DISTRIBUTION AND ABUNDANCE OF WOLVES IN MINNESOTA, 2003-04

John Erb and Steve Benson

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).

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 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 (Table 1). Previous surveys have taken place at 10-year intervals (1978-79, 1988-89, 1997-98) and have shown an expanding population (Berg and Kuehn 1982, Fuller et al. 1992, Berg and Benson 1998). These results are consistent with separate population trend indicators (annual scent station survey, winter track survey, and number of verified depredations) utilized in Minnesota.

Wolf populations in the western Great Lakes have exceeded federal recovery goals for numerous years. In anticipation of a federal delisting proposal in 2004, we opted to conduct another comprehensive wolf population and distribution survey during winter 2003-04. This deviates from our previous 10-year interval for conducting such surveys, but is consistent with action items outlined in our Wolf Management Plan (Minnesota Department of Natural Resources 2001). This report summarizes the results of the 2003-04 survey.

METHODS

The approach we used to delineate wolf distribution and estimate population size was identical to the 1997-98 survey, and similar to the 1978-79 and 1988-89 surveys (Table 1). We mailed instructions, data forms, and maps to natural resource agencies and consultants in early October 2003. Cooperators were essentially identical to the 1997 survey, 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; 9) Voyageurs National Park; and 10) Forest products industries and forestry consultants.

We 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 2003 through April 2004. In situations where sign was recorded, but no group size data was noted, we assumed group size to be 1. If group size was recorded as 'numerous', it was set to 2. We then combined this database with wolf observations recorded on the 2003 DNR scent station survey, the 2003-04 DNR furbearer winter track survey, and locations of USDA verified wolf depredations in 2003. This database is hereafter referred to as 'WISUR 04'.

As in previous surveys, we used the township (~ 93 km^2) as the basis 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 are deemed suitable for wolves if road density is < 0.7 km/km^2 and human density is $< 4/km^2$, <u>or</u> road density is < 0.5 km/km^2 and human density is $< 8/km^2$; hereafter termed 'modeled' townships). As in the previous 2 surveys, we calculated human density using the most recent U.S. Census Data, in this case 2000, as incorporated into the 2000 Minor Civil Divisions GIS layer produced by the Minnesota Legislative Coordinating Commission. We removed surface water from this layer using the Minnesota DNR 1:100,000 Lakes and Rivers GIS data, and calculated human density, by township, as the number of people per square kilometer of land. We calculated road density using the Minnesota Department of Transportation's 1:24,000 roads layer. Roads were intersected with townships, and the total length of roads (km/km^2) was summarized by township.

We loosely defined total wolf range in Minnesota as that area within which there is a reasonable probability of detecting wolf sign. Total wolf range in Minnesota is generally contiguous, with the Canada border to the north and Lake Superior and Wisconsin to the east. We delineated the south and west boundaries by considering the following data: 1) all WISUR '04 observations, particularly those of packs; 2) modeled townships; and 3) land cover. Because systematic searches for sign were not conducted, there is, by necessity, some subjectivity in the positioning of the south and west boundary. While maintaining a contiguous total wolf range, we drew the southwest boundary line to maximize inclusion of wolf pack observations and modeled townships, while minimizing inclusion of areas that neither fit the model nor contained wolf observations.

We computed occupied range by subtracting from the total range all townships that neither contained observations of packs (defined as >1 animal) nor fit model criteria. We 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, we included peripheral portions of these large lakes if the 'edge' township was occupied and extended into lake perimeters.

As in previous surveys, we 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 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). We divided the total number of pack wolves 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 were received from 102 field stations, compared to 179 and 154 in 1997-98 and 1988-89, respectively. A total of 1,719 wolf sign observations were recorded during 2003-04 (Fig. 1), a 53% decline compared to 1997-98, but 38% more than in 1988-89. Observations consisted of 83% tracks, 10% visuals, 5% scat, and 2% other. WISUR '04 observations consisted of 48% single wolves and 52% packs, similar to previous surveys (41% and 59% in 1997-98, and 44% and 56% in 1988-89).

We obtained territory and winter pack size data from 24 radio-marked wolf packs, 12 less than available in 1997-98 due to fewer current studies. Packs were located in northeast MN (n=14), north-central MN (n=7), central MN (n=2), and east-central MN (n=1) (Fig. 2). These packs contained an estimated 127 wolves and territories encompassed approximately 4% of occupied wolf range. A broad-scale land cover comparison indicates that the proportion of cover types in radio-marked pack territories was nearly identical to the distribution for all wolf locations from the winter survey. Comparison of territories with the total area of occupied range shows a slight (~ 12%) shift between the proportion of forest and bog, with slightly more forest and less bog in territories compared to total occupied range. Deer density estimates are not available at the scale of wolf pack territories. However, if we apply spring density estimates from the larger deer permit areas (see 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 wolf territories was ~ 12 deer/mi^2. In comparison, spring deer density for the entire forest zone of Minnesota was ~ 15 deer/mi^2 in 2004.

Average territory size ('uncorrected' for interstitial spaces) was ~102 km^2 (range = 29 to 275 km^2). In comparison, average 'uncorrected' territory size in 1997-98 was 37% larger (140 km^2). Average winter pack size as estimated from marked packs was ~5.3 (range = 2 – 10), similar to summaries from the 1997-98 survey (5.4) and 1988-89 survey (5.55).

Distribution

We delineated total wolf range using WISUR '04 observations, modeled townships, and land cover information. While the total number of wolf observations declined, the broad distribution of observations and modeled townships remained nearly identical to the 1997-98 survey. Packs were observed within close proximity to most portions of southwest boundary delineated in 1997-98, with only 12 observations (< 1% of the total; 8 singles, 4 packs) falling outside the 1997-98 range. Slight variations in the boundary line could be debated, both in 1998 and the present. However, there is no clear indication that there has been a notable shift in total distribution, and numerous variations in this boundary line had little impact on the estimate of occupied range or population size. Hence, we concluded that total wolf range in Minnesota has remained unchanged (88,325 km^2) since the last survey (Fig. 1).

After subtracting out townships that neither met model criteria nor contained pack observations, estimated occupied range was 67,852 km^2 (Fig. 1), or 8% less than in 1997-98. Occupied range included 424 townships (36,447 km^2) known to contain packs, and 402 townships (31,405 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, 21% had higher human and/or road density than 'allowed' in the 1988-89 road-human density model. The same percentages from the 1988-89 and 1997-98 surveys were 11% and 17%, respectively.

Wolf Numbers

Dividing estimated occupied range (67,852 km^2) by average territory size (102 km^2 X 1.37 ≈ 140 km^2) gives an estimate of 485 wolf packs in Minnesota, 26% more than in 1997-98. Multiplying by average pack size (~5.3) and accounting for an estimated 15% lone wolves gives a population point estimate of 3,020 wolves, or 4.45 wolves per 100 km^2 of occupied range. The 90% confidence interval ranges from 2,301 wolves to 3,708 wolves.

Questionnaire Responses

A total of 107 responses were collected in the 2003-04 survey. Considering only the actual office location, 66 were from within the area delineated as total wolf range. Increasing, stable, and decreasing populations were reported by 36, 38, and 17% of these respondents, respectively (Fig. 3). Nine percent were unsure. There was no clear geographic pattern to perceptions, and perceptions often varied within nearby areas (Fig. 3).

DISCUSSION

For the first time since consistent wolf surveys were started in the 1970's, total wolf range in Minnesota did not increase, remaining identical to that delineated in 1998. While the duration between the current survey and the 1997-98 survey was one-half that of previous surveys, it nevertheless suggests wolf range expansion in Minnesota has, at least temporarily, stopped.

Within total wolf range, estimates of occupied range declined 8% in comparison to 1997-98. In addition, the ratio of known (i.e., a pack detected) to presumed (i.e., modeled only) occupied townships declined from 6:1 in 1997-98 to ~ 1:1 (424:402) in 2003-04, increasing the possibility that occupied range could be overestimated. This decline in the ratio of known to presumed occupied townships could have resulted from a real decline in the amount of wolf sign and/or a decline in sampling effort. The true amount of available wolf sign is unknown, so we cannot quantitatively evaluate the former possibility. Nevertheless, sampling effort was notably lower during the current survey. Specifically, a comparison of participants from the 1997-98 and 2003-04 surveys found 8 agencies/departments that contributed data during 1997, but did not in 2003. All 8 were sent survey materials in 2003, but follow-up phone calls indicated that none were able to participate during the current survey because of staff shortages, conflicting responsibilities, and/or limited time in the field. Collectively, these agencies contributed approximately 600 observations during the 1997 survey.

Had these 8 cooperators participated, however, it would not have significantly affected the estimate of occupied range because most were located in areas that were presumed occupied anyway because of low human and road density. It does, however, explain a notable portion of the decline in total wolf observations and the decline in the ratio of known to presumed occupied townships. In addition, for the remaining multi-office agencies that did participate in both surveys, the number of individual offices contributing data in 2003 (102) was substantially lower than in either of the 2 previous surveys (179 in 1997, and 154 in 1988). The average number of observations per contributor was 8 in 1988-89, 20 in 1997-98, and 17 in the current survey. Thus, on average, participating offices recorded a similar number of observations during the last 2 surveys. It seems unlikely that 77 other potential participants, even with a moderate amount of time in the field, would not observe at least 1 indication of wolf activity, given that they did in 1997. Hence, we believe that the 53% decline in total observations, and the resulting decline in the ratio of known to presumed occupied townships, is largely (though perhaps not solely) a function of a decline in sampling effort, with as many as 45% fewer offices participating.

More generally, we believe the methods used to delineate occupied range in the current and previous surveys have several conservative attributes. First, the survey represents opportunistic sampling, with no systematic search of townships. In addition, nearly all participants work for public land management agencies, and notable amounts of private land (particularly in the southern and western portion of the range) are unlikely to be sampled, even opportunistically. Stated differently, pack detection probability is undoubtedly less than 1 in most areas. Finally, while prey- or habitat-based approaches admittedly have some potential to overestimate occupancy at any given time, the 1988-89 human/road density model (Fuller et al. 1992) incorporated here has 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, and 21% in the current survey.

Average mid-winter pack size as estimated from currently radio-marked packs was 5.3, similar to summaries from the previous 2 wolf surveys (5.55, 5.4). In a recent review of published pack size estimates in North America (including many from Minnesota), Fuller et al. (2003) found that the average reported pack size for wolf populations preying primarily on deer was 5.66. While individual pack size undoubtedly varies over time, it appears that average mid-winter pack size estimated from multi-pack studies has remained relatively constant in Minnesota.

In spite of the estimated 8% decline in occupied range, the population point estimate increased. Given that the estimate of average pack size remained similar to 1997-98, the change in the population point estimate was driven solely by a significant decrease in the estimate of average territory size. This decrease in average territory size yields an increase in the estimated number of packs (385 in 1997 vs. 485 in 2003) residing in occupied range (i.e., an increase in wolf density). The current estimate of average territory size (102 km^2, excluding the scaling factor of 1.37) appears to be the smallest published for any multi-pack study in Minnesota (Fuller et al. 2003, Table 6.3), as well as smaller than published estimates from most other areas of North America. At a broad spatial scale, there were 2 areas where territory data was missing in comparison to data available in 1997 – 2 packs in northwestern Minnesota, and 3 packs along the Minnesota-Wisconsin border. Examination of the 1997-98 data for these 5 packs show 4 of the 5 with above-average territory sizes, specifically in the top 30%. Assuming no change in territories from 1997, the lack of data from these packs during the 2003-04 survey could have negatively biased average territory size estimates. Nevertheless, including them with the current data would still have yielded the lowest reported estimate of average territory size in Minnesota, and well below that observed during the 1997-98 survey. Furthermore, we believe there are several biological factors that may explain a decrease in average territory size.

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 have shown an expanding distribution, until the current survey. Average territory size estimates compiled from radio-marked packs during the past 3 wolf surveys have declined from 166 km^2 in 1988 to 140 km^2 in 1997, and now 102 km^2. Hence, the ratio of colonizing packs to established packs may have declined, thereby explaining smaller average territories. However, while this pattern may be real in Minnesota, we suspect it cannot solely explain the currently observed decline in territory size, because average territory size also declined in the long-established population in northeastern Minnesota.

We believe a more likely explanation may be the increase in deer populations. Available prey abundance is arguably the most important factor influencing wolf social and population dynamics. Assuming other factors remain constant, prey abundance is negatively and positively correlated with territory size and population size, respectively (Mech and Boitani 2003, Fuller et al. 2003). The deer population in Minnesota's wolf range is currently at an all time high. Compared to the wolf survey in 1997-98, deer numbers in wolf range are now ~ 70% higher, with increases (20-50%) observed in all areas where wolf packs are currently radio-marked (M.

Lenarz, MN DNR, personal comm.). While we cannot rule out the possibility that currently radio-marked packs were unrepresentative of the entire Minnesota wolf population, we believe the decline in average territory size is reflective of a geographically stationary wolf population, and one with substantially higher prey abundance than 5 years ago. Given the low correlation between average pack size and prey biomass (Fuller et al. 2003), the lack of significant change in average pack size, in spite of higher prey densities, is not unexpected.

While we believe smaller territories can be explained biologically, the potential implications for estimating population size are varied. The current method for estimating population size assumes that the 'open' area created by shrinking territories was, in aggregate, filled by additional packs. Alternative scenarios might be that the area remains vacant (i.e., larger interstitial spaces between packs) and/or the percent of lone wolves (or their survival) increases due to these 'vacant' spaces. These 2 possibilities create opposite effects on population estimates, and the relative support for these different scenarios is unknown. For the purposes of this and previous surveys, the estimated size of interstitial spaces and the percent lone wolves have been held constant.

Of 107 status and trend questionnaires returned, 66 were from within the area delineated as total wolf range. Of these respondents, 36% indicated local wolf numbers had increased over the last 5 years, 38% indicated stable numbers, 17% indicated a decline in numbers, and 9% were unsure (Fig. 3). In comparison, these percentages were 63%, 31%, 1%, and 5% in 1997-98 (n=112 respondents in wolf range), respectively. While few offices perceive a declining wolf population, there has clearly been a shift from a perception of predominantly increasing wolf numbers toward one of stable populations.

For the first time since consistent surveys were initiated in the late 1970's, total wolf range in Minnesota did not increase, and estimated occupied range declined slightly. Nevertheless, the current point estimate of population size is larger than in 1997-98, attributable to smaller territory sizes and a corresponding increase in estimated wolf density. However, the last 2 population size confidence intervals are widely overlapping. Hence, we conclude that, since 1997, there has been no significant change in the distribution or abundance of wolves in Minnesota.

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Table 1. Comparison of 1978-79, 1988-89, 1997-98, and 2003-04 wolf survey and population estimation methods.

	WINTER 1978-79	WINTER 1988-89	WINTER 1997-98	WINTER 2003-04
1.	Field personnel submitted maps with wolf/sign observations and numbers of wolves in approximately delineated pack areas. Personnel also rated wolf population trends in last 5 years and wolf abundance.	Field personnel from additional agencies submitted maps with wolf/sign observations and numbers of wolves. Personnel also rated wolf population trends in last 5 years and wolf abundance.	Field personnel from still more agencies over the northern two-thirds of the state submitted maps with wolf/sign observations and numbers of wolves. Personnel also rated wolf population trends in last 5 years and wolf abundance.	Field personnel from the same agencies/offices were asked to participate, though fewer participated. Offices submitted maps with wolf/sign observations and numbers of wolves. Personnel also rated wolf population trends in last 5 years and wolf abundance.
2.	Field observations consisting primarily of responses from personnel totaled 480.	Field observations were supplemented by data from USDA and scent station surveys and totaled 1,244.	Field observations were supplemented by data from scent station and winter track surveys, and USDA, and totaled 3,659.	Field observations were supplemented by data from scent station and winter track surveys, and USDA, and totaled 1,719.
3.	Field observations were combined with telemetry data from four studies.	Field observations were combined with telemetry data from at least four studies.	Field observations were combined with telemetry data from five studies.	Field observations were combined with telemetry data from four studies.
4.	Two wolf range lines were calculated. The primary wolf range of 36,500 km^2 included all pack range as determined from field observations and telemetry. A peripheral range of 55,600 km^2 included the area occupied by disjunct packs and single wolves.	A contiguous total wolf range was delineated that included 93% of townships with packs as determined from all databases, and encompassed 60,229 km^2 of northern Minnesota. To compensate for a lack of systematic sampling, this included 'modeled' townships with <0.7 km/km^2 roads and <4 $humans/km^2$ or <0.5 km/km^2/roads and <8 $humans/km^2$ even if no wolf packs were detected in the current survey. Unoccupied range (~ 8,000 km^2 with no pack detections and not fitting human/road model) was subtracted from total area to derive total occupied wolf range (~ 53,000 km^2).	A contiguous total wolf range was delineated that included 99% of townships with packs as determined from all databases, and encompassed 88,325 km^2 of northern Minnesota. To compensate for a lack of systematic sampling, this included 'modeled' townships with <0.7 km/km^2 roads and <4 $humans/km^2$ or <0.5 km/km^2/roads and <8 $humans/km^2$ even if no wolf packs were detected in the current survey. Unoccupied range (14,405 km^2 with no pack detections and not fitting human/road model) was subtracted from total area to derive total occupied wolf range (73,920 km^2).	A contiguous total wolf range was delineated that included 99% of townships with packs as determined from all databases, and was identical to 1997 (88,325 km^2). To compensate for a lack of systematic sampling, this included 'modeled' townships with <0.7 km/km^2 roads and <4 $humans/km^2$ or <0.5 km/km^2/roads and <8 $humans/km^2$ even if no wolf packs were detected in the current survey. Unoccupied range (20,473 km^2 with no pack detections and not fitting human/road model) was subtracted from total area to derive total occupied wolf range (67,852 km^2).
5.	Number of wolves calculated from telemetry studies and areas known to contain wolves = 988.	Mean wolf territory size (166 km^2) derived from previous and current telemetry studies was divided into total range (after increasing pack territory size by 37% for interstitial pack area) to estimate number of packs (~233).	Mean territory size (140 km^2) derived from current telemetry studies was divided into total range (after increasing pack territory size by 37% for interstitial pack area) to estimate number of packs (~385).	Mean territory size (~ 102 km^2) derived from current telemetry studies was divided into total range (after increasing pack territory size by 37% for interstitial pack area) to estimate number of packs (~485).
6.	Areas without observations but having low road and human densities were extrapolated from wolf densities in known wolf areas; this amounted to an additional 148 wolves (988 + 148) to get the total number of pack wolves (1,136).	The mean winter pack size (5.55), derived from previous and current telemetry studies, was multiplied by the number of packs to get total number of pack wolves (1,293).	The mean winter pack size (5.4), derived from current telemetry studies, was multiplied by the number of packs to derive the estimated number of pack wolves (2,079).	The mean winter pack size (~5.3), derived from current telemetry studies, was multiplied by the number of packs to derive the estimated number of pack wolves (2,567).
7.	An additional but very conservative 10% was added to account for lone wolves, providing a total of 1,235 wolves. This was a single point estimate without confidence intervals.	The total number of pack wolves was increased to compensate for 15% single wolves in the population (1,293/0.85) = 1,52l total wolves. This was a point estimate with 90% confidence intervals. A separate population estimate (1,750) was calculated from a regression of wolf/ungulate biomass ratios.	The total number of pack wolves was increased to compensate for 15% single wolves in the population (2,079/0.85) = 2,445 total wolves, with a resulting 90% confidence interval of (1995, 2905). The wolf to ungulate biomass ratios were not used in 1997-98.	The total number of pack wolves was increased to compensate for 15% single wolves in the population (2,567/0.85) = 3,020 total wolves, with a resulting 90% confidence interval of (2301, 3708). The wolf to ungulate biomass ratios were not used in 2003-04.

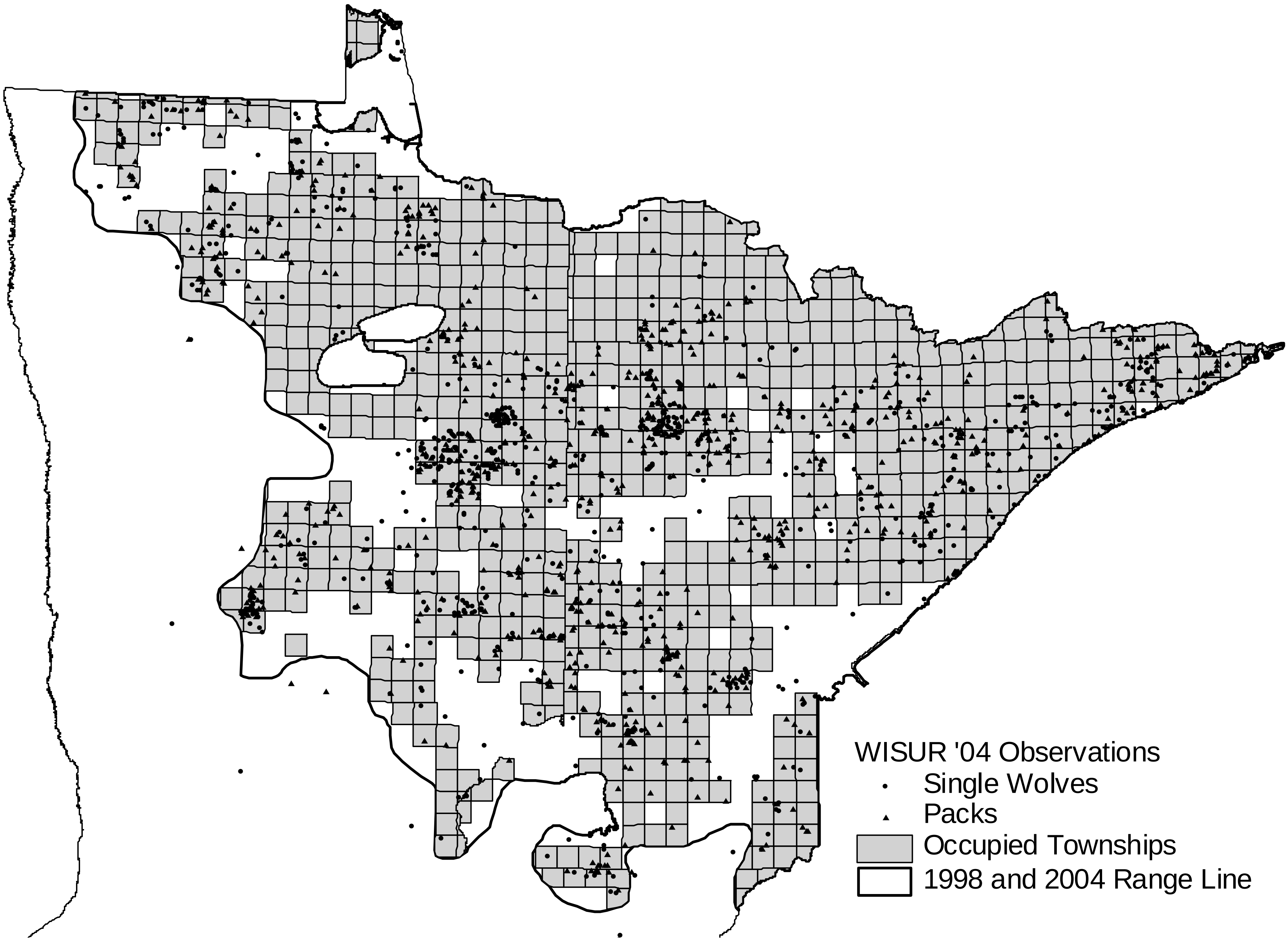

Fig. 1. Wolf sign observations and occupied townships delineated as part of the 2003-04 wolf survey.

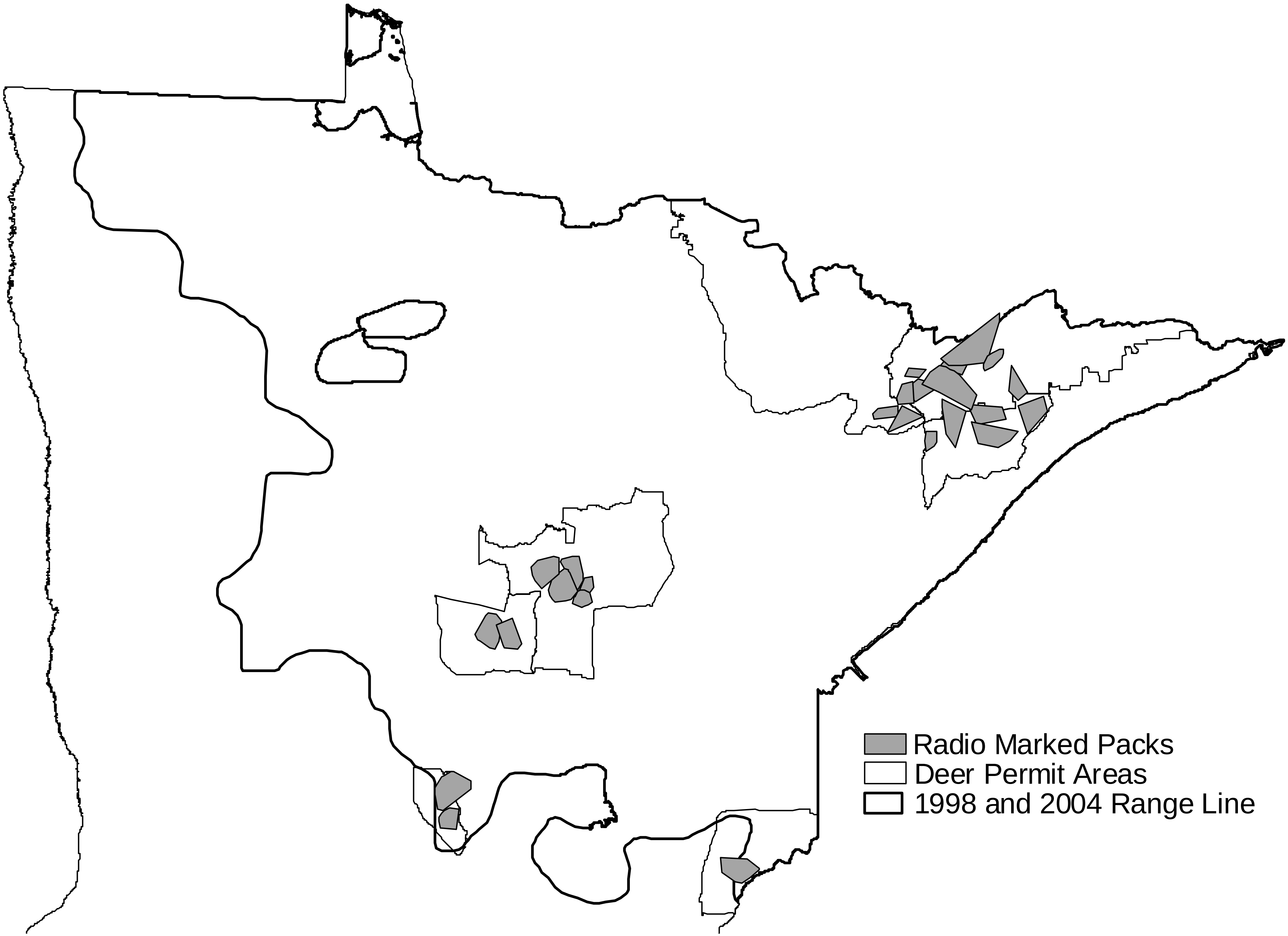

Fig. 2. Location of radio-marked wolf packs and corresponding deer permit areas within which the packs were located.

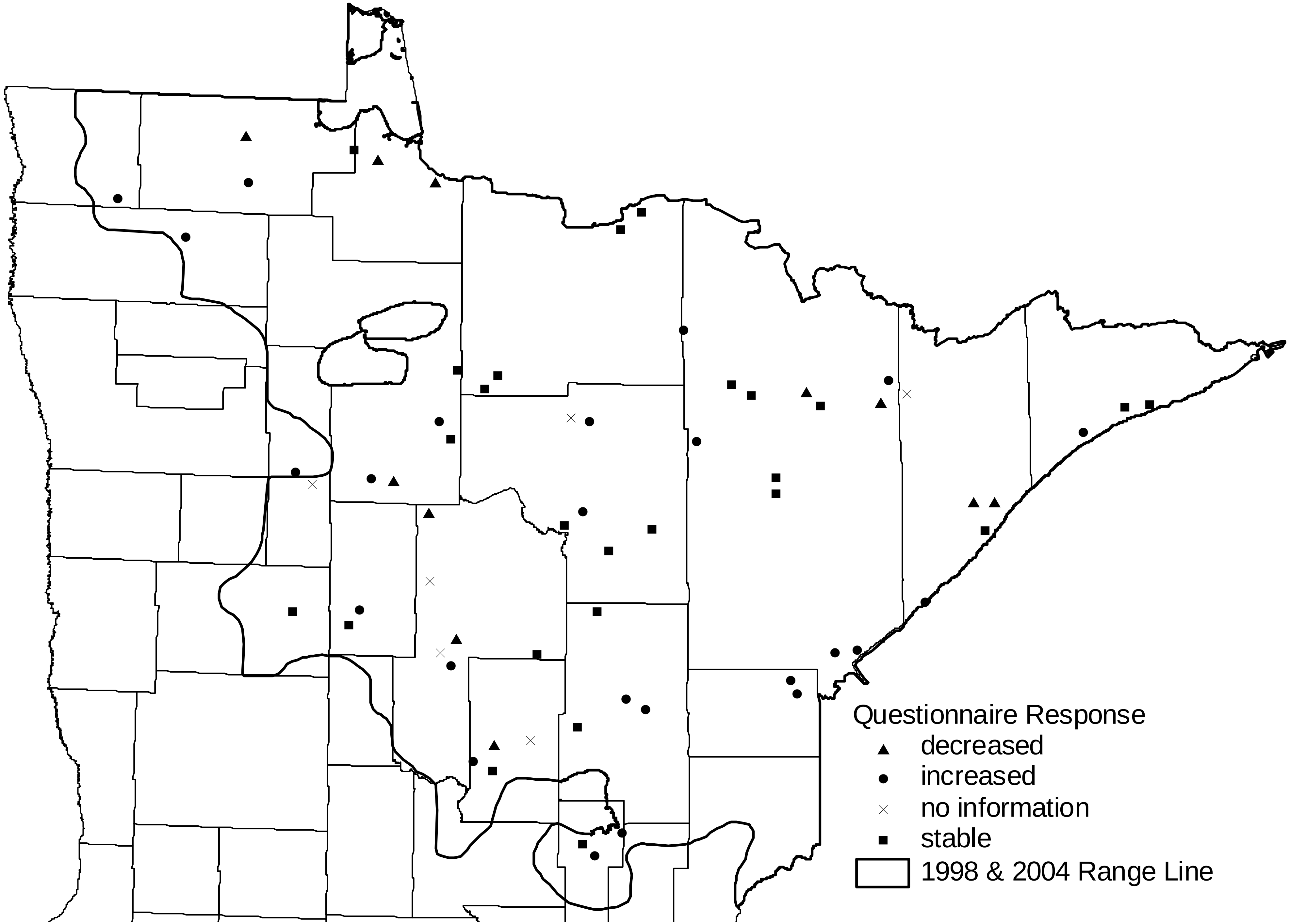

Fig. 3. Winter 2003-04 wolf population status and trend questionnaire results for respondents within total wolf range (n=66).