

## Record High Wolf, *Canis lupus*, Pack Density

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This report documents a year-around Wolf (*Canis lupus*) density of 18.2/100 km<sup>2</sup> and a summer density of 30.8/100 km<sup>2</sup>, in a northeastern Minnesota Wolf pack. The previous record was a summer density of 14.1/100 km<sup>2</sup>, for a Wolf pack on Vancouver Island, British Columbia, Canada.

Key Words: Wolf, *Canis lupus*, Minnesota, Superior National Forest, White-tailed Deer, *Odocoileus virginianus*.

Wolf (*Canis lupus*) densities are highly variable (Mech 1970), depending generally on prey biomass density (Keith 1983; Fuller 1989). Because prey biomass density is related inversely to latitude, Wolves tend to reach their highest densities at lower latitudes (Mech and Boitani 2003). The highest reported naturally occurring Wolf density is 14.1 Wolves/100 km<sup>2</sup> for a pack of nine Wolves on Vancouver Island (Scott and Shackleton 1982).

Herein we report on a Minnesota Wolf pack with a density higher for two years than the highest density reported elsewhere.

### Study area

We studied the Farm Lake Wolf pack (FLP) that inhabited the Superior National Forest (SNF) of northeastern Minnesota where most of the Wolf's diet is White-tailed Deer (*Odocoileus virginianus*). The Wolf packs in the SNF are spaced into territories (Mech 1973, 1986) and the FLP territory, 10.0 km east of Ely (48°N, 92°W), was surrounded by four or five other pack territories. The terrain, vegetation, and land use in the territory are typical of the surrounding region (Mech 1973). However, during winter, much of the territory encompasses part of the Garden Lake deer yard (Nelson and Mech 1981). Deer densities there in the late 1970s were estimated at 16-23 deer/km<sup>2</sup> (Nelson and Mech 1981), and the deer population in the general area has increased considerably since then (Mech and Nelson 2000).

### Methods

Wolves were live-trapped, radio-tagged, aerially radio-tracked weekly when possible, and aerially observed with their packs during winter. Estimates of FLP territory size were made for summer (1 April-30 September), winter (1 October-31 March) and the entire year (1 April-31 March) from 1 October 1997 through 30 March 1999.

We used ArcView (copyrighted) GIS (ESRI Inc., Redlands, California) to estimate each period's territory area corresponding to the combination of all FLP radio-tagged Wolves. UTM coordinates of the FLP Wolf locations were imported into ArcView GIS and converted into point data. Minimum Convex Polygons (Mohr 1947) were then constructed using Animal Movement (Hooge and Eichenlaub 1997) extension to Arcview.

By using observation curve analysis we determined when a territory was defined (Odum and Kuenzler 1955). We subsampled period Wolf locations without replacement, increasing the number of samples (locations) with each subsample treatment, and calculated territory area from each subsample. Five repetitions of each subsample were performed to generate a corresponding mean territory area for each subsample. The mean areas were then plotted against number of locations in the subsample. We considered territories defined when there was  $\leq 1\%$  change in area (suggesting asymptotic behavior) as a result of the addition of one more sample.

We determined pack size through the winter aerial surveys. The greatest number of Wolves seen was considered the pack size. Vegetative cover prevented aerial surveys in summer. Pack sizes were divided by their territory size and then multiplied by 100 to give density in Wolves/100 km<sup>2</sup>.

### Results

We radio-tagged and tracked adult female Wolf 667 and male pup 673 (born in 1997) from 1 October 1997 through 30 March 1999 for this study (Table 1). A total of 127 Wolf locations were obtained, with one Wolf location defined as when one Wolf was at a point. If both Wolves were together, two locations were recorded. Observation curve analysis suggested that 30 locations were needed to accurately define the winter 1997-1998 FLP territory, 50 samples for the 1998-1999

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TABLE 1. Background data for calculations of Wolf density in the Farm Lake Pack, northeastern Minnesota.

Period	Number of Locations	Number of Wolves	Area km <sup>2</sup>	Density/100 km <sup>2</sup>
1 October 1997 – 30 March 1998	39	4	22.88	17.5
1 April 1998 – 30 September 1998	44	–	19.50	30.8*
1 October 1998 – 30 March 1999	44	6	32.88	18.2
1 April 1998 – 30 March 1999	88	6	32.88	18.2

\*Assuming only six Wolves, the number observed during the following winter.

territory, and 30 and 35 samples for the FLP summer and winter periods, respectively. In all these periods, these criteria were met (Table 1).

During winter 1997-1998, the FLP contained four members and used an estimated area of 22.88 km<sup>2</sup>, a density of 17.5 Wolves/100 km<sup>2</sup>. In winter 1998-1999, six FLP Wolves used an area of 32.88 km<sup>2</sup>, a density of 18.2 Wolves/100 km<sup>2</sup>, and in summer only 19.5 km<sup>2</sup> for a minimum density of 30.8 Wolves/100 km<sup>2</sup> (Table 1).

### Discussion

The Wolf densities we found exceeded the highest previous record of 14.1 Wolves/100 km<sup>2</sup> for a Wolf pack on Vancouver Island (Scott and Shackleton 1982). Hebert et al. (1982), citing the Scott and Shackleton (1982) study, claimed a density of one Wolf per 6.3 km, or 15.9/100 km<sup>2</sup>. However, Hebert et al. (1982) included a third pack not mentioned by Scott and Shackleton and presented no territory area data for this pack. Density estimates using radio-locations can be greatly influenced by the number and timing of locations. Our locations were evenly distributed throughout the year and met the observation curve test (Odum and Kuenzler 1955), even though the number of locations available were fewer than recommended by others (Fritts and Mech 1981; Bekoff and Mech 1984; Ballard et al. 1987). No doubt the much smaller size of our territory explains why fewer locations were needed to define it.

It is notable that the previous high record Wolf density (14.1 Wolves/100 km<sup>2</sup>) was based only on summer locations during a relatively short period (11 April to 10 September). Furthermore, this period was before when most of the year's mortality occurs (Fuller et al. 2003). Thus the earlier density is not strictly comparable to either our year-around or winter densities.

The extraordinarily small FLP territory areas of 1997-1998 and 1998-1999 resulted in the highest documented Wolf density to date. This density was no doubt related to the high winter deer density in the area as well as to the relatively harsh winters during that period, with deep snow and extreme cold, that would have caused deer to concentrate with greater density. We know of no garbage dump or other regular source of food in this territory.

Even so, our highest Wolf density (30.8 Wolves/100 km<sup>2</sup>) occurred in summer, and it was a minimum estimate because it was based on the pack size the following winter, after any mortality may have occurred. Thus the winter deer density at first seems irrelevant. However, possibly such a high deer density allowed the Wolves to add sufficient fat and to cache enough surplus food to help carry them through the summer. In any case, this study demonstrates the extreme density that Wolf densities can reach when prey is plentiful.

### Acknowledgments

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