The Practices of Wolf Persecution, Protection, and Restoration in Canada and the United States

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Wolf management can be controversial, reflecting a wide range of public attitudes. We analyzed wolf management case histories representing a spectrum of approaches in Canada and the United States. During the early 20th century, wolves were considered undesirable. They were subject to persecution and were extirpated from large areas of their original range. With increased environmental awareness in the 1970s, attitudes toward wolves began to change. Wolf conservation became a focus of public interest, providing conditions that favored regional wolf recovery. However, in regions where livestock production or big-game hunting is valued, wolves have continued to be controlled by management authorities or through the actions of individual citizens. With US wolf populations recovering in the conterminous states, a rule was approved to delist the species from endangered to threatened status under the Endangered Species Act. Notwithstanding the intent of legal instruments, history has demonstrated that societal values ultimately determine the survival of species such as the wolf.

Keywords: Canis lupus, *conservation, control, North America, wolves*

Apart from humans, wolves are the terrestrial mammals with the broadest natural distribution (Mech 1970). The gray wolf, *Canis lupus,* once ranged over most of the Northern Hemisphere (Young and Goldman 1944, Wayne et al. 1992). However, lethal persecution (Young and Goldman 1944, Mech 1970, 1995) and habitat loss to human development (Corsi et al. 1999, Mladenoff et al. 1999) considerably reduced its range (figure 1a, 1b). In North America, the wolf was extirpated from most of southern Canada and Mexico and from the conterminous 48 US states, except for northern Minnesota, by 1970 (Mech 1970, Parsons 1998). Today large wolf populations can be found only in northern Canada and Alaska (table 1).

In Canada and the United States, attitudes toward gray wolves have changed drastically in recent years (Kellert et al. 1996, Lohr et al. 1996, Enck and Brown 2002, Williams et al. 2002). Now preservationist groups and large sectors of the public regard the wolf positively, viewing its preservation as a high priority for wildlife conservation efforts (Kellert et al. 1996). At the same time, however, wolf reintroduction continues to receive energetic opposition from individuals and organizations (Lohr et al. 1996). Following government protection of wolves in the United States, rehabilitation efforts have enabled the recolonization of areas from which wolves had been extirpated (Young and Goldman 1944, Mech 1970, Fritts et al. 1997, Bangs et al. 1998, Parsons 1998). In the United States, owing to natural recolonization and reintroduction programs, wolves are recovering in the northern, northwestern, and southwestern states (figures 1b, 2). Thus, wolves are returning to areas that support human settlements and activities such as ranching and farming, which may be incompatible with wild wolf populations (Mech 1995, 1998). Depending on circumstances that are highly context specific, people often resort to apparently contradictory management strategies that include hunting, control, reintroduction, and protection of wolves. The degree of application of these strategies in different areas and at different times determines alternative scenarios and outcomes for wolf populations. A current challenge is to make local inputs consistent and to monitor their effects on a broad scale.

Herein, we review information on interactions between humans and wolves by means of focusing on human attitudes and their effects on wolf management. We analyze in detail the problems and opportunities for wolf conservation in

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Table 1. Numbers of gray wolves, and management actions for them, in North American jurisdictions where wolves are established.

Jurisdiction	Wolf numbers (estimated)	Legal status	Hunting	Trapping	Culling to protect livestock	Culling to protect wild ungulates
Canada						
Alberta	4200	Big game, furbearer	Seasonal	Seasonal	Yes	No
British Columbia	8000	Big game, furbearer	Year-round	Seasonal	Yes	Yes
Manitoba	4000–6000	Big game, furbearer	Seasonal	Seasonal	Yes	No
Newfoundland (Labrador)	1000–5000	Furbearer	None	Seasonal	No	No
Northwest Territories and Nunavut	10,000	Big game, furbearer	Seasonal	Seasonal	No	No
Ontario	8000–9000	Small game, furbearer	Year-round	Year-round	Yes	No
Quebec	Not available	Small game, furbearer	Seasonal	Seasonal	Yes	No
Saskatchewan	4300	Furbearer	None	Seasonal	Yes	No
Yukon	4500	Big game, furbearer	Seasonal	Seasonal	Yes	Yes
United States						
Alaska	7500–10,000	Big game, furbearer	Seasonal	Seasonal	No	Yes
Arizona and New Mexico	25	Endangered, nonessential	None	None	Yes	No
Idaho, Montana, and Wyoming			None	None	Yes	No
Central Idaho	261	Endangered, nonessential				
Northwest Montana	84	Threatened				
Yellowstone area	218	Endangered, nonessential				
Michigan	297	Threatened	None	None	Yes	No
Minnesota	2450	Threatened	None	None	Yes	No
Wisconsin	320	Threatened	None	None	Yes	No

Note: Big-game or small-game status reflects the methods allowed to hunt wildlife (for wolves, typically rifle hunting). A furbearer classification applies to wildlife trapped for fur. Information on wolf control for the protection of livestock or wild ungulates does not include individual conflicts that are dealt with by government authorities on a case-by-case basis.

Source: Hayes and Gunson 1995 (Canada); Alaska Department of Fish and Game (Alaska), National Park Service, Nez Percé Tribe, US Fish and Wildlife Service, and US Department of Agriculture (conterminous United States) winter counts: 1994/1995 (Alaska), 1997/1998 (Minnesota), 2000/2001 (Arizona, New Mexico), 2001/2002 (Idaho, Michigan, Montana, Wisconsin, Wyoming).

modern North America, with only passing reference to Eurasia. Because of largely unresolved controversies on taxonomy (Wilson et al. 2000), we do not examine issues regarding the red wolf *(Canis rufus)* or other proposed species of wolves. Finally, we draw on our direct experience with wolf conservation as an important, yet controversial, example of the approach chosen in North America to address the conflicts between wildlife requirements and human interests.

Foundations for historical and current killing of wolves

In North America, people have killed wolves for fur, for the protection of livestock and wild ungulates, for disease control, and out of fear (Cluff and Murray 1995, Orians et al. 1997). Historically, some North American aboriginal peoples hunted and trapped wolves (Nelson 1983). Although little evidence documents such practices, some authors believe aboriginal peoples killed wolves to enhance ungulate populations and claim that wolf hunting was more intense when ungulate numbers were perceived to be low (Berkes 1999). Some ecologists believe wolf predation is a major limitation to the growth of wild ungulate populations, second only to human influences (Kay 1998).

Jedrzejewski and colleagues (2000) addressed this issue in Poland, where red deer *(Cervus elaphus)* was the major food source for wolves and was selected for among other prey items, including roe deer *(Capreolus capreolus),* wild boar *(Sus scrofa),* moose *(Alces alces),* and European bison *(Bison bonasus).* Changes in red deer population size, unlike changes in the population of other prey, caused dietary responses from wolves. Analysis of a 100-year series of survey data showed that the numbers of red deer and of wolves correlated negatively, which resulted from increases in the red deer population during periods of low wolf density. The rate of annual population growth of red deer also correlated negatively with wolf density. However, wolves killed fewer red deer than did human hunters. Results by Jedrzejewski and colleagues (2000) therefore indicated that predation by wolves probably contributed to the population dynamics of red deer, but hunting by humans influenced the phenomenon to a greater extent. This project (Jedrzejewski et al. 2000) provides an example of the difficulties encountered by wolf ecologists in evaluating predator–prey dynamics. Most ecosystems include a variety of prey and predator species as well as humans; the latter exert impacts on the ecosystem indirectly (e.g., through development) and directly (e.g., through

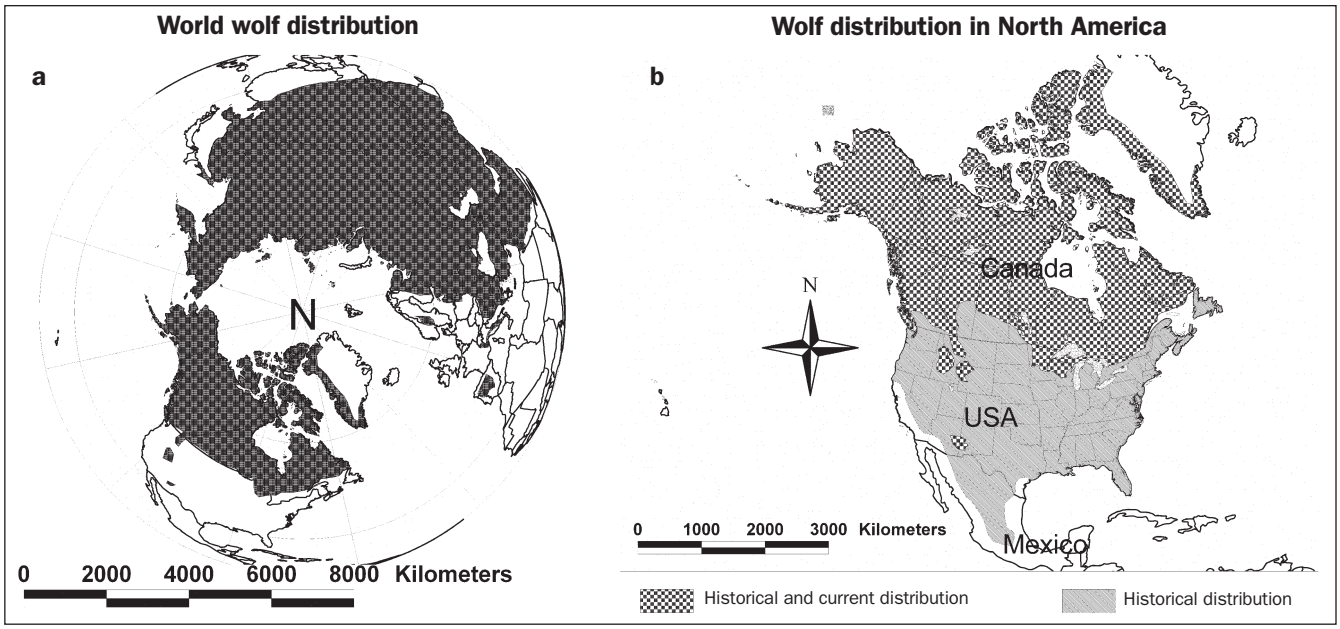

Figure 1. (a) Worldwide distribution of the gray wolf. (b) Historical (pre-European) and current distribution of gray wolves in North America.

hunting or protection of certain species). In addition, plant availability varies seasonally and yearly, and humans can exert impacts on plants through agriculture and forestry practices (Jedrzejewska et al. 1994). Thus, plants, herbivores, predators, and humans often participate in complex food webs. As a result, it can be arduous to sort out the effects of predator densities on prey abundance (Powell 2001).

The relationships between wolves, ungulates, and people described for pre-European North America, and for a protected area in Poland, exemplify conditions in which agriculture is not present (Nelson 1983, Jedrzejewska et al. 1994, Berkes 1999, Jedrzejewski et al. 2000). Yet agriculture is a major source of wolf–human conflict. Wolf depredation on domestic animals that were introduced by Europeans to the Uuited States and southern Canada prompted control programs to eradicate wolves (Young and Goldman 1944). In the 17th century, government agencies began to pay bounties for wolves killed by private individuals (Mech 1970). Until recently, bounty programs had been established, suspended, and reinstated in various North American jurisdictions (Mech 1970, 1995, Cluff and Murray 1995, Hayes and Gunson 1995). Wolves have been poisoned, trapped, snared, and shot from the ground and air (Cluff and Murray 1995). The most successful strategy used to exterminate wolves has probably been the poisoning campaigns that involved personnel hired by government agencies (Mech 1970).

During modern history and until the 1970s, wolves were hunted without restrictions (Mech 1970), and their pelts were sold at auction markets or kept for local use. At present, wolves are killed for recreational and commercial purposes in Alaska and in most Canadian provinces and territories (table 1, figure 3; Gasaway et al. 1992, Cluff and Murray 1995, Hayes and Gunson 1995, Hayes and Harestad 2000). In general, government authorities regulate wolf hunting and trapping by specifying the number of wolves to be killed, the length of the season, and the hunting and trapping techniques allowed. However, in Canada, aboriginal people are not subject to wolf hunting quotas. This lack of restrictions is considered an "aboriginal right" affirmed under the Canadian constitution (Constitution Act, Government of Canada, 1982). Some hunters from northern Canada claim annual incomes of more than CDN$50,000 from selling wolf furs (Canadian Broadcasting Corporation radio interview with Laurence Adam, 18 February 2000, Yellowknife, Northwest Territories, Canada). Thus, large numbers of wolves are hunted, providing an important source of revenue for many communities in Alaska and northern Canada (figure 4).

Unlike wolf populations in southern Canada and the contiguous United States, which have been reduced or extirpated, those in Alaska and northern Canada remain widely distributed and abundant (table 1, figure 1b). In Canada, the wolf is not listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000). The conservation and taxonomical status of the wolf is currently uncertain in the islands of the Arctic Archipelago (COSEWIC 2000) and in southern Ontario and Quebec (Wilson et al. 2000). In addition, some biologists are concerned about the killing of wolves in certain areas of northern Canada. They consider such commercial hunts a problem because of the vulnerability of individual wolves to the specific hunting techniques employed, particularly the use of snowmobiles (Carbyn 2000). Some sectors of the public have also questioned the ethics of using snowmobile technology to hunt wolves. Snowmobiles provide an efficient means of transportation in open environments, such as the multitude of frozen lakes present in the taiga and tundra during winter.

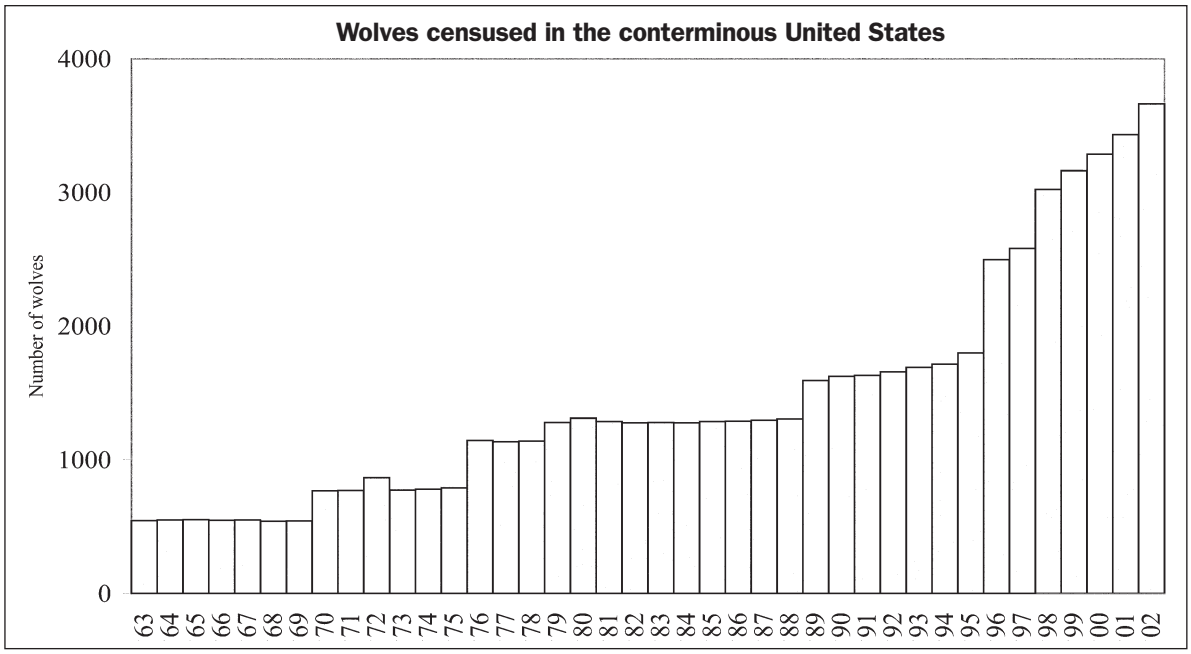

Figure 2. Wolf numbers in the conterminous US states from 1963 to 2002. Censuses were conducted by the National Park Service, the US Fish and Wildlife Service, the US Department of Agriculture, and various state agencies.

Hunters can use snowmobiles to quickly approach escaping wolves until they are within range of a rifle.

Current wolf culling

The idea that wolves can affect the mortality rates and conceivably the actual densities of their prey has provided the basis for researchers' and managers' attempts to diminish wolf densities and thus obtain increases in wild ungulate numbers (Gasaway et al. 1983, Orians et al. 1997, Bergerud and Elliot 1998). During wolf control, Alaskan and Canadian managers could reduce wolf numbers by up to 80% of the winter population (Ballard et al. 1987, Gasaway et al. 1992, Hayes and Harestad 2000). Their stated objective has been to protect populations of wild ungulates (table 1; Orians et al. 1997). Wolf control programs have been demonstrated to increase ungulate numbers (Bergerud and Elliot 1998), but because of negative public reaction, such programs have been delivered at substantial costs to the agencies involved (Orians et al. 1997). Managing agencies may abandon wolf culling to avoid opposition from the scientific community and the public (Mech 1995). In certain areas, government agencies have resorted to fertility control of wolves in an attempt to keep wolf numbers low without culling (Spence et al. 1999).

Some government agencies cull wolves to reduce conflicts between wolves and livestock (table 1). Wolf control is applied for this reason in Minnesota (Mech 1995) and in several Canadian jurisdictions (Hayes and Gunson 1995). In addition, the experimental rules governing the reintroduction of wolves to central Idaho, the greater Yellowstone area, and Arizona allowed for killing of wolves that are suspected to prey chronically on livestock (table 1; Fritts et al. 1997, Bangs et al. 1998, Parsons 1998). Before control actions are authorized, personnel from the US Department of Agriculture confirm the loss of livestock by examining the carcasses. Differences in management among two Canadian provinces and one US state—Alberta, British Columbia, and Montana—sometimes affect wolves that move or disperse between these neighboring jurisdictions (Boyd and Pletscher 1999). Similar circumstances are likely to prevail along other portions of the US–Canadian border where wolves are present.

In some US states, private landowners are authorized to kill wolves in cases of demonstrable threats by wolves toward humans and human property, including livestock (Federal Register 68 [62]: 15803–15875 [to be codified at 50 CFR Part 17]). For example, in Montana, ranchers may kill wolves if they catch them in the act of killing livestock. In addition, some wolves are killed illegally (Fuller 1989). In several Canadian jurisdictions, landowners practice wolf control (Cluff and Murray 1995, Hayes and Gunson 1995). For example, in Alberta, landowners and their delegates may kill wolves without restriction on their property and within 8 kilometers (km) of their land. Landowners whose properties are threatened by wolves may also be issued a special permit to poison wolves. In North America, illegal use of poison to kill wolves has also been reported in several areas, particularly where wolf populations overlap with agriculture. Recently, the conservationist organization Defenders of Wildlife and the US Fish and Wildlife Service (USFWS) offered a $20,000 reward for information leading to the arrest and conviction of those responsible for illegally poisoning gray wolves in central Idaho. Mech (1995) maintains

Figure 3. A Canadian trapper exhibits a male wolf immobilized with a leg trap and subsequently shot in Manitoba in 1986. Photograph: Paul Paquet.

that if some wolf killing by locals is not allowed, more wolves could be killed in the end because of resentment toward the wolves and the government.

Public sensitivity to the killing of predators has made any killing of wolves a contentious issue (Gasaway et al. 1992). Like the hunting and trapping of wolves, culling causes severe conflict between different sectors of the public in Canada (Theberge and Theberge 1998) and the United States (Haber 1996). Such controversy has the potential to exacerbate already entrenched and inflexible positions in the confrontation between wolf preservationists and antiwolf advocates. Such conditions promote discrepancies in human attitudes and may lead to inconsistencies in management of wolves.

The negative contribution of wolf habitat loss and roads

The indirect effects of human land use may intensify impacts on wolf populations through habitat loss (Young and Goldman 1944, Mech 1970, Haight et al. 1998, Theberge and Theberge 1998). Corsi and colleagues (1999) and Mladenoff and colleagues (1999) used geographic information systems and wolf occurrence data to assess the importance of landscape-scale factors in determining favorable wolf habitat. These analyses agree as to the importance of an adequate prey base, the existence of protected areas and public lands, and the absence or low occurrence of livestock. Wolves thrive in areas with high ungulate densities (Jedrzejewski et al. 2000) but tend toward local extinction in areas with high densities of livestock, owing to conflicts with ranchers (Bangs et al. 1998). Positive relationships have also been found between wolf presence and areas with forest cover, few roads, and low human density (Mech et al. 1988). However, some sources (e.g., Mech 1995) maintain that such areas are simply the least accessible to humans, and the lack of human presence remains the most important variable in predicting wolf viability. Depending on the intensity of logging and on the tree species targeted, forestry operations can favor or hamper ungulate species that also constitute wolf food, thereby influencing wolf predation and wolf density (Jedrzejewska et al. 1994).

In areas where public access is restricted, road density is a poor indicator of wolf presence (Merrill 2000), which suggests that wolves may avoid people rather than roads. Wolf absence from roaded areas may be a direct result of higher mortality there (Boyd and Pletscher 1999). Roads and other linear developments provide people access to remote regions, allowing humans to deliberately, accidentally, or incidentally kill wolves. Finally, in mountain terrain, both people and wolves must use valley bottoms where roads converge with high-quality habitat; thus, avoidance of humans and habitat selection by wolves (Kunkel and Pletscher 2001) may conflict. Moreover, protected areas are often located at higher elevations (Scott et al. 2001) and in habitats not selected by wolves.

In general, habitat assessments for developed countries (e.g., Corsi et al. 1999, Mladenoff et al. 1999) conclude that favorable habitat is highly fragmented. Thus, the future of the wolf in human-dominated areas is likely to depend on understanding and implementing a connected network of core areas (Haight et al. 1998) where the wolf will be managed in ways appropriate to local ecological, social, and economic conditions. This approach also focuses on the availability of good habitat in the matrix outside the few existing protected areas (Scott et al. 2001).

Impacts of wolf reductions versus wolf resilience: Two approaches

Inherent biological characteristics render the wolf capable of rapid increases in population numbers following reductions caused by humans (Mech 1970, 1995). Depending on the age and sex structure of the pack, wolves can sustain an annual mortality of about 30% of the winter population (Fuller 1989). After lethal control efforts that reduced populations by as much as 80%, wolf populations in the Yukon rebounded in 4 to 5 years (Hayes and Harestad 2000). The most important factor influencing the rate of recovery, however, was immigration from neighboring areas (Bergerud and Elliot 1998, Hayes and Harestad 2000).

Disagreement about how much human-caused mortality wolves can tolerate is evident in the literature (Orians et al. 1997). Hayes and Harestad (2000) attribute some of this disagreement to uncertain results caused by logistical

problems encountered in field research. They propose that in some projects (Gasaway et al. 1992, Bergerud and Elliot 1998), wolf numerical response was not adequately monitored following reductions. Hayes and Harestad (2000) emphasize that wolf monitoring was not conducted systematically during their own research, and consequently they could not accurately measure dispersal rates or causes of mortality. Despite such inconsistencies in methodologies within and between projects, Hayes and Harestad (2000) maintain that their data, and those of Bergerud and Elliot (1998), support Fuller's (1989) view that dispersal is the primary mechanism determining how wolves adjust their numbers locally. We concur that available results on wolf resilience following human-induced population reductions may not be as equivocal as they first appear. Addressing such issues through a comprehensive meta-analysis of various projects would be beneficial. A meta-analysis would elucidate disparities related to dissimilar environments or to differences in interpretation of data.

Haber (1996) questioned whether the measure of successful wolf conservation should be the presence of wolves on the landscape alone, or whether it should also include the presence of intact social relations. On the basis of a literature review, Haber concluded that humans could affect wolf ecology by influencing the behavior of wolves and their prey. Paradoxically, other researchers (e.g., Ballard et al. 1987, Hayes and Harestad 2000) viewed the same literature as evidence of resilience and reported that in comparison with unexploited populations, mortality rates are higher as a direct consequence of reductions, pack sizes are smaller, home ranges are less stable and occupied at variable times, and more young are produced in the population.

The focus on behavioral effects of control programs argues for the development of methods with less influence on wolf behavior (e.g., Spence et al. 1999). Mech (1995, 1998) maintains that to have wolves coexist with people, some form of wolf control is necessary. The alternative is that wolves at high densities may not survive conflicts with humans. Instead, if most of the public could accept both wolf recovery and wolf control in human-developed areas, then stability could be achieved between the requirements of humans and those of wolves (Mech 1995). The latter scenario would require open debate and clarification of the actual objectives of wolf management. The goal is for wolves and humans to coexist, with neither species resolutely impairing the other.

Human perception of wolves

Some North American aboriginal clans were named after the wolf, attesting to their high respect for these animals (Nelson 1983). More recently, the North American public has demonstrated a remarkable interest in wolves; for example, the Canadian book *Never Cry Wolf* (Mowat 1963) became a bestseller and was made into a popular and acclaimed movie. In several regions, however, the wolf has not been viewed favorably. Where reintroductions have been proposed and where wolves are recovering, some people have feared that wolves would cause livestock losses and declines of ungulate populations (Lohr et al. 1996, Fritts et al. 1997). Nevertheless, numerous organizations have formed advocating the reintroduction of wolves into new areas, such as California, Colorado, and New England (Enck and Brown 2002).

Figure 4. Carcasses of wolves killed in northern Canada by a hunter during the 1990s. Wolves were chased by snowmobile and shot; their pelts were sold at auction markets. Photograph: Marco Musiani.

Contentious and conflicting feelings about wolves were confirmed by Kellert and colleagues (1996) in a survey of human attitudes throughout North America. Most individuals perceived wolves positively, whereas a minority feared wolves. Most wolf-related fears were linked to misperceptions and not to biological characteristics of the animal. To address these erroneous beliefs, some authors recommend education programs (Mech 1995, Kellert et al. 1996, Lohr et al. 1996). Accordingly, a common ethos regarding wolves and related management issues could be constructed. On the other hand, contrasts in attitudes such as those reported by Kellert and colleagues (1996) might lead to litigation and overall polarization of wolf management issues.

Evidence that targeted education programs actually result in accomplishments for wolf conservation is limited or

speculative. Surveys conducted by Lohr and colleagues (1996) and Williams and colleagues (2002) demonstrated that higher levels of education were correlated with positive attitudes toward wolves. Thus, wolf-specific education programs (Kellert et al. 1996, Lohr et al. 1996) might also contribute to enhancing positive attitudes and result in higher tolerance for wolves in the landscape. We suggest conducting studies that measure the performance of wolf-specific education programs.

Wolf protection in areas with little human use

In North America, wolf reintroductions were carried out successfully in Yellowstone National Park and Idaho (Fritts et al. 1997, Bangs et al. 1998). Wolves are currently being reintroduced in Arizona and New Mexico (Parsons 1998). These areas were chosen for their ecological suitability, and consultations with local communities were conducted to detect any incompatibilities between wolves and the social and economic contexts in which they would be introduced (Fritts et al. 1997). Perceived environmental quality plays a significant role in the decision of people to move and establish businesses and homes in an area (Rasker and Hackman 1996). Thus, designation of wilderness areas, often coupled with carnivore protection, can be compatible with business development. Employment and personal income levels in wilderness areas have been shown to grow consistently faster than in other areas (Rasker and Hackman 1996). On a broader scale, economic growth may be viewed as a limiting factor for nature conservation (Czech 2000). In the case of wolf conservation, conflicts may arise between wolves and economic interests such as livestock production, residential development, and transportation (Mech et al. 1988, Corsi et al. 1999, Mladenoff et al. 1999).

According to Forbes and Theberge (1996), the movements of wolves in and out of Algonquin Park, Canada (7726 km^2, an area bigger than the state of Delaware), exemplify management issues regarding the spatial requirements of large predators and the inadequate size of protected areas. Their study demonstrated that for radio-monitored wolves captured in the protected area, the major cause of death was human-related. Most wolves died outside the protected area. This was also related to seasonal movements by wolves out of the park in response to migrating deer (Forbes and Theberge 1996, Theberge and Theberge 1998). In the mid-1990s, under the pressure of various environmental groups, the government banned the killing of wolves in a 200-km^2 deer wintering area next to the park for a period of 30 months (Forbes and Theberge 1996). This led to animosity toward wolves by local communities, which also included ranchers. During the period of the ban, locals killed wolves in areas outside the park. Thus, environmentalists and some of the researchers asked for a 10-km "exclusion zone" all around Algonquin Park as a buffer to protect wolves (Theberge and Theberge 1998). Theberge and Theberge (1998) concluded that complete protection of wolves requires protection beyond the existing boundary of Algonquin Park.

However, in some cases, wolves have proved capable of recovery despite the absence of protected areas such as provincial and national parks. Up to 1995, when wolves were reintroduced in Yellowstone and Central Idaho, documented increases in wolf numbers for the conterminous 48 US states were largely due to recovery in the Great Lakes region (figure 2; Mech et al. 1988, Mladenoff et al. 1999). Haight and colleagues (1998) analyzed wolf population survival with a computer simulation, which assumed that wolf packs occupy home ranges with secure core areas, that higher human-caused mortality occurs in peripheral areas, and that prey are available. The authors arbitrarily varied the levels for wolf natural mortality and immigration. Their results showed that the availability of core areas characterized by low human-caused mortality was an important predictor for the presence of wolves. Nonetheless, wolf survival also depended on natural mortality. Thus, disease-free and legally protected populations could thrive with just a few core areas available. Finally, even limited immigration of wolves could offset higher levels of mortality. Simulations by Haight and colleagues (1998) show that wolves can survive in developed regions if home ranges are allowed to form a network in which each range is reachable by wolves dispersing from other ranges. Such results also confirm the importance of prey availability and mortality risks posed by humans. With regard to the latter, the model produced by Haight and colleagues provides information relevant to the survival of wolf populations in the presence of various levels of human-caused mortality. Thus, these results do allow for some wolf control.

Wolves are highly mobile animals (Mech 1970, Wayne et al. 1992, Boyd and Pletscher 1999) that will encounter people during their wanderings in most areas of North America in which the species occurs. Mech (1995) describes the wolf as a very adaptable and resilient species. Despite the conflicts between wolves and people out of protected areas, wolf conservation status is improving, and wolf numbers are increasing or stable in most North American areas where livestock production is not a priority (figure 2; Hayes and Gunson 1995, Bangs et al. 1998, Mladenoff et al. 1999). Thus, we conclude that coexistence of people and wolves is possible in wild or semiwild areas.

Ongoing conflicts with people and livestock

Wolves typically prey on all ungulates present within their range (Young and Goldman 1944, Mech 1970, Jedrzejewski et al. 2000). Often included are domestic ungulates (figure 5; Mech 1970, Fritts et al. 1997). Before ungulates were domesticated, many human societies hunted them for their valuable animal protein (Kay 1998). Therefore, conflicts with wolves may have arisen (and continue to arise) over competition for highly valued food resources. Now, as the result of wolf recovery, wolves are moving into areas of intense livestock production (Bangs et al. 1998). In these areas, conflicts and associated costs of livestock protection are on the increase. For example, Mech (1998) estimated the monetary costs of maintaining wolves in American wild and agricultural areas and

Figure 5. Two wolves feed on a sheep carcass. Photograph: Stefano Mariani.

concluded that wolves frequenting agricultural areas cost twice as much to manage as wolves living primarily in the wilderness.

In Eurasia, where livestock production has historically coexisted with the wolf, traditional husbandry techniques involve shepherds tending small flocks of livestock and using guard dogs (Ciucci and Boitani 1998). Such husbandry techniques, however, are not economical and are difficult to apply where a guard dog culture is not established (Coppinger and Coppinger 2001). In regions where traditional experience is lacking, dogs are often left without the essential aid of ranchers or shepherds, who typically provide additional guidance and surveillance. In these situations, depredation by wolves and other predators can occur despite the presence of guard dogs (figure 6; Coppinger and Coppinger 2001). In addition, wolves can kill dogs (Mech 1970, 1998), further exacerbating negative attitudes toward wolves.

In areas where guard dogs are not used, typical methods for reducing depredation on livestock include culling (table 1; Cluff and Murray 1995, Bangs et al. 1998) and employment of barriers or electric fences to exclude wolves (Musiani and Visalberghi 2001). However, culling is inherently controversial (Gasaway et al. 1992, Haber 1996, Theberge and Theberge 1998), and conventional fences are expensive and difficult to maintain (Mech 1995). Other methods used include the translocation of wolves from areas of high livestock production to wilder areas and the aversive conditioning of wolves to livestock (Cluff and Murray 1995). Unfortunately, these methods are expensive and provide only temporary relief from depredation.

Research is needed to evaluate the use of nonlethal, cost-effective means to protect human interests from wolves (and consequently wolves from humans) in areas where conflicts exist. Ironically, an ancient wolf-hunting technique may offer a cost-effective solution. This technique, known as *fladry,* was used to hunt wolves in Eastern Europe and Russia. Fladry consists of driving wolves into a bottleneck formed by 50-centimeter (cm) x 10-cm red flags hanging from ropes stretched above the ground. Musiani and Visalberghi (2001) conducted experiments that demonstrated fladry's effectiveness in excluding captive wolves from food and confining wolves in limited spaces. The fladry technique has potential for the management of wolf–livestock conflicts; we are conducting additional field studies to evaluate its effectiveness in protecting livestock (figure 7).

Compensation for livestock losses

Compensation programs are a major means to refund the economic damage to livestock producers created by wolves and thus to reduce conflicts (Mech 1995). In spite of this, compensation may not be socially or economically sustainable over the long term. Costs may increase because preventive husbandry practices are abandoned, and communities may refuse to bear increased costs. For these reasons, some authors suggest that compensation programs should be designed in combination with incentives to encourage preventive management (Ciucci and Boitani 1998).

A real-world example of depredation management is offered by Sweden (Wabakken et al. 2001). Before 1996, the compensation program was run in a standard fashion. Affected livestock producers were required to contact authorities, fill out a compensation request form, and undergo an investigation by government authorities. Since 1996, in the northern regions of Sweden where reindeer production is a major economic activity, the compensation funds are allocated to communities. The only prerequisite is that such communities should demonstrate that predators of livestock frequent the area. In southern Sweden, where sheep production is predominant, the government disseminates some funds, which are to be used for damage prevention measures, to local communities. In this region, compensation of actual livestock losses is paid only if prevention measures are not in place. These multifaceted policies are proving successful and may be facilitating the successful recovery of the wolf population in Sweden (Wabakken et al. 2001).

Compensation programs exist in most US jurisdictions and in some Canadian provinces where wolves and livestock are present (Hayes and Gunson 1995, Fritts et al. 1997, Wagner et al. 1997, Bangs et al. 1998, Mech 1998). Typically, arrays of provincial, state, federal, and private funds provide financial compensation ranging from 85% to 100% of the estimated market value for confirmed kills. Canadian provincial officers or USFWS personnel conduct inspections at depredation sites. Veterinary costs for the treatment of injuries caused by wolves are also often refunded. A confounding factor for compensation programs is that carcasses may not be found or may be found after decomposition and scavenging preclude an assessment of the cause of death. This may result in undercompensating the actual damage caused by wolves. In addition, in some areas (for example, the Canadian province of Alberta), losses of less common livestock species, such as horse, llama, and alpaca, are not refunded. Moreover, those ranchers who spend time and incur expenses trying to reduce the chance of depredation are often not compensated. Nor do programs account for reproductive status (i.e., pregnancy), and only the meat value on a per-pound market basis is compensated. The US-based organization Defenders of Wildlife provides an important logistical and financial contribution

Figure 6. A Maremma livestock guardian dog looks at the carcass of a sheep killed by wolves. Photograph: Marco Musiani.

to both the compensation and the incentive programs. Defenders of Wildlife has opened a Canadian branch and, together with government authorities, is spending resources to address the still-open problems regarding wolf depredation management and to make programs for wolf conservation consistent throughout North America.

Current trends for wolf conservation in North America

In the conterminous US states, the federal Endangered Species Act (ESA) has protected all wolves since 1974 (Mech 1995, Fritts et al. 1997). The ESA is the strongest species protection legislation in the United States, usually superseding state laws. In 1978, Minnesota wolves were delisted by USFWS from endangered to threatened (43 Federal Register 9612, 9 March 1978). This delisting allowed depredating wolves to be killed by authorities. Following recent recovery in the United States (table 1, figure 2), on 1 April 2003 USFWS implemented federal reclassification of wolf populations under the ESA (Federal Register 68 [62]: 15803–15875 [to be codified at 50 CFR Part 17]). The most significant change was delisting the endangered populations to threatened status in the conterminous US states, except for the Yellowstone area, central Idaho, Arizona, and New Mexico. In these areas, wolves retain their "experimental nonessential" designation (Fritts et al. 1997) and will continue to be subject to different regulations. In addition, wolves in the southwestern United States (including Arizona and New Mexico) will retain their endangered status. Finally, wolves are removed from ESA protection in the regions where the species historically did not occur. Delisting the wolf does not lessen the protection of the species, which merely becomes a lesser priority for conservation efforts. However, a stated objective of the reclassification project has been to increase the ability to respond to wolf–human and wolf–livestock conflicts through lethal control (Federal Register 68 [62]: 15803–15875 [to be codified at 50 CFR Part 17]).

Delisting was not an automatic process and depended on gathering information showing the improved status of wolves. Populations that are considered viable will be managed by individual states. However, wolf management will have to be integrated among states belonging to three distinct population segments (DPSs): the western DPS, the eastern DPS, and the southwestern DPS. In addition, the federal government will be required to monitor the wolf populations within such DPSs. If the monitoring shows that the populations are in jeopardy, the federal government can relist the wolf (Federal Register 68 [62]: 15803–15875 [to be codified at 50 CFR Part 17]). Individual states are preparing to manage wolves after delisting; new state legislation may include culling of wolves that depredate on livestock.

Regardless of government regulation, human attitudes will play a pivotal role in the persistence of wolf populations. In Canada and the United States, current human attitudes toward wolves vary profoundly (Lohr et al. 1996, Enck and Brown 2002, Williams et al. 2002). In general, attitudes tend to be positive and are related to attitudes about other carnivores and environmental issues (Kellert et al. 1996). However, opposition by local communities to wolf presence (especially in agricultural areas) may indicate social and economical pressures that are not compatible with successful wolf and wilderness conservation (Czech 2000). Despite the biological resilience of wolves, which often allows them to survive persecution, humans have proved capable of quickly eradicating wolves from agricultural and developed areas (Young and Goldman 1944, Mech 1970).

Management strategies regarding wolves in North America range from full protection to hunting and control (table 1). The latter strategies are supported by the most efficient technologies (e.g., aircraft hunting, poisoning, and snowmobile hunting). This may result in inconsistent management practices across time, jurisdictions, and environments. These inconsistencies are determined largely by real or perceived conflicts between the interests of wolves and people. Among such conflicts, a predominant role is played by the still-unresolved problem of wolf depredation on livestock (Mech 1995, 1998, Fritts et al. 1997, Bangs et al. 1998, Coppinger and Coppinger 2001). Therefore, conservation efforts should focus disproportionately on rural areas, where human–wolf conflicts are more likely to occur. These suggestions are compatible with recent increases in government funding

allocated for conservation of threatened and endangered species in the United States. They could also benefit livestock operations that have not experienced a similar trend in financial support (Berger and Berger 2001).

Existing data on wolf population growth (figure 2) and on wolf presence outside protected or undeveloped regions in the United States (Haight et al. 1998, Mladenoff et al. 1999) demonstrate that wolves can coexist with livestock operations in some rural agricultural areas. However, with increasing losses of livestock in such areas (Bangs et al. 1998, Mech 1998), there is increasing pressure to manage depredation (Federal Register 68 [62]: 15803–15875 [to be codified at 50 CFR Part 17]). As wolves keep moving into rural areas where livestock production is a major economic activity (Bangs et al. 1998, Parsons 1998), managers, ranchers, and farmers may choose to diminish the occurrence of conflicts by proactively protecting livestock from wolves with lethal or nonlethal methods. There is a long history of lethal interventions by the livestock industry to protect stock from wolf depredation (Young and Goldman 1944, Mech 1970). However, today many North Americans prefer nonlethal methods (Haber 1996, Theberge and Theberge 1998), which are not yet in common use. If proved to be cost-effective and efficient, nonlethal methods could become more accepted by livestock producers and have the potential to improve wolf conservation. Nonlethal methods may be particularly appropriate where wolf reintroduction programs are planned, because communities in these areas especially fear economic losses from wolf depredation (Lohr et al. 1996, Fritts et al. 1997).

If cost-effectiveness and successful wolf conservation are desired, then compensation programs should be readily available to livestock producers (Ciucci and Boitani 1998, Wabbaken et al. 2001). Compensation should be designed to refund all real-world costs of wolf depredation, including costs of actual losses that are undetected but can be estimated and, most important, all costs associated with deployment of prevention measures. Nonlethal techniques tend to be costly and are effective only under some conditions. However, changing public attitudes in support of wolf conservation (Kellert et al. 1996, Lohr et al. 1996, Enck and Brown 2002, Williams et al. 2002) necessitate that managers better understand the application of nonlethal alternatives. At present, wolf culling is inherently controversial (Gasaway et al. 1992, Haber 1996). Moreover, opponents to culling have a strong voice in densely populated areas (e.g., in the conterminous 48 US states) where wolves are considered threatened (table 1; Theberge and Theberge 1998). Lethal control is more acceptable in sparsely populated areas, such as Alaska and northern Canada (table 1; Gasaway et al. 1983, 1992, Ballard et al. 1987, Orians et al. 1997, Hayes and Harestad 2000).

Figure 7. Fladry barrier (flags hanging from a rope stretched above the ground) employed to protect livestock from wolves on a Canadian ranch. Photograph: Marco Musiani.

In North America, the rural agricultural areas where wolves occur are often frequented by wild and domestic ungulates, both of which the wolves prey upon. Managing for high densities of wild ungulates could result in decreased livestock depredation by wolves. Some findings from southern Europe suggest that wolves prey more on wild ungulates in areas where these ungulates are at higher densities than livestock (Meriggi and Lovari 1996, Meriggi et al. 1996). Similar mechanisms regarding wolf predation on livestock and wild ungulates were proposed for North America (Mech 1970, Fritts and Mech 1981). Further research is needed to test selection of wild and domestic ungulates by wolves and the factors that influence prey switching. Spatial models based on such research may be useful for predicting wolf depredation intensity and could be combined with economic impact assessment for evaluating alternatives.

Acknowledgments

Support for this work came from the Alberta Cattle Commission, the ranching community of southern Alberta, the Department of Indian and Northern Affairs (Canada), a Government of Canada Award, a Government of Poland Award, Italian National Research Council Scholarships, Izaak Walton Killam Memorial Scholarships, the National Sciences and Engineering Research Council of Canada (NSERC), a Northern Scientific Training Program grant, an NSERC Northern Research Supplement, the University of Calgary, the University of Rome, and World Wildlife Fund Canada. We are grateful to our projects' collaborators, to the numerous individuals who assisted in the field and laboratory, and to four anonymous reviewers for their helpful suggestions on the manuscript.

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