Abundance, social organization, and population trend of the arctic wolf in north and east Greenland during 1978–1998

Ulf Marquard-Petersen

Abstract: Abundance, social organization, and population trend of the arctic wolf (*Canis lupus arctos* Pocock, 1935) in north and east Greenland, 1978–1998, were determined from 353 sightings of 552 wolves by the Danish military, by expeditions, and from 8 consecutive years (1991–1998) of fieldwork. Available evidence suggested that this wolf population consisted of up to 55 wolves in favorable times. Six core packs were identified. Maximum wolf density was estimated at 1 wolf/3745 km^2, which appears to be the lowest wolf density reported, representing 3.5% of maximum late winter wolf density in Denali Park, Alaska, and <1% of that in north-central Minnesota. Social organization was characterized by a preponderance of pairs and lone wolves. Mean early winter pack size was 2.6 wolves/pack; the lowest reported for wolves in North America. Packs >4 wolves were rare, constituting 3.8% of early winter sightings. The population increased, on average, 8% per year during the period 1978–1991 and appeared to reach a peak in 1991–1992. These depressed population characteristics are likely the consequence of the lowest ungulate prey availability in North America, e.g., 2.6% of that of wolves in northeastern Minnesota.

Résumé : Trois cent cinquante-trois observations de 552 loups faites par les militaires danois ou réalisées lors de diverses expéditions et durant 8 années consécutives (1991–1998) de travail sur le terrain ont permis de déterminer l'abondance, l'organisation sociale et les tendances démographiques du loup arctique (*Canis lupus arctos* Pocock, 1935) dans le nord et l'est du Groenland de 1978 à 1998. Les données disponibles indiquent que cette population consiste en un maximum de 55 loups dans les périodes favorables. Six meutes centrales ont pu être identifiées. La densité maximale des loups est estimée à 1 loup/3745 km^2, ce qui semble être la plus faible densité de loups jamais signalée, correspondant à 3,5 % de la densité maximale de loups en fin d'hiver au parc Denali, Alaska, et à <1 % de celle du centre nord du Minnesota. L'organisation sociale se caractérise par une prépondérance de paires et de loups seuls. La taille moyenne d'une meute au début de l'hiver est de 2,6 loups/meute, la valeur la plus basse signalée chez les loups en Amérique du Nord. Les meutes avec >4 loups sont rares et représentent 3,8 % des observations en début d'hiver. La population a crû en moyenne de 8 % par année durant la période de 1978 à 1991 et semble avoir atteint un sommet en 1991–1992. Ces caractéristiques de population réduite sont vraisemblablement la conséquence de la disponibilité d'ongulés proies la plus basse d'Amérique du Nord, représentant, par exemple, 2,6 % de celle que connaissent les loups du nord-est du Minnesota.

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Introduction

The arctic wolf (*Canis lupus arctos* Pocock, 1935) occurs in the Canadian Arctic and in north and east Greenland. It is the least studied subspecies in Canada (Hayes and Gunson 1995), owing to the remoteness of its habitat relative to southern areas. It appears that wolf abundance, density, and pack sizes on the Canadian Arctic Islands are extremely low relative to subarctic areas (Riewe 1975; Miller 1995). In Greenland, similar studies have not been conducted, and wolf population size, density, and social organization are unknown. Wolf range in north Greenland is contiguous with Canadian wolf range owing to the short distance between the two areas and sea ice that makes it possible for wolves to move freely back and forth.

The arctic wolf has a recent history in Greenland. In east Greenland, wolves were exterminated by commercial hunters during the 1920s (Marquard-Petersen 2007). In north Greenland, sightings of wolves or their tracks have been rare, and it was uncertain whether the few wolves seen represented resident wolves or visitors from nearby Ellesmere Island (Dawes et al. 1986). Then, in 1979, two wolves were reported in east Greenland (Hansen 1979). During the following decade, sightings of wolves continued, suggesting that a small population had re-established itself in its former range.

This study analyzed sightings of wolves made during the period 1978–1998 by myself, by military patrols, and by expeditions. The objectives were to investigate wolf abundance, social organization, and population trend, and compare these population characteristics to the wolf population in the Canadian Arctic. I predicted that low prey availability in north and east Greenland relative to southern areas would be reflected in lower wolf densities and smaller pack sizes for two reasons. First, the number of species per unit area decreases with increasing latitude (Pagel et al. 1991). Second, numerous studies have shown that ungulate density exerts a primary influence upon the abundance and density

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U. Marquard-Petersen. 5836 East 10th Circle, Anchorage, AK 99504, USA (e-mail: greenlandwolf@gci.net).

of wolves (e.g., Mech et al. 1998; Forshner et al. 2004; Mech and Tracy 2004).

Materials and methods

The narrow piece of ice-free coastal land comprising wolf habitat in north and east Greenland stretches about 2 100 km along the coastline and comprises a minimum of 205 982 km^2 between 70°N and 83°N. Wolves inhabiting this region face severe environmental conditions. In north Greenland at 82°N, 24 h darkness lasts from 16 October to 26 February (Berthelsen and Mortensen 1997). Mean annual temperature is –19.0 °C (Bay 1992), and temperatures may fall to –52 °C (DMI 2006). Vast areas are classified as polar desert or semi-desert. Six species of land mammals occur at low densities: muskox (*Ovibos moschatus* (Zimmermann, 1780)), arctic hare (*Lepus arcticus* Ross, 1819), Greenland collared lemming (*Dicrostonyx groenlandicus* (Traill, 1823)), ermine (*Mustela erminea* L., 1758), arctic fox (*Alopex lagopus* (L., 1758) = *Vulpes lagopus* (L., 1758)), and arctic wolf. The muskox population was estimated at 9 345 – 12 500 animals (Boertmann et al. 1992); it is the only large ungulate available to wolves. Wolf range is remote, difficult to get to, and is uninhabited with the exception of three military outposts and a weather station. There are no airports with year-round scheduled flights, no roads, and no towns.

I stratified north and east Greenland into 21 zones based upon geographical characteristics for calculations of linear densities (Fig. 1). I then constructed three abundance indices based upon records of wolf observations from 3 independent sources: (1) fieldwork conducted by me, (2) sled patrols during winter by the Danish military, and (3) sports and scientific expeditions. The data were spatially and temporally fragmented, but I conjectured that limitations imposed by incidental and infrequent sightings in part could be overcome by analysis of 21 years of data.

I conducted fieldwork in predicted wolf core areas for 8 consecutive years (1991–1998) during spring and summer to gather data on local and regional abundance of wolves. Areas were targeted based upon the likelihood that wolves would be present as quantified by sightings from 1978 until the summer prior to the planned fieldwork. Wolves were tallied by location and pack size. Tracks were followed on foot, skis, or snowmobile until wolves were sighted or tracks were lost. If tracks were seen, but wolves could not be located, then the tracks were counted. Measurements of each set of tracks were recorded to reduce the possibility of double-counts.

An abundance index was constructed based upon wolf sightings by the Danish Military based in Greenland. These patrols were considered line searches that are particularly useful for long-term monitoring of changes in population density (Seber 1982). I assumed that the number of wolves sighted/1000 km of line transect had a proportional relationship to spatial and temporal wolf abundance.

Incidental wolf sightings by expeditions were collected and analyzed. Expeditions were queried for the following information: area visited, number of days spent in a given area, number of people participating in the expedition, and number of wolf sightings. Details on military patrols, expeditions, and wolf sightings were listed in Marquard-Petersen (2007).

The wolf in Greenland is likely territorial owing to the absence of ungulate migrations. Therefore, packs can be located and observed within their territory, facilitating direct counts for specific areas. Wolf packs are most cohesive and reach their maximum size in fall or early winter, when pups start traveling with their pack (Peterson et al. 1984). Thus, both social organization and maximum population size in a given year can be estimated from observations in early winter (October–December). I pooled the data over the 21-year period and generated an estimate of maximum population size during favorable years by determining the number of packs present, the maximum number of wolves in each pack, and the estimated proportion of lone wolves in the population. I recognized that temporary absence of wolves from their packs may have inflated my estimate of the proportion of loners.

To evaluate my prediction that there was reduced large ungulate prey availability in Greenland relative to lower latitudes, I calculated the ungulate biomass index value/100 km^2 (see Fuller 1989), using the muskox density estimate of 5.3 muskoxen/100 km^2 reported in Marquard-Petersen (2007). I assigned muskox a relative biomass coefficient of 3, using the grand mean of mass of Greenland muskox reported by Vibe (1981).

Sightings per unit effort is a reliable method for estimating yearly population trend for some populations (Roseberry and Woolf 1991). I employed this method under the assumption of constant sighting probability for all wolves in the population averaged over 21 years. I estimated mean exponential rate of increase by taking the known value of the slope of a graph of the natural logarithm of observed wolf numbers plotted against time (Keith 1983; Crawley 1989).

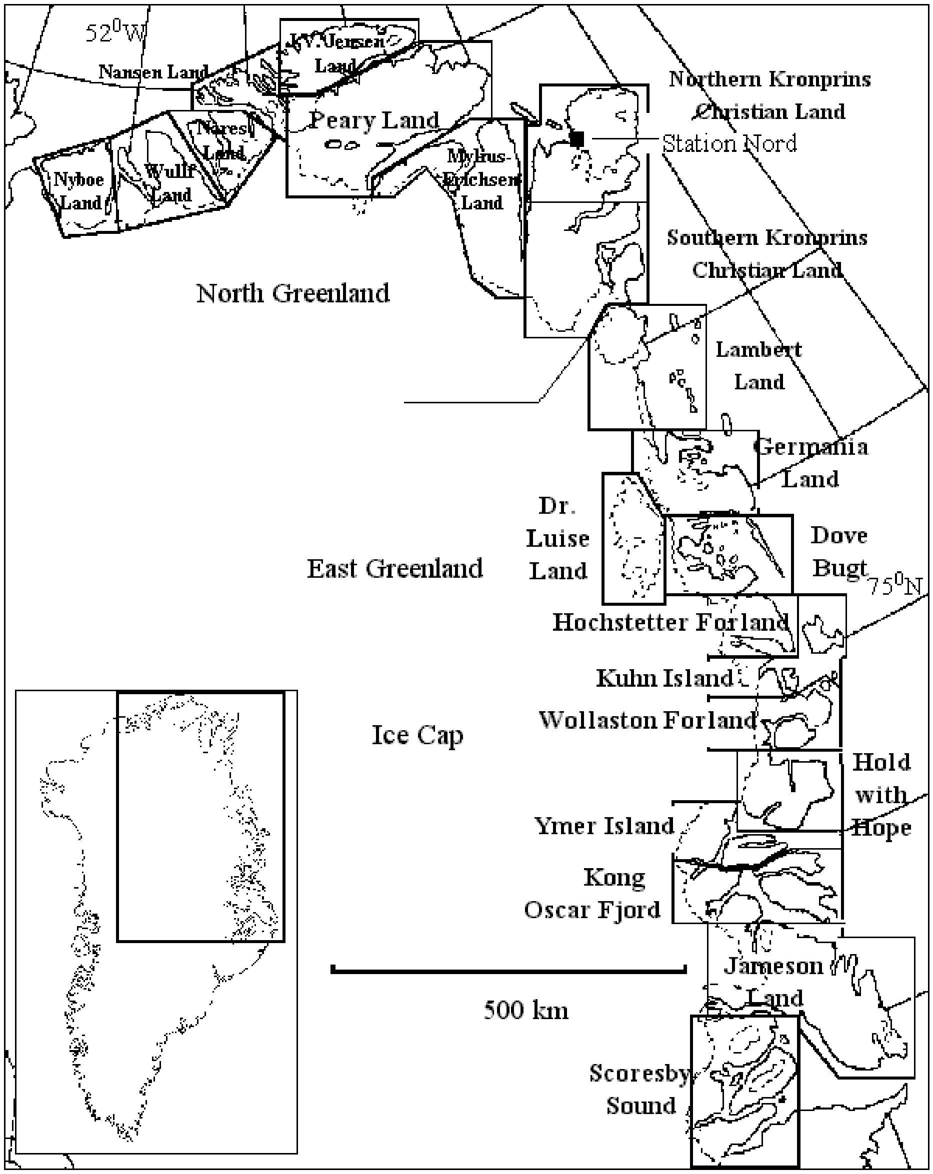
Results

I spent 244 days in the field during 8 consecutive years from 1991 to 1998 (Table 1). The method of predicting wolf presence based upon sightings from previous years was successful (wolves seen) or partially successful (tracks found) during 7 of 8 expeditions, but wolves were sighted during only 4 of 8 field seasons. Some wolves were seen daily for up to 2 weeks, others were seen only once for 2 min. Fieldwork conducted during a single summer was not a reliable indicator of local wolf abundance or density.

During 1978–1998, Danish military personnel traveled a total of 362 290 km by dog sled through the study region. A total of 128 independent sightings of 242 wolves or their tracks were made; 48 sightings were of packs ≥2 wolves. Mean annual distance traveled was 17 252 km (range 12 994 – 20 316). Approximately 77 871 and 228 473 km were patrolled in north and east Greenland, respectively. In all years, patrols sighted more wolves in north Greenland per 1000 km of travel than in east Greenland. Overall mean linear density in north Greenland was 1.91 wolves/1000 km of patrol; overall mean linear density in east Greenland was 0.72 wolves/1000 km of patrol.

Data suitable for analysis were procured from 181 expeditions. The total number of person-days identified by area was 42 220 equal to 34 278 person-days in east Greenland

Fig. 1. Stratification of the study region into 21 areas.



versus 7 942 person-days in north Greenland. A total of 121 independent sightings of 209 wolves or their tracks were reported: 48 sightings were of packs and 73 sightings were of solitary wolves. Expeditions also sighted more wolves innorth Greenland than in east Greenland: 1.15 wolves/ 100 person-days in north Greenland versus 0.26 wolves/ 100 person-days in east Greenland.

Wolves were rare according to all three indices. My fieldwork in core wolf areas indicated that, on average, 16 person-days were required to make an independent wolf sighting. Patrols by military sled teams suggested that, on average, 2027 km by dog sled was necessary before encountering a single wolf. This estimate may have been high, because some wolves may have represented repeat sightings. Data from expeditions showed that, on average, 146 person-days were necessary to encounter a wolf. Such low encounter rates provided compelling evidence that the total north and east Greenland wolf population was very small given available land area and estimated size of the ungulate population.

Only 26 sightings totaling 47 wolves were made during October–December. All of these sightings were made in east Greenland, owing to an almost complete absence of human activity in north Greenland at that time of year. Thirty-four of the 47 wolves occurred in packs with ≥2 wolves and 13 wolves were alone (Fig. 2), suggesting that 27.7% of the population occurred as loners.

Mean early winter pack size was 2.6 wolves/pack (13 packs). Of these packs, 69.2% consisted of pairs. Sizes of packs ranged from 2 to 5 wolves. Packs with >4 wolves were rare, constituting 3.8% of early winter sightings. A total of 93 sightings in late winter (January–April) were reported: 56 sightings of lone wolves (60.2%) and 37 of packs with ≥2 wolves (39.8%). Mean regional late winter pack size was 3.4 wolves/pack.

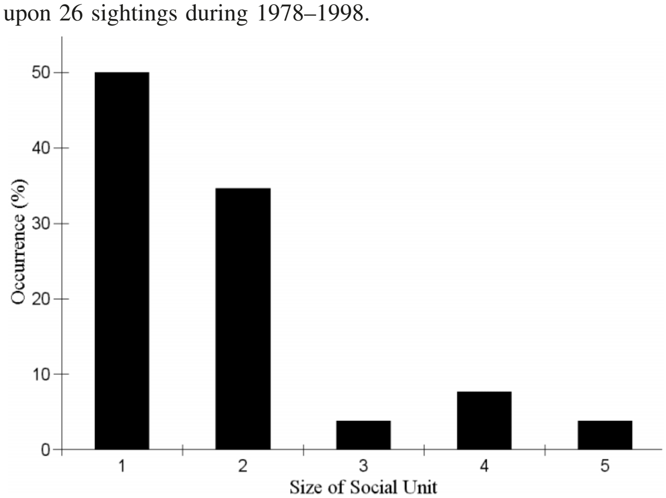
Known maximum pack sizes in each core area, combined

Table 1. Summary of arctic wolf (*Canis lupus arctos*) surveys in north and east Greenland during 1991–1998.

Year	Census area	Survey period	Distance surveyed (km)*	Watch effort (h)	No. of adults seen (or present)†	No. of pups seen
1991	Nansen Land	16 July – 15 August	141	75	2 (2)	0
1992	Hold with Hope	6 July – 1 August	230	104	6 (6)	3
1993	Hold with Hope	7 July – 6 August	162	71	0 (2–4)	0
1994	Hold with Hope	1 June – 2 July	144	72	0 (2–3)	0
1995	J.V. Jensen Land and	6–26 May	1850	67	6 (7)	0
	Northern Peary Land	31 May – 28 June	—	—	—	—
	Nansen Land	27–30 May	52	15	0 (2)	0
1996	Wollaston Forland	9–19 June	48	19	0 (0)	0
	Hold with Hope	20 June – 12 July	145	58	0 (1)	0
1997	Southern Liverpool Land	22–29 July	30	4	0 (0)	0
	Eastern Germania Land	30 July – 7 August	32	6	0 (0)	0
1998	Northern Kronprins Christian Land	11–15 July	10	0	0 (0)	0
	Southern Kronprins Christian Land	16–20 July	40	9	0 (0)	0
	Hold with Hope	21–25 July	19	11	1 (1)	0
	Scoresby Land	26–29 July	5	3	0 (1)	0
Total		—	2908	514	15 (22–26)	3

*On foot or on skis, except 1995 (by snowmobile) and 1997 (on foot and by boat along shore).
†Total of number of seen and unseen animals, the latter revealed by the presence of fresh tracks.

Fig. 2. Early winter (1 October – 31 December) group size of 47 arctic wolves (*Canis lupus arctos*) sighted in east Greenland based upon 26 sightings during 1978–1998.



with an assumed 27.7% lone wolves, suggested that the population probably did not exceed about 55 wolves during favorable times, equaling a maximum overall wolf density in north and east Greenland of 1 wolf/3745 km^2, or 0.27 wolves/1000 km^2 (Table 2). There was evidence that at least 6 packs were active in separate core areas. Details on sightings are given in Marquard-Petersen (2007).

The muskox biomass index/100 km^2 was calculated to be 16. This was low compared with other areas in North America (Table 3), where ungulate biomass index values/100 km^2 range between 85 and 1100 (Fuller 1989).

Linear regression of number of wolves seen/1000 km of military patrol plotted against time suggested that sighting frequency increased, on average, 8% per year until about 1991 (R^2 = 0.78, p <0.0001). Mean rate of increase in standardized sightings was 5% (1978–1985) vs. 16% (1986–1991), suggesting that the late 1980s and early 1990s was a period of major population growth. A linear regression of estimated population size in east Greenland regressed against time using log$_e$-transformed values suggested that the wolf population in east Greenland increased at a mean exponential rate of increase of 0.24 (λ = 1.27) or at an annual population growth of 27% (R^2 = 0.90, p = 0.0004).

Discussion

This study represented the first attempt at assessing the abundance, social organization, and population trend of wolves in the eastern High Arctic, and there were no data with which to compare the resulting estimates. In most years, population size was likely lower than the 55 wolves estimated here, because the estimate was based upon maximum pack sizes observed in each core area during 21 years. Maximum wolf density in my study region was an astonishing 3.5% the density found in Denali Park, Alaska (maximum 7.8 wolves/1000 km^2 in late winter; Mech et al. 1998), and <1% the density found in north-central Minnesota (maximum 40 wolves/1000 km^2 in late winter; Fuller 1989). Population estimates based upon minimum, maximum, or mean pack sizes have also been employed by others (Mech 1977; Fuller et al. 1992).

The most plausible explanation for the observed low wolf abundance and density relates to availability and vulnerability of muskox, the main, year-round prey of these wolves (Marquard-Petersen 1998). In unexploited populations, 72%–92% of the variation in wolf abundance was explained by prey density (Fuller 1989; Messier 1995). Furthermore, wolf density is lower in areas of low ungulate abundance (Messier 1985*b*; Forbes and Theberge 1996).

Wolf food availability in my study region was low, because there were fewer prey species available than in lower latitudes. Also, there was no alternate ungulate prey. Furthermore, muskoxen were neither abundant nor uniformly distributed, but were scattered in small groups over vast

Table 2. Estimated maximum population size of the arctic wolf (*Canis lupus arctos*) in north and east Greenland based upon 88 sightings of wolf packs with ≥2 wolves or their tracks during 1978–1998.

Core area	No. of sightings of packs	Maximum known pack size	Month of maximum sighting
East Greenland			
Jameson Land	10	3*	August
Hold with Hope	29	9	August
Germania Land	15	6	September
North Greenland			
Southern Kronprins Christian Land	10	5	May
J.V. Jensen Land†	10	8	August
Nansen Land	9	7	June
Wulff Land‡	5	5	March
Subtotal	88	43	
No. of lone wolves assumed at 27.7%		12	
Population estimate		55	

*This estimate of maximum pack size was likely biased low, because this sighting was made in August and owing to the high density of large ungulate prey in this area.

†Included sightings of packs on F.E. Hyde Fjord and Frigg Fjord.

‡Included Warming Land.

Table 3. Mean ungulate densities in six regions representative of North America listed in order of decreasing total biomass index.

Region	Mean no./100 km^2	Biomass index/100 km^2	References
Northeast Minnesota	2 moose, 600 deer	612	Fuller 1986, 1989
Central Ontario	45 moose	270	Forbes and Theberge 1996
Interior Alaska	15 moose, 49 caribou	188	Gasaway et al. 1992; Boertje et al. 1996*
Northern Alaska	12 moose, 49 caribou	170	Dale et al. 1995
Southwest Quebec	21 moose	126	Messier 1985*a*†
North and east Greenland	5.3 muskox	16	This study

Note: For a comprehensive list of studies see Fuller (1989).

*From Table 2 of Boertje et al. (1996); area was 12 000 km^2.

†Using only data from low prey area.

areas in a limited and clumped distribution (Thing et al. 1987; Miller 1993). Muskoxen are known for their low reproductive output, and calf production may be limited to a single calf every 2–3 years, depending upon forage availability (Adamczewski et al. 1997). Muskox calves are important food sources to wolves in summer, when nutritional demands of pups are great. Small prey may be seasonally important (Mech 2007).

The Greenland muskox biomass index value/100 km^2 exposed the exceptionally low ungulate density facing Greenland wolves. It appears that these wolves subsist on 8.5% of the ungulate prey biomass available to wolves in interior Alaska and on 2.6% of the ungulate prey biomass available to wolves in north and eastern Minnesota. These calculations suggest that north and east Greenland may have the most impoverished wolf habitat in North America, which raises questions about the long-term viability of a wolf population in Greenland.

Pairs dominated pack sizes in both early and late winter, and packs with >4 wolves were rare. Mean early winter pack size was low relative to lower latitudes based upon studies using similar methods and with comparable sample sizes (e.g., Peterson et al. 1984; Carbyn et al. 1993). The preponderance of pairs suggested that this is the optimum group size in Greenland. Optimum group size is determined by the availability of vulnerable prey and by the efficiency of their capture (Caraco and Wolf 1975). The finding of low pack sizes, combined with low wolf densities, supported my prediction that reduced prey availability in Greenland would be reflected in depressed population variables. This depression in basic population parameters may extend to reproductive characteristics, as this wolf population may have the lowest mean litter size recorded for wolves in North America (Marquard-Petersen 2008).

Lone wolves appeared to be the most common form of social organization in both early and late winter, which may also have been attributable to low prey abundance. On Isle Royale during a period of low wolf density, up to 33% of the population consisted of lone wolves (Thurber and Peterson 1993). One study reported that a decline in food availability increased pack splitting and solitary living of yearlings and adults (Messier 1985*a*). Higher rates of dispersal were reported in areas of low prey density or when food supplies were declining, because adults probably stop provisioning young wolves when food is scarce (Ballard et al. 1987; Peterson and Page 1988; Mech and Boitani 2003). This would explain the apparently high proportion of lone wolves in northeast Greenland. The observed preponderance of pairs and lone wolves may therefore represent a mechanism for dealing with prey scarcity.

There were few data available on social organization of wolves in the Canadian High Arctic, and accuracy of those data was uncertain owing to the pioneering nature of this work. Year-round sightings in the Jones Sound region, Nunavut, showed that pairs and lone wolves dominated the observations (Riewe 1975). An analysis of sightings of wolves on the Canadian Arctic Archipelago (Miller and Reintjes 1995) was based primarily on sightings during the brief arctic summer, when researchers ordinarily visit the region. Therefore, the findings may not be directly comparable with my results.

Sightings by military sled patrols in winter were the primary index of population trend and suggested that the new wolf population in east Greenland increased at a mean annual exponential rate of 0.24, or 27%, between 1979 and 1988. Evidence substantiating this growth was compelling. For 21 consecutive winters, military sled patrols under orders to record all sightings of wildlife traveled, on average, 17 252 km each winter through the wolf range. The observed growth rate was near the mean for seven established wolf populations in North America (r = 0.26, or 30%; Keith 1983). The observed rate of increase should be considered a minimum, because my annual population estimates were based upon minimum sightings.

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