An Assessment of Potential Habitat for Eastern Timber Wolves in the Northeastern United States and Connectivity with Occupied Habitat in Southeastern Canada

A summary report and position paper prepared for the Wildlife Conservation Society
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INTRODUCTION

The eastern timber wolf *(Canis lupus lycaon)* once occupied the northeastern United States, including all of New England and New York (Paradiso and Nowak 1982). The wolf was extirpated from New England, New York, and extreme southeastern Canada by 1900 via direct human persecution, habitat alteration, and human-induced reductions in obligate prey species. By 1960, the only remaining population of wolves within the coterminous 48 United States occurred in Minnesota. Wolves in the coterminous U.S. became protected by the Endangered Species Act in 1974 and a recovery plan for the eastern timber wolf was published by Bailey et al. in 1978. This plan was subsequently revised in 1992, coincident with an expansion of the presumed eastern subspecies into northern Wisconsin and the upper peninsula of Michigan (USFWS 1992).

The primary goal identified in the revised Eastern Timber Wolf Recovery Plan (USFWS 1992) is "to maintain and reestablish viable populations of the eastern timber wolf in as much of its former range as possible". Furthermore, the plan established that the eastern timber wolf will be considered officially recovered when the survival of the wolf in Minnesota is assured, and at least one viable population exists outside Minnesota and Isle Royale in the coterminous 48 U.S. states. The criteria used to define a viable population were: >200 wolves in a population >320 km from the Minnesota population, or >100 wolves occurring in Wisconsin or Michigan within 160 km of the Minnesota population over a 5 year period. Currently, the population of wolves in Minnesota is considered stable or increasing (Fuller et al. 1992), numbers in Wisconsin have increased to nearly 100 individuals (Wydeven 1996), and wolves in Michigan's upper peninsula number >100 (Schadler and Hammill 1996). Thus, the official recovery objective for the eastern timber wolf could be considered achieved by USFWS in 1998 if numbers in Wisconsin and Minnesota remain stable or continue to increase.

Official recovery of the eastern timber wolf may occur without achieving the primary goal of reestablishing the subspecies throughout much of its former range. The recovery plan (USFWS 1992) identified 24,287 km^2 in New York and 35,751 km^2 in Maine as potential habitat warranting further study; however, little was known about the extent of potential habitat in the northeastern U.S. or about the connectivity of potential habitat with occupied habitat in southeastern Canada. Thus, the potential for wolves to naturally recolonize the northeastern U.S. via emigration from extant populations in southern Ontario and Quebec was unknown. Information about potential habitat for the eastern timber wolf east of the Lake Superior basin is particularly relevant because of a recent taxonomic reclassification of *Canis lupus* proposed by Nowak and Federoff (1996). This reclassification reduced the number of subspecies that originally occupied the 48 coterminous states from 8 to 5, and placed the wolves that currently occupy Minnesota, Wisconsin, and Michigan within the same subspecies *(C. l. nubilus)* as the Rocky Mountain timber wolf. If formally recognized by USFWS, this reclassification would change the status of the eastern timber wolf *(C. l. lycaon)* to extirpated from its former range in the U.S. and extant only in southeastern Canada. Based on this classification, recovery of eastern timber wolves would require natural recolonization or reintroduction from extant stocks in southeastern Canada, which themselves are being considered as "vulnerable " or "threatened" by the Canadian government in some parts of their ranges (Committee on the Status of Endangered Wildlife in Canada, unpublished report).

Although the eastern timber wolf recovery plan identified areas in the northeastern U.S. as potentially suitable habitat for wolves (USFWS 1992), the likelihood that dispersing wolves from extant populations in southeastern Canada may naturally recolonize previously occupied habitat in the northeastern U.S. has not been rigorously examined. Provided there is a sufficiently large source population and no barriers of unsuitable habitat, wolves are capable of colonizing distant habitats located hundreds of kilometers from a population source (Mech 1987, Gese and Mech 1991);

documented dispersals of radio-collared wolves from Minnesota have been as far as 886 km (Fritts 1983). Some dispersing wolves have crossed 4-lane highways, areas of high road density, and extensive areas not occupied by wolves, while circumventing large urban areas.

Although wolves are physically capable of dispersing the relatively short distances from extant populations in Canada to potential habitat in Maine and New York, there are potential physical and habitat barriers that may preclude immigration of a sufficient number of wolves to promote population establishment south of the Canada/U.S. border. These potential barriers include the St. Lawrence Seaway, which is situated 75 km from Maine and forms the boundary between New York and Ontario, as well as extensive areas of unforested agricultural land, areas of high human density, and areas with high road densities. Human activities may create barriers that slow or impede range expansion in wolves. For example, several individual wolves that have dispersed south of Minneapolis-St. Paul were documented as having been killed while crossing highways or shot when mistaken for coyotes *(Canis latrans)* (Mech 1995), a species that is legally harvested throughout the coterminous U.S. and southern Canada (Novak et al. 1987). There are considerably higher densities of humans, agricultural areas, and roads within areas of southeastern Canada, south of occupied wolf range, as compared to potential habitats identified for further study in the northeastern U.S. these areas of high human activity could preclude natural recolonization of eastern timber wolves into New England and New York. Further, the St. Lawrence River is a potential barrier or filter to dispersal movements, which could isolate Canadian wolves from potential habitat in the northeastern U.S.

Within well studied wolf populations in Minnesota, humans have been documented as the predominant cause of wolf mortality (Van Ballenberghe et al. 1975, Fritts and Mech 1981, Fuller 1989). Thus, human access to wolf populations is a primary consideration for evaluating habitat suitability. Researchers from the Great Lakes region have reported that resident wolves do not persist in areas where road densities exceed 0.58 km/km^2 (Thiel 1985, Jensen et al. 1986). However, Mech et al. (1988) reported that wolves can persist in areas with road densities as high as 0.73 km/km', if located adjacent to habitat with less human access. Similarly, Fuller et al. (1992) reported that 85% of packs and 80% of single wolves observed in Minnesota occurred in townships with <0.70 km $roads/km^2$ and < 4 $humans/km^2$. Although large, forested areas with low road and human densities occur in northern New England and New York, there have been no assessments of the extent and connectivity of potential habitat below the road and human density thresholds identified by Fuller et al. (1992).

Our objectives were to quantify and map the extent, distribution, and connectivity of habitat in the northeastern U.S. that is in forested land cover, and below thresholds of 0.70 km roads/km^2 and 4 humans/km^2. To provide insight into the potential for natural reestablishment of wolves via emigration from extant populations, we also mapped potential dispersal corridors between wolf populations in southeastern Canada and potential habitat in the northeastern U.S. Further, we used published wolf densities from areas throughout the North American range of the timber wolf, combined with our estimates of the extent of potentially suitable habitat, to evaluate whether areas of contiguous habitat in the northeastern U.S. are sufficient to satisfy the population viability criteria established in the revised recovery plan for the eastern timber wolf (USFWS 1992).

METHODS

Manipulation and analysis of spatial data were conducted using ARC/INFO Geographic Information System (GIS) software (Environmental Systems Research Institute, Redlands, Calif). The land use/land cover data were based on the North America Land Cover Characteristics (NALCC) Data Base from the U.S. Geological Survey (USGS) and the University of Nebraska - Lincoln (UNL). This coverage was a 1-km-resolution classification derived from Advanced Very High Resolution Radiometer satellite imagery collected during 1992-1993. The analysis techniques used by USGS were modeled after a prototype land cover classification for the coterminous U.S. (Loveland et al. 1991, Brown et al. 1993). The land use/land cover types we used were based on the USGS Land Use/Land Cover Classification System (Anderson et al. 1976), one of several thematic versions of the NALCC data provided by USGS.

Human density was mapped at the scale of minor civil divisions (MCD) in the U.S. and census subdivisions (CSD) in Canada. MCD's and CSD's are demographically homogeneous areas that grossly represent townships (generally approximate 36 mi^2) in New England and New York, and similarly represent spatially comparable areas in Canada. Boundaries for states and MCD'S, as well as the 1990 MCD human population data, were obtained from the U.S. Census Bureau. Canadian province and CSD boundaries, and 1991 CSD human population data were obtained from Compusearch Micromarketing Data and Systems (Toronto, Ontario). Human density for each MCD and CSD was calculated as the number of people divided by the area (km^2) of each municipal unit.

Road density in the U.S was based on USGS Digital Line Graph (DLG) 1:100,000-scale road data. We excluded DLG road class 5, which consisted of roads not passable by 2-wheel-drive vehicles. We used the GIS to calculate road density for each MCD and CSD by dividing the sum of the lengths (km) of roads by the area (km^2) of each municipal unit.

We defined potential core wolf habitat in Canada and the U.S. as areas in a forested cover type with <4 humans/km^2. We defined potential wolf dispersal habitat as areas in either forested or mixed forest/cropland cover types with <10 humans/km^2. In the U.S., we further restricted both potential core and dispersal wolf habitat to include areas with <0.7 km roads/km^2 . Data for road density by development class were not available for Canada; however, human densities and road densities are highly correlated. Our human and road density criteria for potential core habitat were based on documented thresholds of wolf occupancy in Minnesota (Fuller et al. 1992). Based on accounts that dispersing wolves sometimes move through farmland and other areas with higher human activity than are typically occupied by resident wolves (Wydeven 1996, Light and Fritts 1994), we expanded the definition of potential dispersal habitat to include 1 km^2 cells classified as a mosaic of agricultural land and forest. Because Harrison (1992) observed numerous instances of dispersing coyotes successfully traversing townships in Maine with human densities exceeding 10 humans/km^2, we also expanded our definition of dispersal habitat for wolves to include cells with <10 humans/km^2 that were classified as forested or as a mosaic of agriculture and forest.

We used the range of wolf densities (1.0 to 4.0 wolves/100 km^2) recorded in the literature from
across North America (Ballard et al. 1987:25), eliminating high values from island populations, to estimate the likely range in wolf numbers that would occur in contiguous areas of potential core habitat within the northeastern U.S. We excluded potential core habitat occurring in Canada, regardless of its proximity to habitat within the U.S., when calculating the range of wolf population sizes that might be supported. We evaluated the viability of potential populations within contiguous areas by comparing the lower range of expected wolf density with the 1992 Eastern Timber Wolf Recovery Plan's (USFWS 1992) viability criteria of "an isolated eastern timber wolf population averaging at least one wolf per 129 km^2 distributed within a minimum area of at least 25,906 contiguous square kilometers" (i.e. 200 wolves).

RESULTS AND DISCUSSION

The shortest straight-line distance from potential core habitat in Maine to the nearest occupied wolf range in Quebec is approximately 70 km; the distance to the long-established wolf population in Laurentides Provincial Park is approximately 140 km. Further, the distance from potential core habitat in New York to occupied wolf range in southern Ontario is approximately 230 km. Thus, potential habitat for wolves in the northeastern U.S. is well within dispersal capability of extant wolf populations, if suitable dispersal corridors exist.

Substantial contiguous areas (Fig. 1) of forested habitat with road and human densities below the thresholds identified by Fuller et al. (1992) occur within Maine and New Hampshire (48,787 km^2; Table 1). These areas meet the criteria for defining potential core habitat, and exceed by 36% (Fig. 1) the habitat identified for future study (35,751 km^2) in the eastern timber wolf recovery plan (USFWS 1992). The recovery plan considered potential wolf habitat in northwestern and eastern Maine as discreet areas; however, our analysis suggests that potential habitat is contiguous throughout northern, western, and eastern Maine, and extends well into northern New Hampshire. Contiguous core habitat in Maine and New Hampshire could likely support a minimum of 488 wolves; these minimum estimates are 2.4 times higher than the minimum population viability criterion defined in the recovery plan (USFWS 1992).Viability of potential habitat in Maine and New Hampshire would be further enhanced by its connectivity with large areas (51,282 km^2) of currently unoccupied, but potentially suitable habitat in Quebec that occurs south of the St. Lawrence River (Fig. 1). Although our habitat assessment did not include New Brunswick, low human populations and extensive forest in the northern part of that province comprise additional suitable habitat that is contiguous with the potential habitat that we identified in Maine and Quebec.

The Adirondack Mountains region of northern New York also represents a large, contiguous area (14,618 km^2) of land meeting our criteria as potential core habitat for wolves (Table 1). Potentially suitable wolf habitat in northern New York, however, is apparently isolated from other suitable habitat (Fig. 1). Significant geographic barriers (e.g. St. Lawrence River, Lake Champlain), as well as expansive areas that do not meet our criteria of either core or dispersal habitat, may isolate potentially suitable areas in New York from extant populations in Canada and potential wolf populations in Maine and New Hampshire. New York would likely support a minimum of 146 wolves, but meets only 56% of the area requirements to maintain long-term viability of an isolated wolf population, according to the criteria established by USFWS (1992). New York state lacks a significant moose *(Alces alces)* population, thus potential population densities of wolves there may be lower than in other regions of eastern North America where sympatric populations of moose, white-tailed deer *(Odocoileus virginianus)* and beaver *(Castor canadensis)* occur.

Figure 1. Distribution of occupied and potential habitat for eastern timber wolves in northeastern North America.

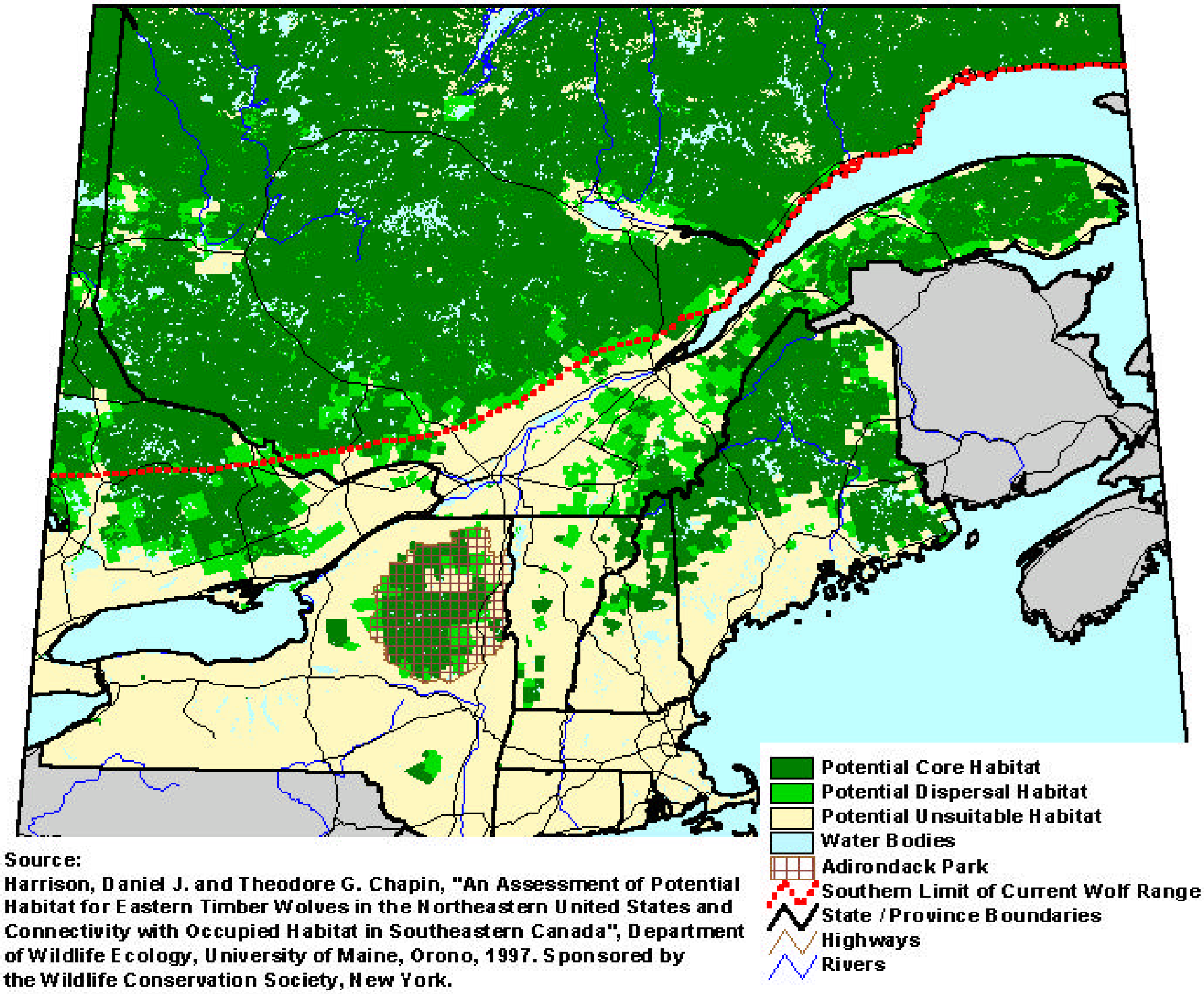

Table 1. Estimated potential habitat (km^2) for wolves in 7 Northeastern states.

Region	Habitat (km^2) Core[1]	Dispersal[2]	Total
Maine	44,196	4,589	48,785
New York[3]	14,618	5,453	20,071
New Hampshire	4,591	1,222	5,813
Vermont	2,470	1,430	3,900
Massachusetts	51	103	154
Connecticut	0	0	0
Rhode Island	0	0	0
All States[4]	65,926	12,797	78,723
Corridor[5]	27,427	30,781	58,208

[1]Total number of 1-km^2 Cells with forested land cover occurring within minor civil divisions with $<$ 4 human residents/km^2, and $<$ 0.7 km of roads/km^2 passable by 2-wheel drive vehicles. Road density criteria were not considered when evaluating corridors in southeastern Canada.

[2]Total number of 1-km^2 cells with land cover comprised of forest occurring in minor civil divisions with $\geq$ 4 and $<$ 10 human residents/km^2 and $<$ 0. 7 km of roads/km^2 passable by 2-wheel-drive vehicles, or cells with land cover of woodland/cropland mosaic occurring in minor civil divisions with $<$ 10 human residents/km^2 and $<$ 0. 7 km of roads/km^2 passable by 2-wheel-drive vehicles. Road density criteria were not considered when evaluating corridors in southeastern Canada.

[3]Excludes small ($<$ 1,000 km^2) patches of habitat in western and southeastern New York that are located $>$ 50 km from large ($>$ 5,000 km^2) contiguous patches.

[4]Includes the total habitat present in Maine, New York, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island.

[5]Includes the habitat present in portions of Ontario and Quebec south of occupied wolf range and directly north of the states of Maine, New Hampshire, Vermont, and New York. Excludes habitat in eastern Canada that occurs within the Gaspe' peninsula and New Brunswick.

The north-south orientation of Lake Champlain and Lake George, coupled with limited (Table 1) and widely scattered potential core (2,470 km^2) and dispersal (1,430 km^2) habitat, suggest that Vermont may neither support significant numbers of resident wolves, nor serve as an effective dispersal corridor linking a potential future wolf population in Maine and New Hampshire with a potential population in New York (Fig. 1). Potential core and dispersal habitat for wolves in Massachusetts, Connecticut, and Rhode Island is either absent (Table 1), or too isolated (Fig. 1) to contribute significantly to restoration or recolonization potential for the eastern timber wolf

Two potential corridors may link wolf populations occurring north of the St. Lawrence River in Quebec with potential habitat in Maine and New Hampshire. One corridor occurs upstream from Quebec City (Fig. 1) in an area where occasional, intermittent ice cover may provide wolves opportunities to cross the St. Lawrence River (M. Manseau, Univ. Laval, Quebec City, personal communication). Another potential corridor occurs near the mouth of the St. Lawrence River, downstream from Quebec City, where home ranges of radio collared wolves occur just north of the river, and where other mammals (e.g., white-tailed deer) have been observed to successfully cross the river (M. Manseau, Univ. Laval, Quebec City, personal communication). It is conceivable that a verified wolf and a second large wolf-like canid recently killed in Maine might have resulted from natural emigration from the Laurentides region of Quebec.

Our analyses are based on thresholds of road and human densities established for long established wolf populations in Minnesota (Fuller et al. 1992). More recently, however, Mladenoff et al. (1995) evaluated landscape characteristics associated with occupancy of habitat by recently reestablished populations of wolves in Wisconsin. In Wisconsin, road density within territories of occupied wolf packs averaged only 0.23 km/km^2, and few portions of pack territories included areas where roads densities exceeded 0.45 km/km^2. Further, human densities within the areas occupied by wolf packs averaged only 1.52 $humans/km^2$, compared to an average of 5.16 $humans/km^2$ within nonpack areas. Because territory space is not saturated in Wisconsin (Mladenoff et al. 1995), patterns of habitat occupancy by expanding wolf populations there may not indicate the full range of road and human densities compatible with viable populations of wolves in the eastern U.S. However, the landscape variables associated with occupancy by wolves in Wisconsin would be useful in predicting a likely sequence of habitat occupancy, if wolves were to recolonize

Maine or New York.

CONCLUSIONS AND RECOMMENDATIONS

Wildlife biologists interested in the potential for reestablishing wolves in the northeastern U.S. could benefit from collaboration and exchange of information with scientists conducting ongoing research on wolves in southern Quebec. Information on population density and movement patterns of wolves in southern Quebec may provide information useful for estimating potential numbers of wolves that might disperse to Maine and New Hampshire. Further, the permeability of the St. Lawrence River as a filter to dispersal needs to be better documented to evaluate the potential for natural recolonization of wolves to Maine and New Hampshire. Some dispersing coyotes in Maine successfully crossed a large river (Harrison 1992), and one dispersing juvenile swam to a coastal island (S. Glass and D. Harrison, Univ. Maine, unpublished data), suggesting that the St. Lawrence River may serve as a filter rather than a barrier to wolf dispersal. However, the maintenance of a very active shipping channel and the unconsolidated nature of ice in the St. Lawrence River during most of the winter, coupled with the presence of dense human development and 4-lane highways parallel to the river, may preclude successful dispersal of a significant number of wolves from Quebec to Maine and New Hampshire.

Given the relative isolation of potential wolf habitat in New York, natural recolonization of potential habitat is unlikely. Further, the success of potential reintroduction efforts for wolves in the Adirondack region of New York would be uncertain because the estimated suitable habitat is less than the area officially considered to be required to sustain an isolated population of wolves (USFWS 1992).

If numbers of dispersing wolves moving from extant populations to potential habitat are insufficient to provide opportunities for dispersers to pair with conspecifics of the opposite sex, then substantial hybridization between dispersing wolves and resident coyotes may occur. Roy et al. (1994) present compelling genetic evidence suggesting that substantial hybridization occurs between coyotes and wolves along the southern edge of wolf range in southeastern Canada. Thus, strategies promoting slow natural recolonization of wolves to the northeastern U.S. should consider potential genetic consequences of hybridization with coyotes.

Although large contiguous areas in Maine and New Hampshire meet the criteria established in the eastern timber wolf recovery plan (USFWS 1992) to define potentially suitable habitat, information on public attitudes towards wolves in the northeastern U.S. are anecdotal. Our habitat criteria are based on factors that influence the extent of human contact with wolves, and presumably, the potential for humaninduced mortality of wolves (Fuller et al.

1992). Thus, our analyses assume that human attitudes towards wolves in the northeastern U.S. are similar to attitudes of humans towards wolves in the Lake Superior basin. Wolves are not intolerant of humans; however, some humans are intolerant wolves. For example, wolves persist despite high human populations in some regions of Europe and Asia where human attitudes and cultures differ significantly from the U.S. (McNamee 1997). Thus, prior to establishing specific management objectives for wolf restoration, significant public education (Mech 1995) and involvement would be required.

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