europe. Ursus **12**:9-20.

Zimmermann, B., P. Wabakken, and M. Dotterer. 2003. Brown Bear-Livestock Conflicts in a Bear Conservation Zone in Norway: Are Cattle a Good Alternative to Sheep? Ursus **14**:72-83.

APPENDIX A. ZONING SURVEY

I sent this survey via e-mail to large carnivore experts and wildlife managers from around the world. E-mail addresses were gathered from journal articles and internet sites. A short explanatory note about the study was sent with the survey, and respondents were asked to forward the survey to their colleagues.

Survey of Zoning as a Carnivore Management Strategy

Name: ______________________________________

Position: ___________________________________

1. In your experience with zoning, what species have you studied or worked with? In what location(s)?

2. Please describe the types of zoning have you had experience with.
    a. Management of a single species
    b. Management at the ecosystem or landscape level (for example, a national park with zoned areas)
    c. Other (please explain)

3. In your experience, what are the most important factors that influence the success or failure of zoning as a carnivore management strategy? Possible factors could include characteristics of the species, human land use patterns, public acceptance of zoning, etc.

Please respond to the following statements using a scale from 1 to 5, where 1 = strongly disagree and 5 = strongly agree.

4. Zoning is an effective method for managing large carnivores. Please explain.

    1 2 3 4 5

5. Zoning is an effective method for minimizing conflict between large carnivores and people and/or livestock. Please explain.

    1 2 3 4 5

6. a) An effective approach to zoning is to control the density of carnivores in each zone. Please explain.

   1 2 3 4 5

   b) An effective approach to zoning is to control the management techniques (hunting, compensation, etc) that are used in each zone. Please explain.

   1 2 3 4 5

7. a) Zoning is an effective method for conserving rare species. Please explain.

   1 2 3 4 5

   b) Zoning is an effective method for managing commonly occurring species. Please explain.

   1 2 3 4 5

8. Would you like to suggest any papers, articles, or other sources that are relevant to this study?

9. May I contact you again for additional information or questions? If yes, please include your preferred contact information.