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Managing Minnesota's recovered wolves

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Abstract The Minnesota wolf (*Canis lupus*) population was estimated by the Minnesota Department of Natural Resources at 2,450 during winter 1997–1998 and had increased at an average annual rate of 4.5% since winter 1988–1989. The population may be removed from the federal endangered species list by 2002, and management would then return to the state. A federal recovery team recommended a population goal of 1,250–1,400 wolves for Minnesota, with none in the agricultural region. A plan approved by the Minnesota legislature, however, continues the protection of wolves, except for pet and livestock depredation control, for at least 5 years after delisting. I compare number of wolves of the 1997–1998 population that would have to be killed each year by humans for various types of control versus numbers if the population continued to expand. For the 1997–1998 population, those numbers are—in addition to natural mortality, depredation control, and illegal and incidental take—at least 110 wolves and probably many more to limit wolf range, 685–1,149 wolves for sustained yield, and 929–1,956 to reduce the population. Given conservative assumptions, continued livestock depredation control, and a 4.5% rate of population and range increase as occurred during the past decade, comparable figures for 2007 are at least 171 wolves to limit range expansion, 1,064–1,786 for sustained yield, and 1,444–3,042 to reduce the population. The trend in the population since 1997–1998 is unknown, but these numbers illustrate the magnitude of the potential problems that could arise in managing Minnesota's wolves under various scenarios.

Key words *Canis lupus,* control, endangered species, management, population, recovery, wolf

Gray wolves (*Canis lupus*) in Minnesota, Wisconsin, and Michigan have increased and expanded their range considerably during the past 20 years (Fuller et al. 1992, Michigan Department of Natural Resources [DNR] 1997, Berg and Benson 1999, Wisconsin DNR 1999), greatly exceeding the recovery criteria of the Eastern Timber Wolf Recovery Plan (United States Fish and Wildlife Service 1978, 1992).

For Minnesota, the recommended recovery population level was a minimum of 1,250 wolves (United States Fish and Wildlife Service 1978, 1992), but the population in winter 1997–1998 was double that and increasing at 4.5%/year (Berg and Benson 1999). Although average wolf density remained about the same from 1989 to 1997, the wolf population expanded into more agricultural areas and thus increased from an estimated 1,625 in winter 1988–1989 (Fuller et al. 1992) to 2,450 in 1997–1998 (Berg and Benson 1999). At that rate of increase, the projected population in 2007 would be 3,800.

Since 1989, when the Minnesota wolf population was proliferating into regions with more agriculture (Fuller et al. 1992), wolf depredations on livestock and associated costs have increased considerably (Fritts 1982, Fritts et al. 1992, Mech 1998*b*). Because Minnesota's wilderness and semi-wilderness are saturated with wolves, the only areas left for the wolf population to colonize are primarily agricultural (Figure 1).

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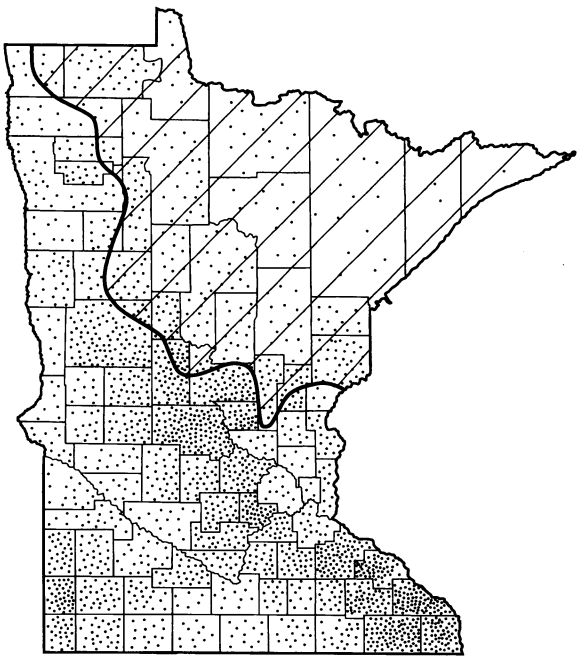

Figure 1. Distribution of livestock in Minnesota (Minnesota Agricultural Statistics Service 1997) and 1997 wolf range (cross-hatching, Berg and Benson 1999). Each dot represents 500 head of livestock.

Thus, without population control, the increase in rate of depredations on livestock will likely continue and accelerate. The following should increase similarly: costs of wolf depredation control, compensation payments by the Minnesota Department of Agriculture for livestock killed by wolves, number of wolves killed by the United States Department of Agriculture [USDA] depredation control program, and potential wolf-human interactions (Mech 1998*b*). Because wolves can habituate to humans and endanger them (Shahi 1983, Jhala and Sharma 1997, Mech 1998*a*, Route 1999), the increased wolf population in Minnesota has raised fears of attacks on children (Niskanen 1998).

On the other hand, the wolf's long tenure on the endangered species list has resulted in another constituency that strongly favors continued protection (Kellert 2000). Thus, wolf management has assumed a sociopolitical dimension that extends well beyond fundamental biological concerns.

When the United States Fish and Wildlife Service is confident that proposed state management plans will ensure maintaining wolf populations at or above recovery levels, it will propose delisting the wolf from the endangered species list in at least Minnesota, Wisconsin, and Michigan, probably in 2001 or 2002 (R. Refsnider, United States Fish and Wildlife Service, personal communication), and the states can resume wolf management. There are no specific federal requirements for the state wolf management plans except that they must ensure the survival of the wolf at or above recovery level. Wisconsin and Michigan have developed state wolf management plans.

Stakeholder prescription for wolf management

In Minnesota, sociopolitical factors translated into an approach to develop a wolf management plan that allowed key vested interests (stakeholders) to establish basic elements of the plan. The DNR held a series of public meetings followed by 8 day-long stakeholders' (Minnesota Wolf Management Roundtable) discussions that led to a consensus on wolf management recommendations. The Minnesota DNR had agreed that if the Roundtable achieved consensus, the DNR would propose the consensus to the state legislature.

The Roundtable consensus recommended no wolf population control for the first 5 years after delisting. It did recommend continuing the United States Department of Agriculture (USDA) wolf depredation control program that has been in effect since 1978 (Fritts 1982, Fritts et al. 1992). That program's average kill of 126 wolves each year since 1989 (W. J. Paul, United States Department of Agriculture, personal communication) has not prevented the Minnesota wolf population from expanding its range or population (Berg and Benson 1999).

The gray wolf (*Canis lupus*) has reached recovery level in Minnesota and may soon be delisted by the United States Fish and Wildlife Service.

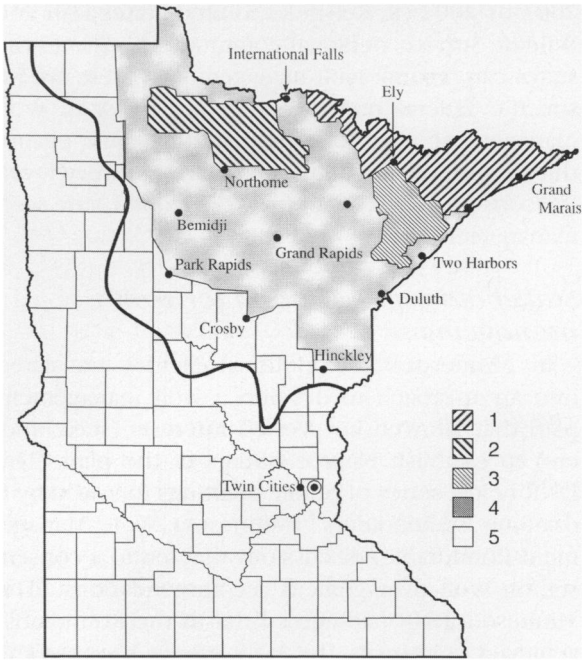

Figure 2. Minnesota wolf management zones (1–5) proposed by the Wolf Recovery Team (United States Fish and Wildlife Service 1978, 1992) and current wolf distribution (northeast of solid line, Berg and Benson 1999). Current wolf densities in zones 1–3 (Berg and Benson 1999) approximate those recommended by the Recovery Team. Within zone 4, the population is more than 3 times the Team recommendation, and in 1997 an estimated 425 wolves lived in zone 5, where the Team recommended no wolves (Minnesota Department of Natural Resources, unpublished).

Wolf recovery plan recommendations

The Roundtable consensus contrasted markedly with the plurality (45%) of Minnesota citizens who favored controlling wolves rather than allowing them to spread farther (Kellert 2000). It also differed from the recommendations of the Eastern Timber Wolf Recovery Plan (United States Fish and Wildlife Service 1978, 1992). To minimize conflict between wolves and humans, the Wolf Recovery Team recommended as early as 1983 that the Minnesota wolf population be controlled in addition to livestock depredation control. However, courts held that such population control could not be permitted while the wolf was on the endangered species list (O'Neill 1988).

The recovery team also recommended an optimum population level of 1,250–1,400 wolves for Minnesota after delisting, with no wolves in the primary agricultural zone, zone 5 of the recovery plan (United States Fish and Wildlife Service 1978, 1992). By 1989 wolves had been colonizing zone 5 for several years (Fuller et al. 1992, Fritts et al. 1992), and by 1997 they were well established in many parts of that zone (Figure 2).

The 1999 Minnesota legislature rejected the Roundtable-DNR wolf management plan. In 2000 the legislature passed a slightly modified version of that plan that still rejected population control for at least 5 years after delisting (Minnesota House File 3046).

Wolf population control in Minnesota

The Minnesota Roundtable consensus did recommend that the subject of wolf population control be reconsidered 5 years after delisting, and the Roundtable agreed to meet annually to review its recommendations. Because maintaining the Minnesota wolf population at current or increased levels will be expensive and contentious (Mech 1998*b*), population control probably will be discussed and considered frequently. The subject, however, is biologically complex and needs clarification. I attempt here to provide that clarification.

Wolf productivity

Wolves are prolific, each pack usually producing an average litter of 5-6 pups/year (Mech 1970). Because average pack size in Minnesota is about 5.5 (Berg and Benson 1999), annual production about doubles the wolf population. In most areas, wolf pup survival over summer is high (summarized by Mech et al. 1998), although in parts of Minnesota where canine parvovirus is present, it is sometimes less (Mech and Goyal 1995).

Wolves in the wild mature sexually when 2-4 years old (Mech 1970, Mech and Seal 1987), and as they mature they disperse distances up to 886 km (Fritts

Management of Minnesota's wolf population of about 2,500 will return to the state after removal from the federal Endangered Species List.

Table 1. Summary of number of wolves that must be killed annually to effect various types of wolf population control in Minnesota.

Type of control	Wolf population[a]	
	1997–1998	3,800 in Year 2007[a]
Range limitation	110[b]	171[b]
Sustained yield	685–1,149	1,064–1,786
Population reduction	929–1,956	1,444–3,042

[a] Figures based on an assumed 4.5% annual increase starting at 2,450 in 1997–1998 (Berg and Benson 1999).

[b] These wolves must be taken along the edge of the wolf range and this is a minimum number because the area could become a sink for dispersers from the population interior. This number also assumes the 1989–1998 average annual kill of 126 wolves by the USDA in year 1998 and 250 in year 2007 for livestock depredation control.

1983) from their natal packs (Fritts and Mech 1981, Mech 1987, Fuller 1989, Gese and Mech 1991). When dispersed wolves of the opposite sex meet in a wolf-free area with prey, they pair, mate, and produce their own pups (Rothman and Mech 1979).

Wolf mortality

Wolves perish from a variety of causes. In extensive, well-established wolf populations where human-related mortality is low, the main causes of death are starvation and intraspecific fights (Mech 1977, 1994; Fuller 1989; Mech et al. 1998), as well as disease in some areas (Brand et al. 1995, Mech and Goyal 1995). This mortality, plus emigration of dispersers, tends to stabilize the wolf population in the long-established part of its range (Mech 1986, Fuller 1989, Mech and Goyal 1995) while allowing it to increase its distribution and numbers by spreading into new areas (Fritts and Mech 1981, Fritts et al. 1992, Fuller et al. 1992, Berg and Benson 1999).

Wolves also suffer loss from illegal and accidental killing by humans, however, even where legally protected. In addition, up to 216 Minnesota wolves have been killed annually by the USDA to help control depredations on domestic animals (W. J. Paul, USDA, personal communication), and this take could increase to more than 400 by 2005 (Mech 1998*b*).

Potential population increase

In prey-filled areas relatively free of wolves, such as Wisconsin and Michigan, natural wolf mortality tends to be low, so populations thrive and increase rapidly. Average annual wolf population increase in Wisconsin from 1993 to 1999 was 31% (Wisconsin DNR 1999), and in Michigan from 1991 to 2000 it was 33% (Michigan DNR 1997; and Michigan DNR, unpublished). In Minnesota the same phenomenon has occurred. However, because of the annual USDA kill of wolves in the newer parts of the wolf range and because Minnesota has such a large base population of wolves, the average annual percentage increase of the whole population has been only about 4.5%. Nevertheless, the rate of increase of wolf numbers on the periphery of Minnesota's wolf range would be much greater, for the wolf population in the long-established parts of its range is relatively stable (Berg and Benson 1999).

Types of population control

Whenever population control is considered for the Minnesota wolf population, the objectives of that control also must be considered. Three possible objectives would be 1) attempting to limit the population and its distribution at wherever it is when control is initiated, 2) controlling the total population through harvesting it on a sustained-yield basis, or 3) reducing the population and its range (Table 1).

Population and range limitation

Because the Minnesota wolf population is increasing by only 4.5%/year, it might seem possible to limit the population by removing only 4.5% of it. Assuming that the Minnesota wolf population stopped increasing after the last estimate was made in winter 1997–1998, a highly conservative assumption, this number would be only about 110 wolves annually so long as they were taken along the periphery of the range and so long as the USDA kill continues at its current or a greater level.

However, because lone wolves disperse such long distances and drift over thousands of km^2 seeking new areas to colonize (Mech and Frenzel 1971, Fritts and Mech 1981, Berg and Kuehn 1982, Merrill and Mech 2000), each wolf killed along the edge of wolf range might be replaced quickly. Thus the harvesting area could become a "sink" for these individuals and a much larger number might still have to be killed just to limit wolf range. It is notable in this respect that some Canadian provinces are able to keep their wolf population from spreading into agricultural land by harvesting only 4–11% each year (Hayes and Gunson 1995), but most of that take presumably is concentrated at the edge of the wolf range.

Asserting this type of wolf population control would tend to minimize the number of wolves in

zone 5 (Figure 2), as recommended by the Recovery Team (United States Fish and Wildlife Service 1978, 1992), and would help minimize increases in livestock depredations (Fritts et al. 1992, Mech 1998*b*).

Control by sustained yield

If the method of wolf population control in Minnesota were to be harvesting wolves for a sustainable yield, then a much larger number could be taken. It is well established that wolf populations can sustain annual winter harvests of 28-47% without permanently reducing their numbers (Mech 1970; Peterson et al. 1984; Ballard et al. 1987, 1997; Fuller 1989; Lariviere et al. 2000). For the Minnesota wolf population, that would be 685–1,149 wolves annually.

The reason the annual sustainable harvest can be so much greater than the kill necessary merely to limit the population is that much human-caused mortality is compensatory.

Compensatory loss

Compensatory loss is the loss that occurs in lieu of human harvesting. Wolves that are not killed by human harvesting would then be available to disperse and to perish from fights with other wolves and from starvation, disease, accidents, illegal taking, and removal by the USDA.

A reasonable estimate of the number of wolves killed by other wolves in an unharvested population each year is 10% of the population (Mech 1977, Fuller 1989, Mech et al. 1998). This would amount to about 245. The fact that in harvested wolf populations, few wolves are killed by other wolves (Peterson et al. 1984; Ballard et al. 1987, 1997) supports the conclusion that such mortality is compensatory to harvesting.

The main prey species of Minnesota wolves is white-tailed deer, which live throughout Minnesota.

This leaves 18-43% (440–1,051 wolves) of the Minnesota population each year that if not harvested might be lost to starvation or disease, struck by vehicles or railroad trains (Mech, unpublished), mistakenly killed as coyotes (*Canis latrans*), illegally taken, lost through emigration to adjoining states (Licht and Fritts 1994, Mech et al. 1995), or added to the population each year. If only the Minnesota figure for sustainable harvest (28% in addition to the USDA kill, Fuller 1989) is used and 10% are assumed killed by other wolves, the annual number of wolves lost to all these causes is 440 minus the 110 that add to the population increase each year, or 330.

Population reduction

To permanently reduce a wolf population, an even greater proportion of the population must be taken each year than for a sustainable yield. Although no such estimate has been derived for Minnesota, to reduce wolf populations in Alaska and Canada, some 38-80% of each winter's population were killed annually and populations rebounded within a few years when control was ended (Gasaway et al. 1983, Ballard et al. 1987, Potvin et al. 1992, Hayes 1995). Applying these figures would mean that to reduce the Minnesota population of 2,450 wolves, some 929–1,956 wolves would have to be killed each year.

Control of the future wolf population

The above estimates were based on the winter 1997–1998 Minnesota wolf population and recent rate of increase (Berg and Benson 1999). However, the Minnesota wolf management plan prohibits wolf population control for 5 years after delisting by the federal government. Assuming the probable scenario that Minnesota wolves will not be delisted before the year 2002 and assuming that the population will continue to increase at an average annual rate of 4.5%, it would reach some 3,800 wolves by 2007. Annual kill quotas comparable to the above for the projected 2007 population would be at least 171 for population limitation, 1,064–1,786 for sustainable harvest, and 1,444-3,040 for population reduction, assuming an annual depredation control take of at least 250 wolves (Table 1).

Will the Minnesota wolf population continue to expand?

It is notable that in the western United States, wolf delisting has been recommended when wolf numbers reach about 100 in each of 3 states

(United States Fish and Wildlife Service 1987), thus exposing those wolves to state population control. Michigan's wolves would be eligible for population control when they exceed 200 (Michigan DNR 1997) and Wisconsin's when they reach 350 (Wisconsin DNR 1999). There is no wolf population anywhere in the world as large as Minnesota's that is not subject to harvesting or attempted population control (Ginsburg and MacDonald 1990). Romania's is legally protected, but the law is not enforced (Promberger et al. 1998).

Whether the Minnesota wolf population will continue to expand its range and numbers is difficult to predict. Even without population control, wolf numbers within a given part of their range will fluctuate over time depending on food supply and availability, as they do everywhere else (Mech 1977, 1986; Peterson 1977; Fuller 1989; Mech and Goyal 1995; Peterson et al. 1998; Mech et al. 1998). The critical question is whether the wolf population will continue to expand its range and thereby its numbers.

The answer depends on how adaptable the wolf becomes in Minnesota. Much has been made of the wolf's affinity for wilderness (Theberge 1975, Mladenhoff et al. 1995), but that affinity was imposed by human persecution in accessible areas, which changed after passage of the Endangered Species Act of 1973 (Mech 1995). Wolves in Minnesota and Wisconsin have begun to adapt to human disturbance, even denning near very disturbed areas (Thiel et al. 1998) and colonizing areas that are increasingly open, agricultural, and human-inhabited (Fritts et al. 1992, Fuller et al. 1992, Berg and Benson 1999, Figure 1).

Wolves can live in almost any habitat in the northern hemisphere (Mech 1970), requiring only food and lack of human persecution. Because deer (*Odocoileus virginianus*), the wolf's primary prey in Minnesota, inhabit most of the state (M. H. Dexter, unpublished), the potential for wolves to colonize the remainder of the state seems great. That Minnesota wolves disperse long distances through and into open agricultural land is well documented (Licht and Fritts 1994, Mech et al. 1995, Merrill and Mech 2000). So too is the wolf's ability to colonize disjunct forest and brushland surrounded by open, agricultural areas (Fritts et al. 1992, Thiel 1996).

Depredation control and accidental and illegal killing of relatively few wolves in the agricultural frontier of their range, where they may be more vulnerable, might retard range expansion or perhaps stop wolves from ever colonizing the most open areas of the state. Despite such losses from 1989 through 1997, however, the Minnesota wolf population expanded its range into agricultural areas by 44-74% and even began to colonize disjunct open areas within 25 km of Moorhead (Berg and Benson 1999).

The extent to which the Minnesota wolf population can continue to expand into the even more open region south and west of its current range remains an open question. Such a spread would require a greater number of wolves dispersing into the new range than are killed. As indicated above, the net number of such wolves currently available each year to disperse and colonize is about 110, assuming that the 1997-1998 population did not increase. It does not seem likely that a species that has survived in areas of such high human density as Italy, India, and Israel (Mech 1970, Ginsburg and MacDonald 1990) and that even forages in urban areas of Romania (Promberger et al. 1998) would have much trouble colonizing the remainder of Minnesota.

Can Minnesota's future wolf population be controlled?

The main method of wolf extirpation in the past was the widespread use of poison by citizens and a concerted government program (Young and Goldman 1944), and poison is still used to control wolf populations in parts of Canada (Cluff and Murray 1995).

Poisoning is illegal in Minnesota. Thus, other methods would be required to halt the spread of the population (Mech 1998*b*). However, wolves are difficult to hunt systematically and there is no tradition for doing so; those shot illegally are killed opportunistically. Wolf trapping and snaring require much skill and experience and are very inefficient under Minnesota's current trap-checking laws. No new population control technology is on the horizon except sterilization (Mech et al. 1995), and that appears useful only to control small, disjunct wolf populations (Haight and Mech 1997). Thus, if the Minnesota wolf population does colonize more of the state during the 5 years after federal delisting, it is questionable whether further range or population expansion can be curtailed.

Even if the wolf population does not increase beyond its 1997-1998 level, it is important for all to understand that a moderate to large kill of wolves from the general population will 1) have little limiting or reducing effect on the population and 2) not threaten or endanger it. Each year, the wolf population can be expected to produce over 2,000 pups,

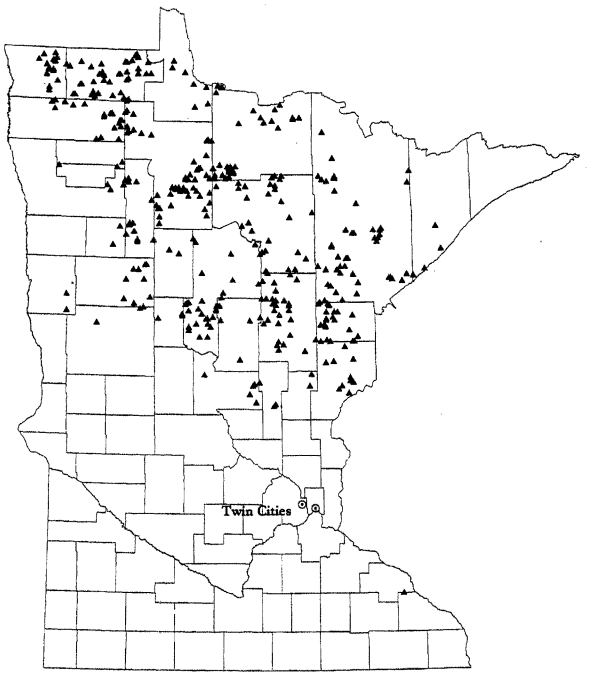

Figure 3. Locations of farms where at least one livestock depredation has been verified by the USDA, 1989–1998 (W. J. Paul, personal communication).

assuming that its 385 packs (Berg and Benson 1999) bear an average of 5.5 pups each (Mech 1970), a conservative average (Stenlund 1955, Fuller 1989).

In view of all the above considerations, the only effective management approach may be to focus any type of control or harvesting of wolves in zone 5 (Figure 2) and in areas where most of the depredations on livestock are occurring (Figure 3). While this would not control the statewide population, it would at least help minimize the accelerating conflict between wolves and humans.

On the other hand, public pressure might build for control or reduction of the wolf population. Such pressure could result from the expected increase in wolf depredations on livestock and pets (Mech 1998*b*) or from perceived competition by wolves for deer or moose (*Alces alces*) sought by hunters. If so, it should be apparent from the above discussion that wolf control or reduction without poison might require such a major sustained effort that it might have to include both federal and state agents. The longer this effort is deferred, the more difficult it will be (Table 1).

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Literature cited

Ballard, W. B., Whitman, J. S. and Gardner, C. L. 1987. Ecology of an exploited wolf population in south-central Alaska. Wildlife Monographs 98.

Ballard, W. B., L. A. Ayres, P. R. Krausman, D. J. Reed, and S. J. Fancy. 1997. Ecology of wolves in relation to a migratory caribou herd in northwest Alaska. Wildlife Monographs 135.

Berg, W. E., and D. W. Kuehn. 1982. Ecology of wolves in north-central Minnesota. Page 4-11 *in* F. H. Harrington and P. C. Paquet, editors. Wolves of the world. Noyes, Park Ridge, New Jersey, USA.

Berg, W., and S. Benson. 1999. Updated wolf population estimate for Minnesota, 1997-1998. Minnesota Department of Natural Resources Report, Grand Rapids, USA.

Brand, C. J., M. J. Pybus, W. B. Ballard, and R. O. Peterson. 1995. Infectious and parasitic diseases of the gray wolf and their potential effects on wolf populations in North America. Pages 419–429 *in* L. N. Carbyn, S. H. Fritts and D. R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Edmonton, Alberta, Canada.

Cluff, H. D., and D. L. Murray. 1995. Review of wolf control methods in North America. Pages 491–504 *in* L. N. Carbyn, S. H. Fritts, and D. R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Edmonton, Alberta, Canada.

Fritts, S. H. 1982. Wolf depredation on livestock in Minnesota. United States Fish and Wildlife Service, Resource Publication 145, Washington, D.C., USA.

Fritts, S. H. 1983. Record dispersal by a wolf from Minnesota. Journal of Mammalogy 64: 166–167.

Fritts, S. H., and L. D. Mech. 1981. Dynamics, movements, and feeding ecology of a newly protected wolf population in northwestern Minnesota. Wildlife Monographs 80.

Fritts, S. H., W. J. Paul, L. D. Mech, and D. P. Scott. 1992. Trends and management of wolf-livestock conflicts in Minnesota. United States Fish and Wildlife Service, Resource Publication 181, Washington, D.C., USA.

Fuller, T. K. 1989. Population dynamics of wolves in North-Central Minnesota. Wildlife Monographs 105.

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: 42-55.

Gasaway, W. C., R. O. Stephenson, J. L. Davis, P. E. K. Shepherd, and O. E. Burris. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildlife Monographs 84.

Gese, E. M., and L. D. Mech. 1991. Dispersal of wolves (*Canis lupus*) in northeastern Minnesota, 1969–1989. Canadian Journal of Zoology 69: 2946-2955.

Ginsburg, J. R., and D. W. MacDonald. 1990. Foxes, wolves, jackals, and dogs. Species Survival Commission Canid Specialist Group, International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Haight, R. G., and L. D. Mech. 1997. Evaluating vasectomy as a means of wolf control. Journal of Wildlife Management 61: 1023–1031.

Hayes, R. D. 1995. Numerical and functional responses of wolves, and regulation of moose in the Yukon. Thesis, Simon Fraser University, Burnaby, British Columbia, Canada.

Hayes, R. D. and J. R. Gunson. 1995. Status and management of wolves in Canada. Pages 21–34 *in* L. N. Carbyn, S. H. Fritts and D. R. Seip, editors. Ecology and conservation of wolves

in a changing world. Canadian Circumpolar Institute, Edmonton, Alberta, Canada.

JHALA, Y. V., AND D. K. SHARMA. 1997. Child-lifting by wolves in eastern Uttar Pradesh, India. Journal of Wildlife Research 2:94-101.

KELLERT, S. R. 2000. The public and the wolf in Minnesota, 1999. International Wolf Center, Brooklyn Center, Minnesota, USA.

LARIVIERE, S., H. JOLICOEUR, AND M. CRETE. 2000. Status and conservation of the gray wolf *Canis lupus* in wildlife reserves of Quebec. Biological Conservation: 94: 143-151

LICHT, D. S., AND S. H. FRITTS. 1994. Gray wolf (*Canis lupus*) occurrences in the Dakotas. American Midland Naturalist 132: 74-81.

MECH, L. D. 1970. The wolf, the ecology and behavior of an endangered species. Doubleday, New York, New York, USA.

MECH, L. D. 1977. Productivity, mortality and population trend of wolves in northeastern Minnesota. Journal of Mammalogy 58: 559-574.

MECH, L. D. 1986. Wolf population in the central Superior National Forest, 1967-1985. United States Department of Agriculture, Forest Service, North Central Forest Experiment Station, Research Paper NC-270, St. Paul, Minnesota, USA.

MECH, L. D. 1987. Age, season, distance, direction, and social aspects of wolf dispersal from a Minnesota pack. Pages 55-74 *in* B. D. Chepko-Sade, and Z. Halpin, editors. Mammalian dispersal patterns. University of Chicago, Chicago, Illinois, USA.

MECH, L. D. 1994. Buffer zones of territories of gray wolves as regions of intraspecific strife. Journal of Mammalogy 75: 199-202.

MECH, L. D. 1995. The challenge and opportunity of recovering wolf populations. Conservation Biology 9: 270-278.

MECH, L. D. 1998*a*. Who's afraid of the big bad wolf?—Revisited. International Wolf 8(1): 8-11.

MECH, L. D. 1998*b*. Estimated costs of maintaining a recovered wolf population in agricultural regions of Minnesota. Wildlife Society Bulletin 26: 817-822.

MECH, L. D., AND L. D. FRENZEL, JR. 1971. Ecological studies of the timber wolf in northeastern Minnesota. United States Department of Agriculture, Forest Service, North Central Forest Experiment Station, Research Paper NC-52, St. Paul, Minnesota, USA.

MECH, L. D., AND SEAL, U. S. 1987. Premature reproductive activity in wild wolves. Journal of Mammalogy 68: 871-873.

MECH, L. D., AND S. GOYAL. 1995. Effects of canine parvovirus on a wolf population in Minnesota. Journal of Wildlife Management 59: 565-570.

MECH, L. D., S. H. FRITTS, AND D. WAGNER. 1995. Minnesota wolf dispersal to Wisconsin and Michigan. American Midland Naturalist 133: 368-370.

MECH, L. D., L. G. ADAMS, T. J. MEIER, J. W. BURCH, AND B. W. DALE. 1998. The wolves of Denali. University of Minnesota, Minneapolis, USA.

MERRILL, S. B., AND L. D. MECH. 2000. Details of extensive movements by Minnesota wolves (*Canis lupus*). American Midland Naturalist 144: 428-433.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES. 1997. Michigan gray wolf recovery and management plan. Wildlife Division, Michigan Department of Natural Resources, Lansing, USA.

MINNESOTA AGRICULTURAL STATISTICS SERVICE. 1997. Minnesota and United States Department of Agriculture, St. Paul, USA.

MLADENHOFF, D. J., T. A. SICKLEY, R. G. HAIGHT, AND A. P. WYDEVEN. 1995. A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. Conservation Biology 9: 279-294.

NISKANEN, C. 1998. Minnesotans divided on best approach to wolves. Pioneer Press, 27 February 1998: 1A, St. Paul, Minnesota, USA.

O'NEILL, B. B. 1988. The law of the wolves. Environmental Law 18: 227-240.

PETERSON, R. O. 1977. Wolf Ecology and Prey Relationships on Isle Royale. United States National Park Service Scientific Monograph Series 11: 1-210.

PETERSON, R. O., J. D. WOOLINGTON, AND T. N. BAILEY. 1984. Wolves of the Kenai Peninsula, Alaska. Wildlife Monographs 88.

PETERSON, R. O., N. J. THOMAS, J. M. THURBER, J. A. VUCETICH, AND T. A. WAITE 1998. Population limitation and the wolves of Isle Royale. Journal of Mammalogy 79: 828-841.

POTVIN, F., H. JOLICOEUR, L. BRETON, AND R. LEMIEUX. 1992. Evaluation of an experimental wolf reduction and its impact on deer in Papineau-Labelle Reserve, Quebec. Canadian Journal of Zoology 70: 1595-1603.

PROMBERGER, C., O. IONESCU, A. MERTENS, M. MINCA, G. PREDOIU, B. PROMBERGER-FURPA, A. SANDOR, M. SCURTU, AND P. SURTH. 1998. Carpathian large carnivore project. Munich Wildlife Society, Annual Report 1997-98, Ettal, Germany.

ROTHMAN, R. J., AND L. D. MECH. 1979. Scent-marking in lone wolves and newly formed pairs. Animal Behavior 27: 750-760.

ROUTE, B. 1999. Wolf-human incidents in Algonquin Provincial Park. International Wolf 9(1): 15-16.

SHAHI, S. P. 1983. Status of the grey wolf (*Canis lupus pallipes*, Sykes) in India. Acta Zoologica Fennica 174: 283-286.

STENLUND, M. H. 1955. A field study of the timber wolf (*Canis lupus*) on the Superior National Forest, Minnesota. Minnesota Department of Conservation, Technical Bulletin 4, St. Paul, USA.

THEBERGE, J. B. 1975. Wolves and wilderness. J. M. Dent and Sons, Toronto, Ontario, Canada.

THIEL, R. P. 1996. The wolf returns to central Wisconsin. International Wolf 6(2): 3-6.

THIEL, R. P., S. MERRILL, AND L. D. MECH. 1998. Tolerance of denning Wolves, *Canis lupus,* to human disturbance. Canadian Field Naturalist 112: 340-342.

UNITED STATES FISH AND WILDLIFE SERVICE. 1978. Recovery plan for the eastern timber wolf. United States Fish and Wildlife Service, Twin Cities, Minnesota, USA.

UNITED STATES FISH AND WILDLIFE SERVICE. 1987. Northern Rocky Mountain Wolf Recovery Plan. United States Fish and Wildlife Service, Denver, Colorado, USA.

UNITED STATES FISH AND WILDLIFE SERVICE. 1992. Recovery plan for the eastern timber wolf. United States Fish and Wildlife Service, Twin Cities, Minnesota, USA.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES. 1999. Wisconsin wolf management plan draft. Wisconsin Department of Natural Resources, Madison, USA.

YOUNG, S. P. AND G. E. GOLDMAN. 1944. The wolves of North America. General Publishing Company, Toronto, Ontario, Canada.

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