

Exploring the diet of Arctic wolves (*Canis lupus arctos*) at their northern range limit

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Abstract

The grey wolf (*Canis lupus* L., 1758) is one of the most widespread large carnivores on Earth, and occurs throughout the Arctic. Although wolf diet is well studied, we have scant information from high Arctic areas. Global warming is expected to increase the importance of predation for ecosystem regulation in Arctic environments. To improve our ability to manage Arctic ecosystems under environmental change, we therefore need knowledge about Arctic predator diets. Prey remains in 54 wolf scats collected at three sites in the high Arctic region surrounding the Hall Basin (Judge Daly Promontory, Ellesmere Island, Washington Land and Hall Land, both northwest Greenland), pointed to a dietary importance of Arctic hare (*Lepus arcticus* (Ross, 1819), 55% frequency of occurrence) and muskoxen (*Ovibos moschatus* (Zimmerman, 1780), 39% frequency of occurrence), although we observed diet variation among the sites. A literature compilation suggested that Arctic wolves preferentially feed on caribou and muskoxen, but can sustain themselves on Arctic hares and lemmings in areas with limited or no ungulate populations. We suggest that climate change may alter the dynamics among wolves, Arctic hare, muskoxen, and caribou, and we encourage further studies evaluating how climate change influence predator-prey interactions in high Arctic environments.

Keywords: Arctic wolf, *Canis lupus arctos*, food habits, diet, high Arctic, *Lepus arcticus*, *Ovibos moschatus*

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Introduction

The grey wolf (*Canis lupus* L., 1758) has one of the largest distribution ranges of all terrestrial mammals (Mech 1970). Despite some taxonomic controversy regarding sub-species delineation, both cranial measures (Krizan 2005) and genetic data (Carmichael et al. 2008) separate Arctic wolves from southern populations (Nowak 2003). While the grey wolf is one of the most well-studied carnivores on Earth (Brooke et al. 2014), ecological data on Arctic wolves are scarce. For example, wolf diet is well documented globally (reviewed in Newsome et al. 2016), but the number of diet studies on Arctic wolves remains limited. In high Arctic environments, publications are restricted to a study from north Greenland (Marquard-Petersen 1998) and to anecdotal observations from central Ellesmere Island (Tener 1954, Mech 1988, Mech and Adams 1999, Mech 2010). This relative lack of information is likely due to low densities and to logistic constraints associated with working in Arctic environments (Hayes et al. 2016).

Arctic regions harbor harsh environments with relatively simple ecosystems. Since cold areas may be more affected by climate change than temperate regions (Gitay et al. 2002), global warming is expected to cause significant alterations to Arctic environments (Chapin III and Körner 1996). Terrestrial Arctic ecosystems are, to a large extent, regulated by bottom-up processes linked to plant-herbivore interactions (Oksanen and Oksanen 2000). However, recent food-web modeling suggests that global warming could lead to a productivity induced shift in the body-size distribution of large vertebrate prey, which could result in an increased importance of top-down regulation of Arctic ecosystems through predation processes (Legagneux et al. 2014). These trophic effects have wide ecological impacts (Nolet et al. 2013), with consequences for both local and global societies (Chapin et al. 2005) as well as important feedback effects on resilience to climate change (Ims and Ehrlich 2013). Therefore, comprehensive knowledge about the food habits of Arctic predators may be a cornerstone for a pro-active approach towards managing Arctic ecosystems in the face of current and future environmental change.

Here we present data on wolf diet estimated from scats collected during August 2015 at three adjacent high Arctic areas around the Hall basin, a section of the Nares Strait between Ellesmere Island and north Greenland. Using an international ice-breaker expedition to the Petermann glacier area as our logistic base, we managed to collect wolf scats at three high Arctic sites where no known wolf studies have been conducted: Judge Daly Promontory, northern Ellesmere Island, Hall Land, north Greenland north of the Petermann Glacier, and Washington Land, also north Greenland but south of the Petermann Glacier. In addition, we surveyed potential prey species at all three sites (Dalerum et al. 2017). These areas lie at the northern range limit for wolf populations. Therefore, any observations of wolf feeding habits may function as important baselines for evaluations of the potential effects of climate change on Arctic predation patterns.

Materials and methods

Study area

We collected wolf scats on Judge Daly Promontory on Ellesmere Island (81.3833 N / 65.2430 W), Nunavut, Canada and two sites in north Greenland: Hall Land (81.5945 N / 60.7027 W) and Washington Land (80.2585 N / 60.7958 W) (Figure 1). Judge Daly Promontory was visited 19–26 August, Hall Land was visited 3–13 August and Washington Land was visited 15–18 August in 2015. The sites are far enough apart to make it unlikely they were inhabited by the same packs, and further isolated by either the Nares Strait or the Peterman Glacier. Vegetation cover is sparse and our observations suggested an average cover of less than 10% for all three sites.

Potential prey on all three sites include Arctic hares (*Lepus arcticus* (Ross, 1819)), collared lemmings (*Dicrostonyx groenlandicus* (Traill, 1823)), and rock ptarmigans (*Lagopus muta* (Montin, 1776)), as well as seasonal prey such as snow geese (*Anser caerulescens* L., 1758), shorebirds and waterfowl. Muskoxen (*Ovibos moschatus* (Zimmerman, 1780)) occur on Ellesmere Island and were observed by our team on both Hall and Washington Land, despite muskoxen previously having been reported absent from Washington Land (Bennike 2002). Caribou (*Rangifer tarandus* L. 1758) are present on Ellesmere Island but are likely absent from the Greenland sites, although both sites have had caribou populations in historical times (Meldgaard 1986).

Sample collection and processing

We collected wolf scats opportunistically during fieldwork on the three study sites. Although we did not exclusively search for wolf scats, we did visit mounds and suspected den sites for any prey remains and carnivore scats. We collected all scats that we came across. A total of 54 samples were collected, 16 from Ellesmere Island, 21 from Hall land and 17 from Washington land. We did not try to distinguish the age of the scats. The majority of the collected scats were dry although none was in an advanced state of decomposition. Scats were labeled and stored in zip-lock bags. We distinguished wolf scats from those of Arctic foxes, the only other canid in the area, by their conspicuous size and shape.

Scats were broken apart and washed with water over a 1 mm mesh screen and dried for a minimum of 24 hours in an oven at 80° C (Dalerum et al. 2009). Prey remains were identified based on hairs and feathers as well as fragments of bone, teeth, beaks, and claws. Size, shape, and structure aided in identification. Hairs and feathers that could not be identified directly were mounted on a glass slide and examined under a microscope. Identification of hairs was done by comparing them to known reference samples as well as to the identification guide by Teerink (1991). Feathers were identified through their barbs to genus level using the identification key from Brom (1986). We broadly grouped prey items into the following classes: caribou, muskoxen, Arctic hare, lemming, wolf, Arctic fox, birds, invertebrates, and unknown medium sized mammals. We quantified diets as frequency of occurrence, which we have expressed as the percentage of scats that each prey class was identified in (i.e. the number of scats containing a prey class divided by the number of scats for each location multiplied by 100).

Observations of prey species

We recorded the presence of Arctic hare, muskoxen and caribou pellets in 1 m² plots, which were used for a concurrent plant survey in the same study areas where we collected the wolf scats (Figure 1). The plots were clustered in groups of 5 placed within 25 m of each other, and 5 clusters were spaced 250 m apart along 1 km transects. The transects were spaced 2-3 km apart. We recorded pellets in 175 plots along 7 transects on Judge Daly Promontory, in 150 plots along 6 transects on Hall Land (> 90 m altitude), and in 250 plots along 10 transects on Washington Land. We have excluded plots on Hall land below 90 m asl., since we recorded no vegetation and no presence of herbivores below this altitude (Dalerum et al. 2017).

Literature compilation

We augmented our results with a brief literature compilation of wolf diet in Arctic environments. We used studies identified in Newsome et al. (2016) from Arctic areas, including one study from Arctic Alaska, supplemented with the reports from Tener (1954) and Hayes et al. (2016). For this

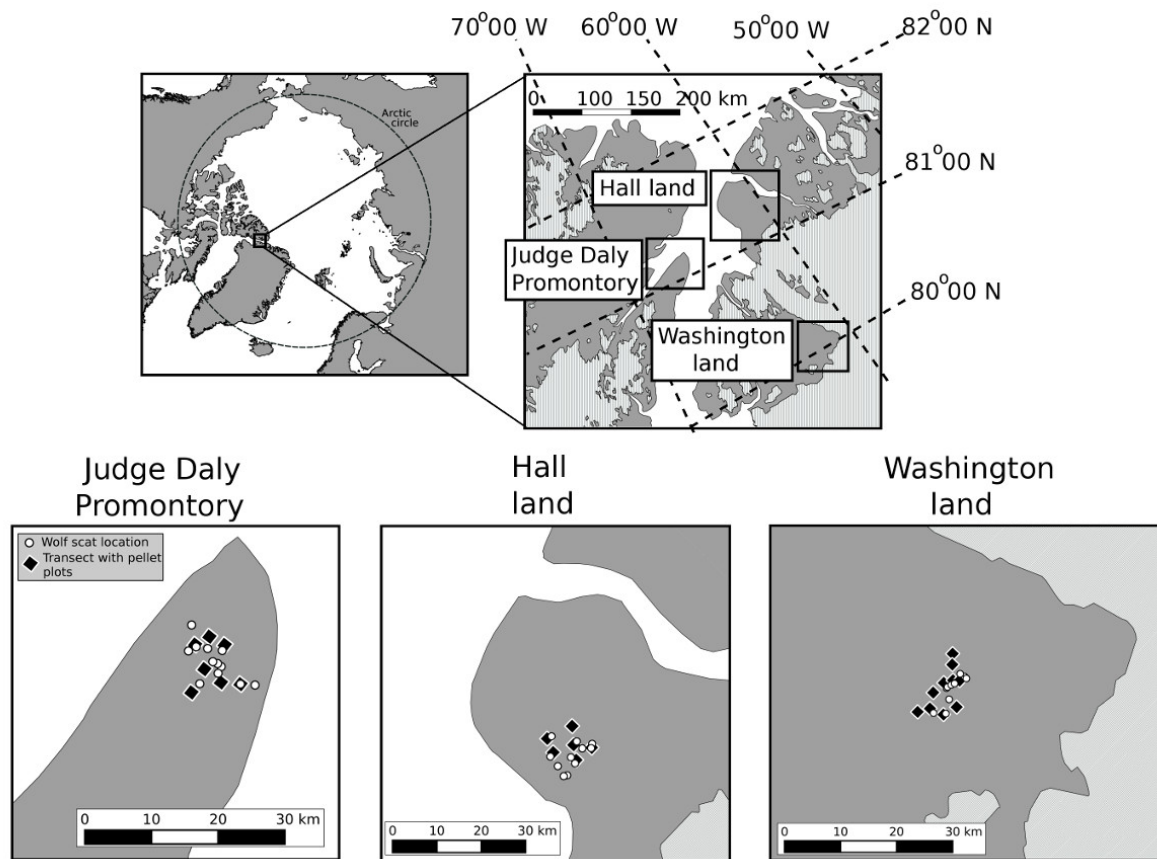


Fig. 1. Locations of the study three areas on Judge Daly Promontory, Ellesmere Island, and Hall Land and Washington Land, north Greenland, as well as details of each study sites with the locations of the collected wolf scats and the transects where pellet plots were placed for prey surveys.

literature compilation we defined Arctic environments as areas north of the boreal tree line. We only included diet studies based on scat or stomach content, since any inclusion of direct observations of hunting events (e.g., Mech 2010) may bias the data towards larger prey classes.

Results and discussion

Overall, we found a greater variety of prey items in the scats from Judge Daly Promontory and Hall Land compared to scats from Washington Land (Table 1). Arctic hares were the most common prey item on Judge Daly Promontory (50% frequency of occurrence) and Washington Land (100% frequency of occurrence), and the second most common prey item on Hall Land (24% frequency of occurrence). Muskoxen was the most common prey item on Hall Land (76% frequency of occurrence) and the second most common prey item on Judge Daly Promontory (31% frequency of occurrence) together with lemmings (31% frequency of occurrence). Lemming was the only prey item apart from Arctic hare that was found in scats from Washington Land (12% frequency of occurrence). We identified remains from canids in two separate scats from Judge Daly Promontory, one likely containing remains of an Arctic fox pup and the other likely from wolf. Since all wolves groom themselves and we only found wolf hair in one scat, we regard it unlikely that the hair had been ingested while grooming. This interpretation is further supported by the scat containing a large amount of guard hair. We also found one scat on Judge Daly Promontory that contained bird remains, which consisted of feathers from a skua (*Stercorarius* sp.). We found one scat each on Judge Daly Promontory and Hall land that contained cuticle remains from arthropods.

We recorded Arctic hare pellets in 17% of the plots on Judge Daly Promontory, 49% of the plots on Hall Land, and 72% of the plots on Washington Land, and muskox pellets in 5% of the plots on Judge Daly Promontory and 13% of the plots on Hall Land. We did not observe any muskox pellets on Washington Land, but observed both animals and pellets while moving around in the study area. We did not observe caribou pellets in plots from any of the areas, nor did we directly observe any caribou.

Our observations suggest that muskoxen and Arctic hare dominated wolf diet in this Arctic region. However, we observed spatial variation in wolf diet among the three study sites, with a strong domination of Arctic hare on Washington land, and more varied diet on Judge Daly Promontory and Hall Land. Our pellet counts suggest that this spatial variation in diet was correlated with a spatial variation in prey abundance, with higher abundance of Arctic hare and lower abundance of muskoxen on Washington Land. Both muskoxen (Marquard-Petersen 1998, Mech 2005) and Arctic hares (Tener 1954, Mech 2007) have previously been suggested as important for Arctic wolves in other sites of Ellesmere and Greenland. However, Arctic hares appear to have been the most common herbivore if we combine information from all three areas. We suggest that Arctic hare may be a pivotal species for wolves in this high Arctic system (e.g., Mech 2004), and that Arctic hares may permit wolves to persist in high Arctic areas even in the absence of large ungulates.

The literature survey suggests that low Arctic populations rely heavily on moose (*Alces alces* (L. 1758)) or caribou, central Arctic populations on caribou or muskoxen and high Arctic populations on muskoxen, Arctic hare and microtine rodents (Table 1). We suggest that wolves in the North American Arctic, including Greenland, may be feeding on three different prey bases; (i) migratory caribou supplemented by moose, (ii) muskoxen supplemented by Arctic hare in areas with populations of muskoxen but not caribou, and (iii) Arctic hare supplemented by lemmings in areas without either caribou or abundant muskoxen. Our data support such an

Table 1. Diet from this and other studies of wolves in high, central, and low Arctic areas estimated from scat or stomach content. Diet values are reported as frequency of occurrence (i.e. the number of scats containing a prey class divided by the number of scats for each location multiplied by 100).

Region	High Arctic			East Greenland			Canadian central Arctic			North American low Arctic			
Site	Ellesm. Island	Hall Land	Wash. Land	Ellesm. Island	Nansen Land	Hold w. Hope	Karrak Lake	Banks Island	Victoria Island	NE Yukon	NW Terr.	NW Alaska	
Source	This study			Tener 1954	Marquard-Petersen 1998		Wiebe et al. 2009	Larter 2013		Hayes et al. 2016	Kuyt 1969	Spaulding et al. 1998	Stephenson and James 1982
No samples	16	21	17	85	107	344	85	153 ^a	29 ^a	208	153	1182	920
Caribou							65%	5%	10%	18%	5%	69%	62%
Moose										41%		32%	1%
Caribou or moose										37%			32%
Muskoxen	31%	76%		7%	79%	65%	9%	90%	97%		90%		
Arctic hare	50%	24%	100%	83%	7%	2%	18%	1%	3%		1%		
Microtines	31% ^b	29% ^b	12% ^b		20% ^b	10% ^b	12%	16%	10%	4%	16%	16%	11% ^c
Canid	13%				2%			3%	3%		3%		
Medium sized mamm.										37% ^e		8% ^e	15% ^f
Birds	6%					36%	29%	3%		0.5%	3%	20%	2%
Arthropods	6%	5%				0.3%							1%

^a Stomachs and scats combined

^b Greenland lemming *Dicrostonyx groenlandicus* only microtine rodent present

^c Microtines and squirrels combined

^d Includes shrews and unidentified rodents

^e Includes beaver (*Castor canadensis* (Kuhl, 1820)), muskrat (*Ondatra zibethicus* (L., 1766)), snowshoe hare (*Lepus americanus* (Erxleben, 1777)) and unknown furbearer

^f Includes Arctic ground squirrel (*Spermophilus parryii* (Richardson, 1825)), snowshoe hare, and unidentified carnivore

interpretation, and suggest that Arctic wolves may switch from ungulates to Arctic hares and lemmings even on a regional basis in cases where abundant populations of muskoxen or caribou are absent. We note a scarcity of information regarding the diet of wolves in the Eurasian Arctic, although some information may be available in Russian (e.g., Tumanov 2003).

To conclude, our study suggests that muskoxen and Arctic hare are the two most important prey for Arctic wolves in this region at the northern limit of their range. Since global warming is likely to alter the distribution of Arctic terrestrial mammals, partly as a consequence of a northward expansion of warm adapted species, we suggest that the current predation dynamics between wolves, muskoxen, and caribou may see significant alterations. Such alterations may not only affect these three species, but could also affect plant herbivore dynamics and predator-prey interactions among other species including Arctic foxes and avian predators. Therefore, we urge for further studies evaluating if climate induced alterations in the distribution and population dynamics of Arctic herbivores may cause shifts in high Arctic terrestrial predator-prey interactions.

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