DISTRIBUTION AND ABUNDANCE OF WOLVES IN MINNESOTA, 2007-08

John Erb, Minnesota Department of Natural Resources

At the time wolves were federally protected in the mid-1970's, Minnesota contained the only known reproducing wolf population in the lower 48 states, except for that on Isle Royale. Over the years, much attention has been focused on studying and monitoring Minnesota's wolves. Research efforts began in the mid-1930's (Olson 1938), and with few lapses, continue to this day. Efforts to delineate wolf distribution and enumerate populations have also been made at various times over the last 50 years (see Minnesota Department of Natural Resources 2001, Erb and Benson 2004).

Early estimates of Minnesota's wolf population, often derived from bounty records and anecdotal information, were by necessity more subjective. With the advent of radio-telemetry, geographic information systems (GIS), and global positioning systems (GPS), more detailed monitoring and mapping of wolf populations has been possible. However, financial and logistical considerations often limit intensive monitoring to small study areas. Enumerating elusive carnivore populations over large areas, particularly in forested habitats, remains a difficult task. In such situations, radio-marking all (or most) packs or using mark-recapture methods is usually not possible. Other approaches have been employed for predicting/estimating abundance of large carnivores. Approaches based on prey or habitat assessments (Fuller 1989, Boyce and Waller 2003) may be useful for estimating potential abundance of large carnivores, but may not always match realized abundance due to other time-varying factors (e.g., disease, weather). Newer aerial sampling methods (Becker et al. 1998, Patterson et al. 2004) show promise, but may be logistically challenging when applied to broad expanses of dense forest. Further evaluation is needed, including a cost-benefit analysis.

Since the late 1970's, Minnesota has monitored its statewide wolf population using an *ad hoc* approach that combines several sources of data. Methods have changed only slightly during this time. Previous surveys have taken place at 10-year intervals, more recently at 5-year intervals (1978-79, 1988-89, 1997-98, 2003-04). Results indicated a geographically and numerically expanding population through the 1997-98 survey, with little geographic expansion since 1998 (Berg and Kuehn 1982, Fuller et al. 1992, Berg and Benson 1998, Erb and Benson 2004). These results are generally consistent with separate population trend indicators (annual scent station survey, winter track survey, and number of verified depredations) utilized in Minnesota.

In 2007, wolves in the Great Lakes Distinct Population Segment were removed as a listed species under the federal Endangered Species Act. Hence, the periodic survey of Minnesota's wolf population was moved up 1 year from it's originally scheduled date (2008-09), consistent with plans outlined in the Minnesota wolf management plan (Minnesota Department of Natural Resources 2001). This report summarizes the results of the 2007-08 survey.

METHODS

The approach I used to delineate wolf distribution and estimate population size was essentially identical to the previous 3 surveys (Fuller et al. 1992, Berg and Benson 1998, Erb and Benson 2004), and conceptually similar to the 1978-79 survey (Berg and Kuehn 1982). I mailed instructions, data forms, and maps to natural resource agencies and consultants in early October 2007. Cooperators were similar to previous surveys, and included: 1) all MN DNR disciplines; 2) U.S. Forest Service; 3) U.S. Fish and Wildlife Service; 4) USDA-Wildlife Services; 5) U.S. Geological Survey; 6) Tribal and Treaty resource authorities; 7) County Land Departments; 8) Camp Ripley Military Reservation; 9) Voyageurs National Park; 10) University field projects; and 11) biological staff at forest product companies.

I asked participants to record a location and group size estimate for all wolf sign (visual, track, scat) observed during the course of normal work duties from October 2007 through April 2008. While these group size estimates are not used in any calculations, the assessment of township-specific wolf occupancy, as discussed below, treats observations of single wolves differently than pack (> 1 wolf) observations. I conservatively assumed group size to be 1 in situations where sign was recorded but no group size data was noted. If group size was recorded as 'numerous', it was set to 2 (i.e., a pack). I then combined this database with wolf observations recorded on the 2007 DNR scent station survey, the 2007-08 DNR furbearer winter track survey, and locations of USDA verified wolf depredations in 2007. This database is hereafter referred to as 'WISUR 08'.

As in previous surveys, I used the township (~ 93 km^2) as the spatial scale for classifying wolf observations. Delineation of both total range and occupied range includes, but is not limited to, consideration of whether townships meet human and road density criteria outlined by Fuller et al. 1992 (i.e., townships within wolf range are presumed to be occupied by wolves if road density is < 0.7 km/km^2 and human density is < $4/km^2$, <u>or</u> if road density is < 0.5 km/km^2 and human density is < $8/km^2$; hereafter termed 'modeled' townships). As in previous surveys, human density was calculated using the most recent (i.e., 2000) U.S. Census Data as incorporated into the 2000 Minor Civil Divisions GIS layer produced by the Minnesota Legislative Coordinating Commission. Surface water is subtracted out from this layer using the Minnesota DNR 1:100,000 Lakes and Rivers GIS data, and human density is calculated, by township, as the number of people per square kilometer of land. Road density calculations are based on the Minnesota Department of Transportation's 1:24,000 roads layer and summarized within each township as the number of kilometers of road per km^2 of land.

Delineation of total wolf range is intended to reflect the coarse distribution of wolves within the state, thereby documenting larger-scale expansions or contractions of wolf range. Although wolf range has expanded south and west since the 1970's, it has remained essentially contiguous, with the Canadian border to the north and Lake Superior and Wisconsin to the east. Because systematic searches for wolf sign are not conducted, there is some subjectivity in the approach used to delineate the south and west boundary. Using the previously delineated boundary as the reference point, the south and west border was evaluated based on the following data: 1) all WISUR '08 observations; 2) modeled townships; and 3) forest cover. While maintaining a contiguous total wolf range, the overall approach is designed to maximize inclusion of wolf pack observations and modeled townships, while minimizing inclusion of areas that neither fit the model nor contained wolf observations.

I computed occupied range by subtracting from the total range all townships that neither contained observations of a pack (defined as >1 animal) nor fit model criteria. I also excluded the interior portions of lakes larger than 200 km^2 (n=3) from calculations of both total and occupied range. Because wolves commonly travel on lakes in winter, I included outer portions of these larger lakes immediately adjacent to the shoreline if the township bordering the lake was occupied and the township boundary extended into lake perimeters.

As in previous surveys, I estimated population size by combining estimates of occupied range, average territory and winter pack size as computed from ongoing telemetry studies, and published estimates of interstitial spaces between packs and the percent lone wolves in the population. Specifically,

N = ((km^2 of occupied range/(mean pack territory size*1.37))*mean pack size)/0.85.

Territories were delineated using minimum convex polygons, and average territory size was increased 37% to account for spaces between packs (Fuller et al. 1992:51). The total number of pack wolves is divided by 0.85 to account for an estimated 15% lone wolves in the population (Fuller et al. 1992:46). Using the accelerated bias-corrected percentile method (Manly 1997), the population size confidence interval (90%) was generated from 1000 bootstrapped re-samples of the pack and territory size data, and does not incorporate uncertainty in estimates of occupied range, percent lone wolves, or size of interstitial spaces.

In addition to the survey outlined above, a questionnaire was mailed to most survey participants asking them to provide an informal assessment of the status and trend of wolf populations in their respective management areas. While this data was not quantitatively incorporated into the estimates of wolf abundance or distribution, it does provide an overview of the perceptions of field personnel in Minnesota's wolf range. Identical surveys were conducted in each of the previous wolf population assessments conducted in Minnesota.

RESULTS

Wolf location data was received from 128 field stations, compared to 102, 179 and 154 in 2003-04, 1997-98 and 1988-89, respectively (Table 1). A total of 2,710 opportunistic wolf sign observations were recorded during the 2007-08 survey (Fig. 1), a 58% increase compared to 2003-04, but less than the maximum previously recorded (3,659) in 1997-98. Observations consisted of 74% tracks, 16% visuals, 7% scat, and 3% other (howls, deer kills, etc).

I obtained territory and winter pack size data from 32 radio-marked wolf packs. Packs were located in northeast MN (n=20), north-central MN (n=5), northwest MN (n=3), central MN (n=2), and east-central MN (n=2) (Fig. 2). These packs contained an estimated 158 wolves and territories encompassed approximately 5% of occupied wolf range. A broad-scale land cover comparison indicates that there was a greater proportion of forest cover (64% vs 54%) and a smaller proportion of grassland/cultivated/brushland (4% vs 13%) in radio-marked pack territories compared to overall occupied range. This likely reflects a tendency to radio-collar packs on public land with more contiguous forest cover. Deer density estimates are not available at the scale of wolf pack territories. However, if I apply spring density estimates from the larger deer permit areas (Fig. 2) within which the wolf territories were located, and weight by the number of radio-marked wolf packs within the permit area, average spring deer density in radio-marked pack territories was ~ 12 deer/mi^2. In comparison, spring deer density for the entire forest zone of Minnesota, a close approximation of wolf range, was ~ 17 deer/mi^2 in spring 2008. The lower deer density in marked pack territories is primarily a result of 8 packs located in deer permit area 116, an area largely within the Boundary Waters Canoe Area Wilderness where deer occur at low density, but where moose are relatively common.

Average territory size ('uncorrected' for interstitial spaces) for radio-marked packs was ~104 km^2, nearly identical to results from the 2003-04 survey (102 km^2). In comparison, average 'unadjusted' territory size in 1997-98 and 1988-89 was 140 km^2 and 166 km^2, respectively (Table 1). While average pack size did not change significantly from previous surveys (5.3 – 5.6; Table 1), it did drop below 5 (4.9) for the first time since surveys began.

Distribution

I evaluated potential shifts in total wolf range by comparing current information (WISUR '08 observations, modeled townships, and forest cover) to the wolf range boundary from the previous survey. While the total number of wolf observations increased from 2003-04, the broad distribution of observations and modeled townships remained similar to the previous 2 surveys. Packs were observed within close proximity to most portions of the southwest boundary delineated in 1997-98 (and deemed adequate in 2003-04), with only 20 observations (12 pack and 8 'singles'), < 1% of the total, falling outside the previously delineated range. Slight variations in the boundary line could be debated, both in the 2003-04 and current survey. However, there is no clear indication that there has been a notable shift in total wolf range, and numerous variations in this boundary line had negligible impact on the estimate of occupied range or population size. Hence, I concluded that total wolf range in Minnesota has remained essentially unchanged (88,325 km^2) since the 1997-98 survey (Fig. 1).

After subtracting out townships that neither met model criteria nor contained pack observations, estimated occupied range was 71,514 km^2 (Fig. 1), 5% larger than in 2003-04, but 3% smaller than in 1997-98 (Table 1). Occupied range included 558 townships (48,656 km^2) known to contain packs, and 282 townships (22,858 km^2) presumed to contain packs because of low human and road density (i.e., modeled townships). Of all the townships in wolf range that contained pack observations, 20% had higher human and/or road density than the thresholds in the road-human density model previously developed. The same percentages from the 1988-89, 1997-98, and 2003-04 surveys were 11% and 17%, and 21%, respectively (Table 1).

Wolf Numbers

Dividing estimated occupied range (71,514 km^2) by average territory size (~104 km^2 X 1.37 ≈ 142 km^2) gives an estimate of 503 wolf packs in Minnesota, 4% more than 2003-04 and 26% more than in 1997-98. Multiplying by average pack size (~4.9) and accounting for an estimated 15% lone wolves provides a population point estimate of 2,921 wolves, or 4.1 wolves per 100 km^2 of occupied range. The 90% confidence interval ranges from 2,192 wolves to 3,525 wolves.

Questionnaire Responses

A total of 71 responses were collected in the 2007-08 survey. Considering only the actual office location, 59 were from within the area delineated as total wolf range. For those who responded to the question of local population trend since the last survey, increasing, stable, and decreasing wolf numbers were reported by 40, 58, and 2% of these respondents, respectively (Fig. 3). Compared to the previous survey (40, 42, and 18%, respectively), a higher proportion of respondents perceived the local population to be stable, while fewer perceived a decline. There was no clear geographic pattern to perceptions, and perceptions often varied within nearby areas (Fig. 3).

DISCUSSION

Although total wolf range had increased over a period of 20 years, the last 2 wolf surveys indicate that the broad distribution of wolves in Minnesota has not changed since the mid to late 1990's. While the duration between surveys has recently been shortened from 10 years to 5 years, recent surveys nevertheless indicate that coarse-scale wolf distribution in Minnesota is now static.

Within total wolf range, the estimate of occupied range increased 5% from 2003-04, but was 3% less than results from 1997-98. While I can't rule out sampling variation as the cause of the slight changes in occupied range, these fluctuations are consistent with natural fluctuations that many wildlife populations undergo as a result of changes in annual survival or reproductive success. Since 1998, when total wolf range appears to have stabilized, there has been no consistent increasing or decreasing trend in the amount of occupied range.

Because 32% of the townships were deemed occupied based on 'low' human/road density alone (i.e., not pack detections), it remains possible that occupied range could be overestimated. However, in a majority of cases, a lack of pack detections likely reflects a lack of sampling effort rather than a lack of wolves. Some wolves occupy remote areas (e.g., the BWCAW) and are unlikely to be opportunistically detected, and notable amounts of private land, particularly in the southern and western portion of the range, are also unlikely to be opportunistically surveyed. Stated differently, pack detection probability is undoubtedly less than 1 in most areas. Finally, while prey- or habitat-based models have some potential to overestimate occupancy at any given time, the 1988-89 human/road density model (Fuller et al. 1992) incorporated here has generally been a conservative descriptor of wolf 'habitat' in Minnesota. The percentage of townships containing pack observations but not conforming to the 1988-89 road-human density model was 11% in 1988-89, 17% in 1997-98, 21% in 2003-04, and 20% in the current survey.

Average mid-winter pack size as estimated from currently radio-marked packs was 4.9, below results from the previous 3 wolf surveys (5.55, 5.4, 5.3). Fuller et al. (2003) estimated the average reported pack size for wolf populations preying primarily on deer to be 5.66. While Minnesota's forest deer population is significantly higher today than in the late 1970's when wolf surveys were initiated, average mid-winter pack size, as summarized during each wolf survey, has not changed substantially during this time. This is not surprising given the low correlation between average pack size and prey biomass (Fuller et al. 2003). Nevertheless, average pack size does appear to have slightly declined through time. While the deer population has not undergone a steady decline during this same period, the spring 2008 forest deer population is estimated to be 11% lower than 4 years ago during the last wolf survey (Lenarz 2008). It remains unclear whether other prey-independent changes in recruitment or survival may be causing slight declines in average pack size.

Average territory size was essentially identical during the last 2 wolf surveys. While numerous factors can influence territory size, we believe 2 have been particularly important over the course of past wolf surveys. First, wolf populations (or portions thereof) that compose a significant number of colonizing packs have been shown to exhibit declines in average pack territory size as the population becomes more established (Fritts and Mech 1981, Hayes and Harestad 2000). Successive wolf surveys in Minnesota documented a geographically expanding population until ~ 1998. During this time, average territory size estimates compiled from radio-marked packs declined from 166 km^2 to 140 km^2, likely due in part to space-use competition in an increasingly saturated wolf range. Furthermore, territory size is negatively correlated with prey density (Mech and Boitani 2003, Fuller et al. 2003). Deer density increased notably during the first 20 years of wolf recovery, allowing wolf packs to persist in smaller territories. Had it not been for the severe winters of 1995 and 1996, which caused a significant decline in deer numbers just prior to the 1997-98 wolf survey, we suspect average territory size in 1997-98 (140 km^2) would have been similar to the most recent 2 surveys (~ 103 km^2). For approximately the past 9 years, broad-scale wolf distribution and deer density have not undergone systematic changes, likely explaining the lack of change in average territory size.

Comparison of results for total wolf range, occupied range, and population size over the past 3 surveys (10 years) suggests that the wolf population has been, on average, geographically and numerically stable. Total range has remained essentially unchanged, occupied range has fluctuated only slightly (+/- 5-8%), and population estimates have ranged between ~ 2,500 and 3,000 with all 3 confidence intervals overlapping. The current estimate of 2,921 wolves occupying 71,514 km^2, equivalent to 4.1 wolves per 100 km^2, is near the theoretical upper density threshold previously proposed by Pimlott (1967), and with a few localized exceptions (e.g., Van Ballenberghe et al. 1975, Peterson and Page 1988, Fuller 1989), is near the upper end of previously recorded densities in North America (Fuller et al. 2003).

ACKNOWLEDGEMENTS

I thank Sherry Buckley for entering WISUR '08 data, Laura Gilbert for assistance with survey mailings, and Steve Benson for helpful discussions on previous surveys. I also thank Dan Stark and Mark Lenarz for comments on previous drafts, and John Fieberg for statistical advice. Barry Sampson, Carolin Humpal, and staff with USDA-Wildlife Services conducted wolf trapping and radio-collaring activities on behalf of the Minnesota DNR. Finally, I thank Dave Mech and Mike Nelson (USGS), Brian Dirks (Camp Ripley), Adrian Wydeven and Jane Wiedenhoeft (Wisconsin DNR), and Angela Aarhus (1854 Treaty Authority) for providing data from radio-marked packs, and all those who provided wolf observations during the winter survey.

LITERATURE CITED

Becker, E. F., M. A. Spindler, and T. O. Osborne. 1998. A population estimator based on network sampling of tracks in the snow. Journal of Wildlife Management 62:968-977.

Berg, W., and S. Benson. 1998. Updated wolf population estimate for Minnesota, 1997-98. Pages 85 – 98 *in* B. Joselyn, editor, Summaries of wildlife research findings, 1998. Minnesota Department of Natural Resources, St. Paul.

Berg, W. E., and D. W. Kuehn. 1982. Ecology of wolves in north-central Minnesota. Pages 4-11 *in* F. H. Harrington and P. D. Paquet, editors. Wolves: a worldwide perspective of their behavior, ecology, and conservation. Noyes Publishing, Park Ridge, New Jersey.

Boyce, M. S. and J. S. Waller. 2003. Grizzly bears for the Bitterroot: predicting potential distribution and abundance. Wildlife Society Bulletin 31:670-683.

Erb, J., and S. Benson. 2004. Distribution and abundance of wolves in Minnesota, 2003-04. Minnesota Department of Natural Resources, St. Paul.

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

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.

Fuller, T. K., L. D. Mech, and J. F. Cochrane. 2003. Wolf population dynamics. Pages 161-191 *in* L. D. Mech and L. Boitani, editors. Wolves: behavior, ecology, and conservation. University of Chicago Press, Chicago, Illinois.

Hayes, R. D., and A. S. Harestad. 2000. Demography of a recovering wolf population in the Yukon. Canadian Journal of Zoology 78:36-48.

Lenarz, M. S. 2008. Population trends of white-tailed deer in the forest zone – 2008. Minnesota Department of Natural Resources, St. Paul.

Manly, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Chapman and Hall, London.

Mech, L. D. and L. Boitani. 2003. Wolf social ecology. Pages 1-34 *in* L. D. Mech and L. Boitani, editors. Wolves: behavior, ecology, and conservation. University of Chicago Press, Chicago, Illinois.

Minnesota Department of Natural Resources. 2001. Minnesota wolf management plan. Minnesota Department of Natural Resources, St. Paul.

Olson, S. F. 1938. A study in predatory relationship with particular reference to the wolf. Scientific Monthly 46:323-336.

Patterson, B. R., N. W. S. Quinn, E. F. Becker, and D. B.Meier. *In Press*. Estimating wolf densities in forested areas using network sampling of tracks in snow. Wildlife Society Bulletin.

Peterson, R.O., and R.E. Page. 1988. The rise and fall of the Isle Royale wolves. Journal of Mammalogy 69:89-99.

Van Ballenberghe, V., A.W. Erickson, and D. Byman. 1975. Ecology of the timber wolf in northeastern Minnesota. Wildlife Monographs 43:1-43.

Table 1. Comparison of results for the past 4 wolf surveys in Minnesota.

	1988/89 Winter Survey (Fuller et al. 1992)	1997/98 Winter Survey (Berg and Benson 1998)	2003/04 Winter Survey (Erb and Benson 2004)	2007/08 Winter Survey (Erb 2008)
Observation Sources	Winter observations, scent station survey, USDA-verified depredations, radio-marked pack territories	Winter observations, scent station survey, carnivore winter track survey, USDA-verified depredations, radio-marked pack territories	Winter observations, scent station survey, carnivore winter track survey, USDA-verified depredations, radio-marked pack territories	Winter observations, scent station survey, carnivore winter track survey, USDA-verified depredations, radio-marked pack territories
# field offices that provided sightings	154	179	102	128
Total # observations	1,244	3,659	1,719	2,710
% of townships with pack detection that exceed the human/road density thresholds [a]	11	17	21	20
Total Wolf Range (km^2)	60,229	88,325	88,325	88,325
Occupied Range (km^2)	53,100	73,920	67,852	71,514
% Occupied Range confirmed by pack detection in township	55	84	54	68
# Radio-Marked Packs	108[b]	36	24	32
Average mid-winter pack size	5.55	5.4	5.3	4.9
Average Territory Size [c] (km^2)	166	140	102	104
Estimated # packs	233	385	485	503
Population Estimate (90% CI)	1,521 (1,338, 1,762)	2,445 (1,995, 2,905)	3,020 (2,301, 3,708)	2,921 (2,192, 3,525)
Questionnaire: % respondents that perceive that the local wolf population **(increased, stable, decreased)** since last survey		(71, 29, 0)	(40, 42, 18)	(40, 58, 2)

[a] thresholds from Fuller et al. (1992)
[b] included packs marked in years prior to the survey
[c] unadjusted for interstitial spaces

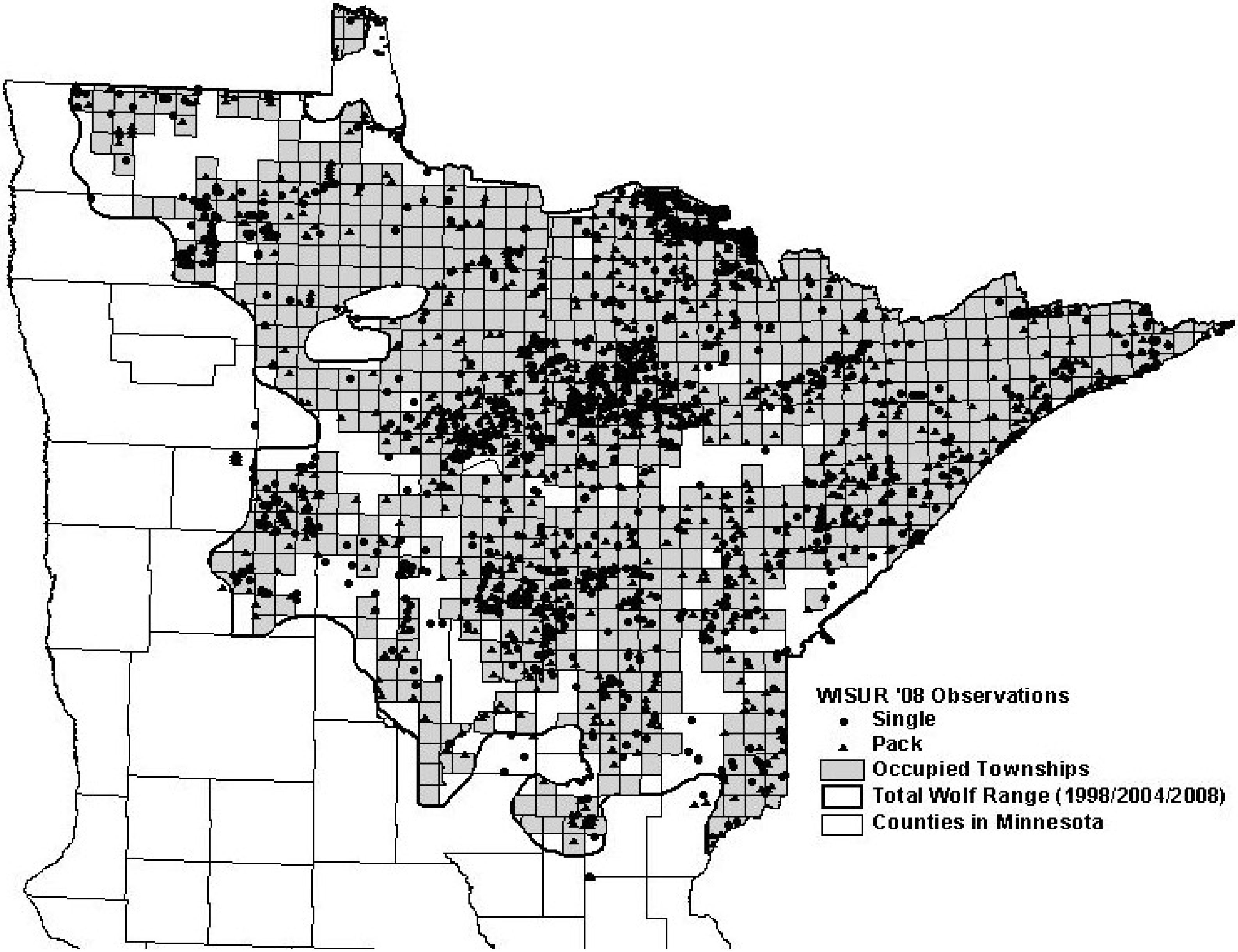

Figure 1. Wolf sign observations and occupied townships delineated as part of the 2007-08 wolf survey.

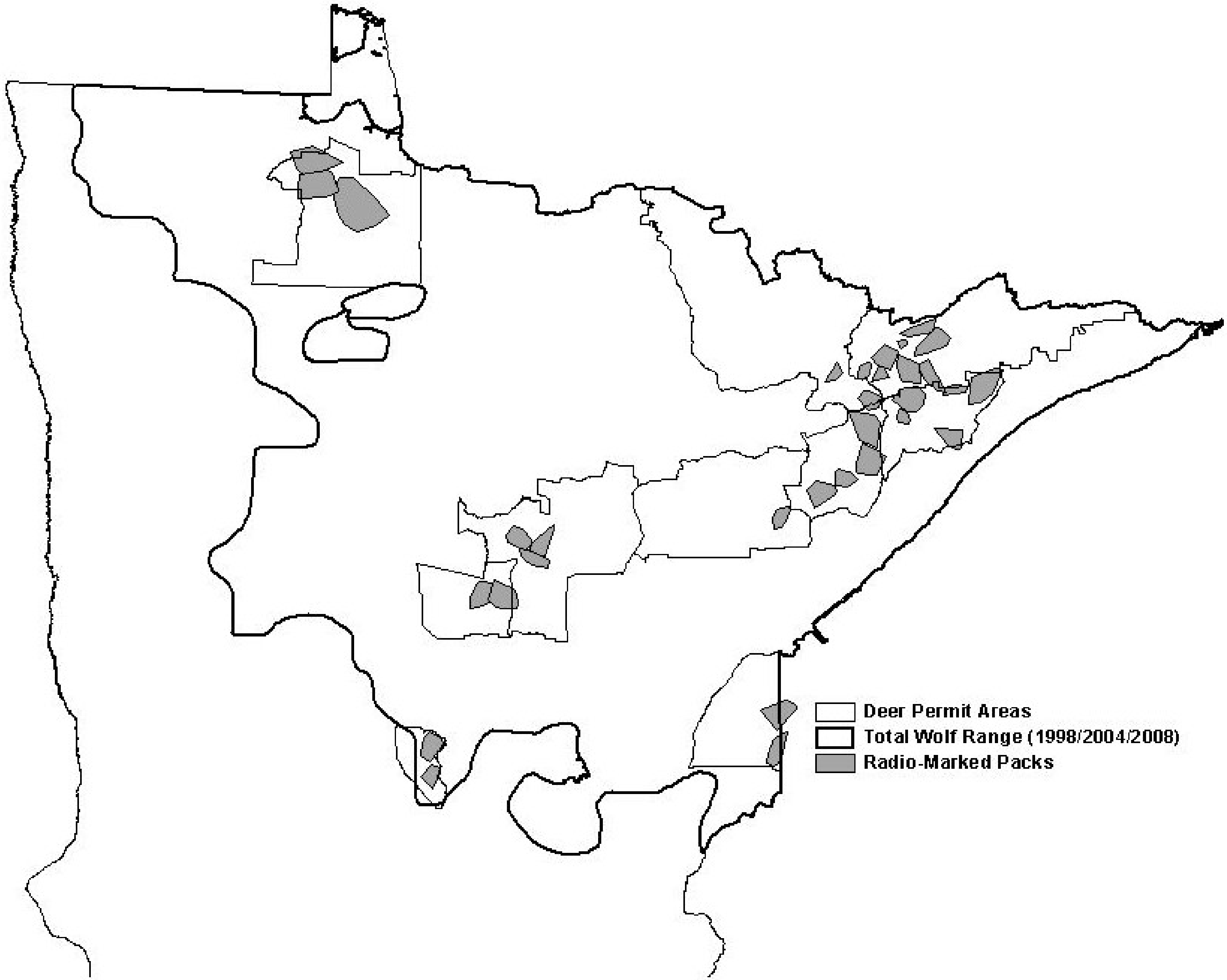

Figure 2. Location of radio-marked wolf packs and corresponding deer permit areas within which the packs were located.

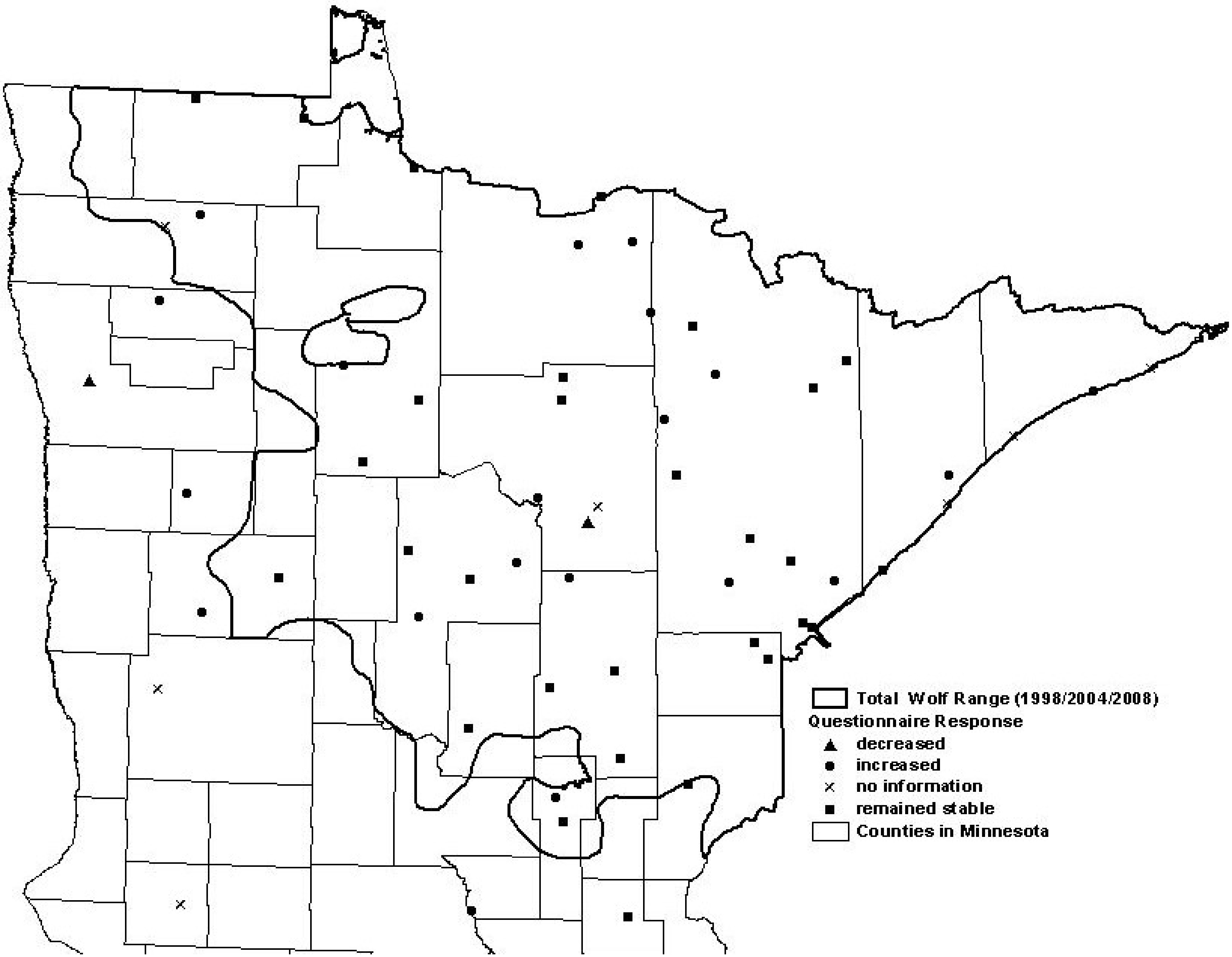

Figure 3. Winter 2007-08 wolf population trend questionnaire results for respondents near primary wolf range.