HIGH ARCTIC WOLF ECOLOGY
FIELD REPORT, SUMMER 2015

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Summary
In summer 2014, 3 Arctic wolves were fitted with Global Positioning System (GPS) satellite collars near Eureka, Ellesmere Island, and another collar was deployed on a wolf on eastern Axel Heiberg Island. Two collars released prematurely, and in June 2015 2 new collars were deployed, one on the Axel Heiberg pack and one on the previously uncollared Eureka pack. Location data from collars will allow us to define movement and home range parameters for the collared wolves, which have mostly maintained discrete territories over summer and winter seasons since 2014, with occasional forays off-territory. This space use pattern is more consistent with boreal wolves than with tundra wolves, which follow migratory caribou herds. The Eureka pack has made several movements across frozen fiords, and preliminary genetic evidence also supports that eastern Axel Heiberg Island and the northern Fosheim Peninsula function as an interisland population. In contrast, the collared wolves have rarely crossed into the Sawtooth Mountains, south of the study area. Wolf density in the study area appears to be similar to parts of the boreal forest, about 7 wolves per 1,000 km^2, at least under current conditions and prey densities.

Although we visited several location clusters that could have been kill sites in 2015, there was still too much snow by mid-June in most areas to determine conclusively whether or not there were any prey remains at the cluster sites. The slow decomposition rates and previous work suggest that old clusters could be visited by crews in summer 2016, in addition to new clusters (which would be prioritized).

We checked 13 den sites for wolf activity and found 4 active dens: Vesle Fiord, 2 dens on Axel Heiberg Island used by the same pack, and a den south of Slidre Fiord. The only pup count available was for the Eureka pack, which had 3 pups. This pack also had 2 nursing females, one of which died in July, but all 3 pups survived until at least fall 2015.

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2014 ᐊᐅᔭᖅᑕᓂᑦ, ᐱᖅᑕᓱᑦ ᐅᑭᐅᖅᑕᖅᑑᑉ ᐊᒪᕈᖅᑎᑦ ᖁᖅᑕᓯᕈᓕᖅᑕᐅᓚᐅᖅᐳᑦ ᒫᓃᑉᐳᖅᑖᕈᑎᓂᑦ ᖃᖅᑕᑦᑕᖅᑎᑕᐅᓯᒪᔪᑎᒍᑦ ᔪᓈᑲ, ᐊᐅᓱᐃᑦᑑᑉ ᕿᑭᖅᑖᓗᐊᑕ ᖃᓂᒋᔮᓂᑦ, ᐊᑕᐅᓯᕐᓗ ᐊᒪᕈᖅ ᖁᖅᑕᓯᕈᓕᖅᑕᐅᓚᐅᖅᓱᓂ ᑲᓇᖅᓇᖅᐸᓯᐊᓂᑦ ᓇᐹᖅᑐᓕᐅᑉ. ᒪᕐᕉᒃ ᖁᖅᑕᓯᕈᓖᑦ ᐲᖅᓵᓕᔾᔪᔾᔨᓚᐅᖅᐴᒃ, ᔫᓐ 2015–ᒥᑦ ᒪᕐᕉᖅᓂᒃ ᖁᖅᑕᓯᕈᓕᖅᓱᔪᖅᑲᓚᐅᖅᐳᖅ, ᐊᑕᐅᓯᖅ ᓇᐹᖅᑐᓕᖅᒦᑦᑐᓂᑦ ᐊᑕᐅᓯᕐᓗ ᖁᖅᑕᓯᕈᓕᖅᓯᒪᓚᐅᙱᑦᑐᓂᑦ ᔪᓈᑲᒦᑦᑐᓂᑦ. ᖁᖅᑕᓯᕈᖅᑎᓐᓄᑦ ᖃᐅᔨᒪᔾᔪᑎᒋᓂᐊᖅᑕᕗᑦ ᓄᒃᑕᖅᓂᖅᑎᑦ ᐃᓂᒋᕙᒃᑕᖅᑎᓪᓗ ᑕᒪᒃᑯᐊ ᖁᖅᑕᓯᕈᓖᑦ, ᐊᑕᐅᓯᑦᑕᐃᓐᓂᓕᐸᓗᒃᓱᑎᒃ ᐊᐅᔭᒃᑯᑦ ᐅᑭᐅᒃᑯᓪᓗ ᑕᐃᒪᙵᓂᓂᑦ 2014–ᒥᑦ, ᐃᓂᒋᔭᑎᒃ ᓯᓚᑖᓄᐊᓚᐅᓱᖅᑕᖅᐸᒃᓱᑎᒃ. ᑕᒪᓇ ᐅᐸᒃᑕᐅᕙᒃᑐᖅ ᐊᔾᔨᓪᓗᐊᑕᖅᑕ ᖁᑦᑎᒃᑐᖅᒥᐅᑦ ᐊᒪᕈᖅᑎᓐᓂ ᓄᓇᑐᐃᓐᓇᒥᐅᑖᖁᑎᒃ, ᒪᓕᒍᖏᓪᓗᑎᒃ ᑐᒃᑐᐃᑦ ᑕᓪᔪᐊᖅᑎᓪᓗᒋᑦ. ᑖᒃᑯᐊ ᔪᓈᑲᐅᑉ ᐊᒪᖅᑯᖅᑎᑦ ᓅᓯᒪᖃᑦᑕᖅᓯᒪᔪᑦ ᐊᒥᓱᐊᖅᑎᖅᓱᑎᒃ ᓯᑯᓯᒪᔫᒃᑯᑦ, ᑕᑯᔭᐅᓯᒪᔪᓂ ᑭᓱᕙᓂᖅᑎᓐᓂᑦ ᐅᐸᒃᑕᐅᓯᒪᖃᑦᑕᖅᒥᔪᐃᑦ ᑲᓇᖅᓇᖅᐸᓯᐊ ᓇᐹᖅᑐᒃ ᐅᐊᖅᓇᖅᐸᓯᐊᓂᓪᓗ *Fosheim Peninsula* ᓄᓇᐅᓂᖅᑕᓂᓪᓗ. ᑕᐃᒫᒃ, ᖁᖅᑕᓯᕈᖅᓯᒪᔪᑦ ᐊᒪᕈᐃᑦ ᓂᒋᐊᓄᐊᓗᐊᖅᓯᒪᙱᑦᑐᑦ *Sawtooth Mountains*, ᖃᐅᔨᓴᖅᑕᐅᕝᕙᐅᔪᑦ ᓂᒋᐊᓂ. ᐊᒪᕈᐃᑦ ᖃᐅᔨᓴᖅᑕᐅᔪᑦ ᐊᔾᔨᒋᔭᐅᑐᐃᓐᓇᖅᑰᔨᔪᑦ ᖁᑦᑎᒃᑐᖅᒥᐅᓂ, ᐃᓪᒪᖄ 7–ᖑᕙᒃᓱᑎᒃ ᐊᒪᖅᑯᑦ 1,000 km^{2-}ᑕᒫᑦ ᖃᓄᐃᓕᖅᑕᓂᖅᑎᑎᒍᑦ ᒫᓇᐅᔪᖅ ᐊᒥᓲᓂᖅᑎᑎᒍᓪᓗ.

ᓇᒧᙵᐅᕈᓘᔭᓚᐅᕋᓗᐊᖅᐸᑕ ᑐᖁᑦᑎᕝᕕᐅᓯᒪᔪᕕᓂᐅᑐᐃᓐᓇᓇᐊᓕᖅᓂᑦ 2015–ᖑᑎᓪᓗ, ᐊᐳᑎᑦᖃᓗᐊᓚᐅᖅᒪᑦ ᓱᓕ ᔫᓂᐅᑉ ᕿᑎᐊᓂᑦ ᖃᐅᔨᓇᓱᓪᓗᑦᑖᓇᐊᒃᓴᖅ ᐊᒥᐊᒃᑯᑦᑕᖅᑲᓚᐅᕋᓗᐊᖅᒪᖅᒫᖅᑕᓐᓂᑦ ᓇᐅᒃᑰᕈᓘᔭᕝᕕᐅᓚᐅᖅᑐᒥᑦ. ᓄᖑᑉᐸᓪᓕᐊᕋᔮᖅᓂᖅᑎᓐᓄᑦ ᐱᓕᕆᐊᖑᓂᑯᕕᓂᐅᓂᖅᑎᓪᓗ ᑕᒪᒃᑯᐊ ᐅᐸᒃᑕᐅᑯᓘᔭᖅᑲᑦᑕᓚᐅᖅᑐᑦ ᐅᐸᒃᑕᐅᔪᓐᓇᓈᖅᑐᑦ ᐊᐅᔭᖅᑕᓂᑦ 2016, ᐅᐸᒃᑕᐅᔭᐅᓇᐅᑲᑕᓛᖅᑐᓄᓪᓗ (ᐋᖅᑭᒃᓱᖅᑕᐅᓚᖅᑐᑦ ᓯᕗᓪᓕᐅᔾᔭᐅᔭᓇᐊᓕᖅᑎᑎᒍiii).

ᖃᐅᔨᓴᓚᐅᖅᐳᒍᑦ 13–ᓂᑦ ᑎᓯᓂᒃ ᐅᐸᒃᑕᐅᓯᒪᔪᓂᓪᓗ ᑎᓴᒪᓂᒃ ᑎᓯᓯᐊᖅᑐᑕ: *Vesle Fiord*, ᒪᕐᕉᒃ ᑎᓰᒃ ᓇᐹᖅᑐᓕᖅᒥᑦ ᐃᓂᒋᔭᐅᔪᑦ ᑖᒃᑯᓄᖅᑕᔅᓴᐃᓐᓇᖅ ᐊᒪᖅᑯᓄᑦ, ᑎᓯᒥᓪᓗ ᓂᒋᐊᓂᑦ *Slidre Fiord*. ᓇᐃᓴᑕᒃᓴᑐᐊᖑᓚᐅᖅᑐᓪᓗ ᐊᒪᕈᐊᕐᔪᖅᑎᑦ ᔪᑮᒪᒦᑦᑐᓄᑦ ᐊᒪᖅᑯᓄᑦ, ᐱᖅᑕᓱᐃᓐᓇᐅᓚᐅᖅᑐᑦ. ᑖᒃᑯᐊᑦᑕᐅᖅ ᒪᕐᕉᖅᓂᒃ ᓴᕐᓕᐊᖅᑐᕐᑯᑎᕐᑲᓚᐅᖅᑐᒃ, ᐱᕐᑳ ᑐᕐᑯᓪᓗᓂ ᔪᓚᐃᒥᑦ, ᑭᓱᐊᓂᓕ ᐱᖅᑕᓱᑦ ᑕᒪᖅᒥᒃ ᐆᒪᓚᐅᖅᑐᑦ ᐅᑭᐊᒃᓵᖅᑐᕐᑲᖅᑕᓂᑦ 2015.

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Introduction

Arctic wolves (*Canis lupus arctos*), a subspecies of grey wolf inhabiting the Canadian Arctic Archipelago, were classified in 1999 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Data Deficient due to insufficient information on populations, trends, and diet (Van Zyll de Jong and Carbyn 1999). They are generally white or whitish, with darker hairs along the shoulders, spine, and base of the tail at the precaudal gland (Mech 1970). They are believed to have persisted at low densities in the arctic islands, possibly reaching only about 200 individuals on the Queen Elizabeth Islands (Miller 1993, Miller 1995), and declining after population crashes of their ungulate prey (Miller and Reintjes 1995, Mech 2007). Carmichael et al. (2007) noted signatures of genetic bottlenecks in High Arctic wolves (11 samples from Devon and southern Ellesmere islands), and suggested that High Arctic populations may be maintained by occasional influxes of wolves from Victoria Island in the west and Baffin Island in the east. Their range also extends to Greenland, where low densities and low invasion/re-invasion rates may be partially responsible for a 40-year absence of wolves in northern Greenland, although they have since recently become re-established, apparently from northern Ellesmere Island (Marquard-Petersen 2009, Marquard-Petersen 2011).

Arctic wolves frequently approach and inspect field camps and weather stations, and they are especially well-known for this at Eureka. The Eureka weather station was established in 1947 on the north shore of Slidre Fiord on the Fosheim Peninsula, Ellesmere Island. The wolves were originally viewed as a threat, consistent with the prevailing attitude towards predators in the 1940s and 1950s. From 1947 to 1954, wolves were recorded 102 times and shot at 58 times, of which 31 were known killed and 7 known injured (Grace 1976 in Miller 1993). As the general perception of wolves shifted, they were more often tolerated around the station, even actively fed and habituated. Changing attitudes, tighter regulations, and more oversight have re-defined the wolf-human relationship at Eureka, and staff no longer feed the wolves. Food waste is incinerated and weather station staff and military personnel (at Fort Eureka, 3 km from the weather station at the airstrip) are not permitted to feed the wildlife. The wolves remain accustomed to people and will often approach people and vehicles, sometimes within a few feet and occasionally even stealing items from peoples' pockets.

These habituated wolves provided a unique opportunity to document wolf behaviour, and from 1986-2010, Mech and associates observed wolves around Eureka (Mech 1987, 1995, 1997, 2004, Mech and Cluff 2011). The pack could usually be tracked and followed when they visited the weather station, and usually denned at a relatively accessible rock den on a ridge 6 km north of Eureka. There were no observations made in 1999, no pups were produced in 1998 or from 2000-2003, and no resident wolves were at the den in 2001 or 2002 (Mech 2005).

In July 2009, the breeding male W410 of the Eureka pack was fitted with a satellite collar (Mech and Cluff 2011). He ranged from Eureka, west to Axel Heiberg Island, and south to the Svendsen Peninsula before he died in April 2010, apparently of starvation and/or cancer (Mech and Cluff 2011). The 6 wolves collared in 2014 and 2015 have been more sedentary than W410, although they did still undertake long forays off-territory. The 2014 collars definitively showed home range fidelity in all seasons under the conditions currently experienced by wolves on eastern Axel Heiberg and the Fosheim Peninsula (Anderson et al. 2015). Continued community support and provision of in-kind aircraft support by a crew filming wolves in the area allowed the project to continue in 2015. We checked known dens for occupancy, retrieved the 2 dropped collars, deployed 2 additional collars, and investigated several location clusters. The objectives of the 2015 field season were to update den status, collect and deploy GPS satellite collars, and verify kill sites to inform a developing cluster algorithm to locate potential kill sites from telemetry data.

Den Status

Thirteen dens or potential dens had been previously recorded by researchers and weather station staff. These were checked in early June 2015 to determine whether they were active. Two of the dens were not located in 2014: one of the recorded dens was only an observation of a young pup, and the other den could not be found in a rocky canyon. These locations were not checked in 2015, although the site where the pup was seen was used as a rendezvous site by the Eureka pack. A second, previously unknown, den was located for the Axel Heiberg pack during capture activities.

In total, 4 of the known dens were active in June 2015 (Figure 1). The den at Vesle Fiord was attended by 5 adult wolves, although we only visited it once on June 4 and any pups would still be in the den. This den was active in 2014 as well, with 3 adults and 3 pups. Dens occupied in 2014 at Cañon Fiord, Mount Lockwood, and Bay Fiord were not occupied this year; both Lockwood and Cañon were still snowed in. One adult was present at the den north of Gibbs Fiord on Axel Heiberg Island, but another 8 adults were at another den south of Gibbs Fiord. Collar locations confirmed that the pack used both dens this year. The Axel Heiberg pack also had at least 2 breeding females in 2014. The pack of at least 13 wolves around Eureka denned south of Slidre Fiord, and had 3 pups which were seen by weather station staff until at least fall/winter 2015.

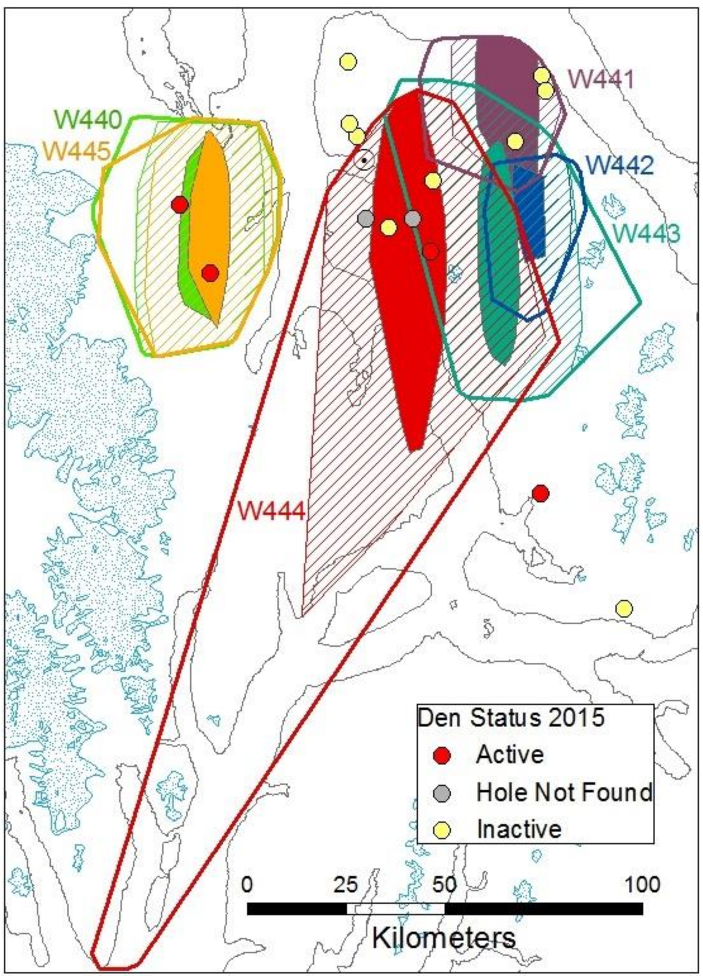

Figure 1. Status of known dens in June 2015. Polygons show minimum convex polygon home ranges for collared wolves in summer 2015, or summer 2014 if not collared in 2015 (100% - hollow, 95% - hatched, 50% - solid).

Pack and Litter Size

The limited field season in 2015 reduced confidence in pack counts and prevented litter size counts at most dens. A film crew at the Eureka pack den was able to confirm 3 pups there. The limited field time also reduced the number of incidental sightings of other packs and prevented searching for previously collared packs to update pack size (W441, W442, and W443). Table 1 summarizes the packs and pup counts from the summer, compared to 2014.

Table 1. Arctic wolf packs observed during summer 2015 fieldwork.

Pack/Area; Collared Wolf	2014 Adults (Pups)	2015 Adults (Pups)	Comments
Eureka; W444	15-16	13 (3)	Pack count was not clear in summer 2014, when 5 or 6 wolves were seen regularly at the airstrip and 6 wolves were also seen at Eastwind Lake, and no den was located. However, weather station staff reported 15-16 wolves in winter 2014-15. Weather station observations in winter 2015-16 also included pack counts of 15-16 wolves.
Gibbs Fiord (Axel Heiberg); W440 and W445	7 (9)	9 (unk)	8 adults seen at south den and 1 at north den (assumed to be breeding female and not present at south den).
Vesle Fiord; uncollared	3 (3)	5 (unk)	Checked June 4, 2015.
Blacktop Ridge; W443	2 (0)	Unk (0)	Collar locations suggest he is not localized at a den. We were unable to get a pack count or determine if he is with a pack in 2015; in 2014 he was with an adult female and raised-leg marking.
Hot Weather Creek (Cañon Fiord); W441	6 (3)	Unk (unk)	Known dens were not occupied and pack not located in 2015.
Mount Lockwood; uncollared	5 (3)	Unk (unk)	Single known den not occupied and pack not located in 2015.
Bay Fiord; uncollared	2 (3)	Unk (unk)	Only breeding female seen repeatedly in 2014 but assume the breeding male was hunting. No wolves seen at the one known den June 4, 2015.
Wolf Valley; W442	4 (4)	Unk (unk)	Den not located in 2014 or 2015.

For the known wolf packs in 2014 and 2015, pack counts averaged 5.3±SD3.4 wolves not including pups, or 8.8±SD4.7 including summer pup counts. Mech and Boitani (2003) review winter pack sizes, so pack sizes reported here are not directly comparable – wolf packs are generally smallest in late winter. The pack sizes reported here (maximum pack sizes in summer including pups) are still smaller than the minimum (winter) pack sizes reported for packs that primarily subsist off bison, moose, and moose/caribou farther south, but larger than packs that consume mostly small animals or scavenge at landfills (Mech and Boitani 2003, and references therein). Pack size and prey size are not definitively linked, as many other factors influence pack size, but the High Arctic packs do appear to be smaller than packs where the main prey are very large ungulates (bison and moose). This would be consistent with their smaller prey (muskoxen, Peary caribou, and arctic hare). Litter size also remained smaller than the 4-5 pups usually reported for wolves farther south (Mech and Boitani 2003, and references therein), at 3.3±SD0.5 pups in June/July. The Eureka wolves did have 5 pups in 2010 (although whether from 1 or 2 females is unknown) and 5 pups in the Axel pack that could have been from one litter. Litter sizes (based on number of pups in summer) were higher than in Greenland, where the average litter size over 22 years was 2.0 pups (Marquard-Petersen 2008).

This is the second year when the Axel Heiberg wolves have had 2 breeding females at 2 dens, and the Eureka wolves also apparently had 2 breeding females, although all 3 pups were together at one den. One of the nursing females, the subordinate, experienced declining health and was last seen alive, gaunt, trembling, and standing with difficulty, by the film crew at the den at 11:00 on July 4. The dominant female moved the pups northwest from the den on July 6 at 22:05. The other female was later found dead in the den tunnel. The pack moved to a rendezvous site about 5 km northwest of the den, which had apparently been used in 2009 and 2013 as a rendezvous site as well. All 3 pups survived until at least November 2015.

Double litters occur infrequently in wolf packs, often where wolves are colonizing new ranges. Several instances of multiple breeding females in a pack were reported in the Greater Yellowstone Ecosystem during wolf reintroduction in the 1990s, and in Idaho and Montana as wolves recolonized those areas (Bangs 2003, Smith and Bangs 2009). Smith and Bangs (2009) estimated that 15% of breeding attempts in packs with more than one adult female result in double litters, particularly if the packs contain unrelated animals. Other reports of double litters come from Denali (Murie 1944, Mech et al. 1998) and Baffin Island (Clark 1971), as well as the Eureka wolves in 2010, when 2 females were nursing 5 pups. Genetic samples were collected from the 2010 Eureka pups, but were not sufficient to determine whether the litter was comprised of offspring from both females. Frame et al. (2004) recorded 3 lactating females caring for a litter of 6 pups in the Northwest Territories, and recorded multiple breeding females at one or more dens every year from 1997 to 2002. They hypothesized that multiple breeding females caring for the pups could be a strategy to deal with seasonal scarcity of prey, allowing for long foraging movements to aggregations of caribou on or near calving grounds (Frame et al. 2004). The High Arctic wolves are not dependent on migratory caribou herds, but the same strategy could address unpredictable prey abundance and distribution. Alternately, the system could be more productive than previously expected, mirroring areas of high prey density and expanding wolf populations.

Collar Deployment

Since helicopter darting proved successful in 2014, we used a Pneu-Dart rifle with brown .22 blank and barbed 3-cc darts, but to reduce the impact on the wolves, we also brought a net-gun to determine whether it was a feasible capture method. W444 was darted and W445 was netted. Net-gunning was the preferred method, since it lowers the risk to the animal and it is still feasible from a Bell 206 with a window. A padded Y-pole was used to restrain the wolf while Telazol was hand-injected (7 mg/mL at 15 mg/kg). Once immobilized, wolves were weighed, measured, sampled, and fitted with Vectronic Vertex Iridium satellite collars. W445's collar is programmed for 2-hour fixes and a drop-off in summer 2017; W444's collar is programmed for 1-hour fixes and a drop-off in summer 2016. The shorter deployment on W444 will ensure that accelerometer data stored on-board the collar (it cannot all be transmitted via satellite) are retrieved in a timely manner to allow ground-truthing of behaviour and kill sites. Collared wolves are summarized in

Table **2** and locations are shown in Figure 2.

Table 2.GPS-collared wolf update for fall 2015, High Arctic wolf ecology project.

Wolf ID	Collar ID	Pack	Collar Duration	Sex	Age	Capture Latitude	Capture Longitude	Weight (kg)
W444	18851 (Vectronic); 2-hr fixes	Eureka	03-Jun-15 to present	M	Adult	79.991	-85.772	38.0
W445	18850 (Vectronic); 1-hr fixes	Axel Heiberg – Gibbs Fiord	05-Jun-15 to present	F	Adult	79.744	-87.858	32.0
W443	36137 (Lotek); 1-hr fixes	Blacktop Ridge	06-Sep-14 to present	M	Adult	80.12227	-84.5502	35.0
W442	36135 (Lotek); 1-hr fixes	Slidre River	06-Sep-14 to 28-Sep-14 (23 days)	F	Adult	79.95317	-84.6779	27.0
W441	36136 (Lotek); 1-hr fixes	Hot Weather Creek	30-Jun-14 to 10-Dec-14 (164 days)	F	2 yr	80.17695	-83.5726	29.5
W440	36134 (Lotek); 1-hr fixes	Axel Heiberg – Gibbs Fiord	15-Jul-14 to 03-Aug-15 (384 days)	M	2 yr	79.89303	-88.3022	34.5
W410	Telonics GPS/Argos; 12-hr fixes	Eureka	09-Jul-09 to 12-Apr-10 (278 days)	M	Est. 9 yrs	Eureka		41.0

From our limited sample, males average 34.1 kg and females are slightly smaller at 29.5 kg. Mech (1970) reported female wolves averaging 35-40 kg and males 43-45 kg, which would put these wolves slightly on the small side, but well within the range reported for Northwest Territories/northern Alberta (23-54 kg females, 29-60 kg males; Kelsall 1968, Fuller and Novakowski 1955) and Alaska (25-37 kg females, 27-51 kg males; R. A. Rausch pers. comm. in Mech 1970).

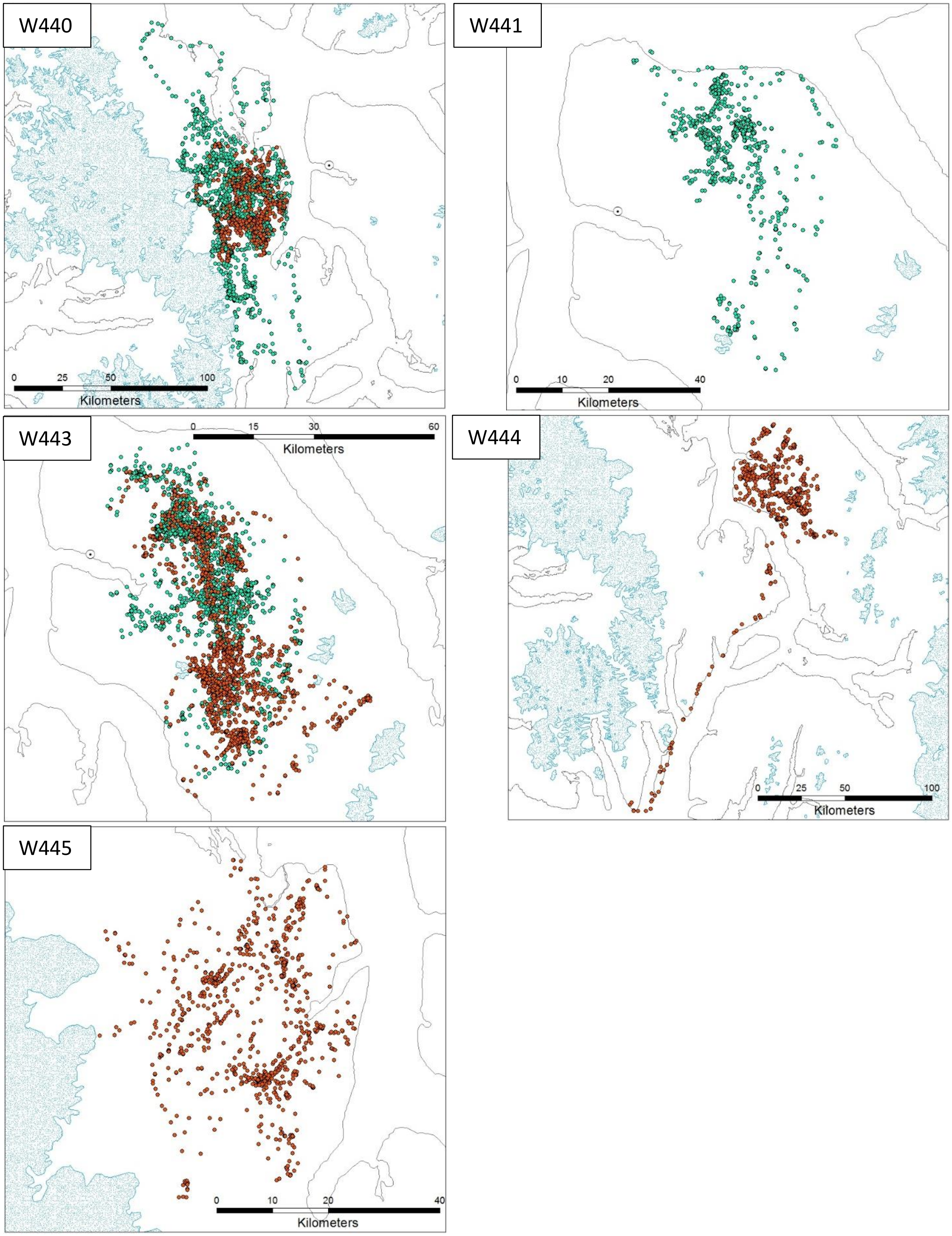

Figure 2. Locations for GPS-collared wolves in winter (Oct 1, 2014 - May 31, 2015; green points) and summer (Jun 1-Sep 30, 2015; orange points). Each point represents an hourly location, except the 2-hour locations of W444. White bull's-eye is Eureka weather station.

Home Range

We calculated minimum convex polygon (MCP) home ranges using the R user interface 'rhr' (Signer and Balkenhol 2015), which uses several R packages, detailed with the parameters in the output and provided in Appendix 1 for reproducibility of home range estimators. MCPs are a simple, intuitive way to represent and compare home ranges. They are particularly useful for comparing to historic home ranges, calculated before quantity and quality of data allowed the development of other home range estimators. However, MCPs do not provide any indication of the degree to which animals use parts of their home ranges.

To address this shortfall, we calculated Brownian bridge movement model (BBMM) home ranges using the R package 'adehabitat' (Calenge 2006) in R 2.15.3 (R Core Development Team 2013). Unlike kernel methods, which calculate a utilization distribution based on locations only, BBMMs assume a Brownian walk between successive locations, with the probable path influenced by the length of time and the distance between points (Bullard 1999, Horne et al. 2007, Kie et al. 2010). Also unlike kernel methods, BBMM home ranges avoid the problems associated with assuming independent points when locations depend on previous locations, and they avoid problems associated with large datasets, which are becoming increasingly common in telemetry studies (Hemson et al. 2005, Kie et al. 2010). The greatest positional uncertainty is halfway between known location points. The method works best with short intervals between successive locations, like the 1-hour fix interval used on these collars, and since it takes the time between points into consideration, autocorrelation is not an issue. It is sensitive to 2 smoothing parameters, one based on the GPS positional accuracy (taken here conservatively as 30 m, Loveless 2010, although retrieval of dropped collars will give us a better estimate for our system) and one based on the distribution of locations (i.e. the animal's behaviour and movement) and estimated here with the liker function in adehabitat.

[Note: adehabitat is not supported in newer versions of R and the package adehabitatHR now has the home range functionality.]

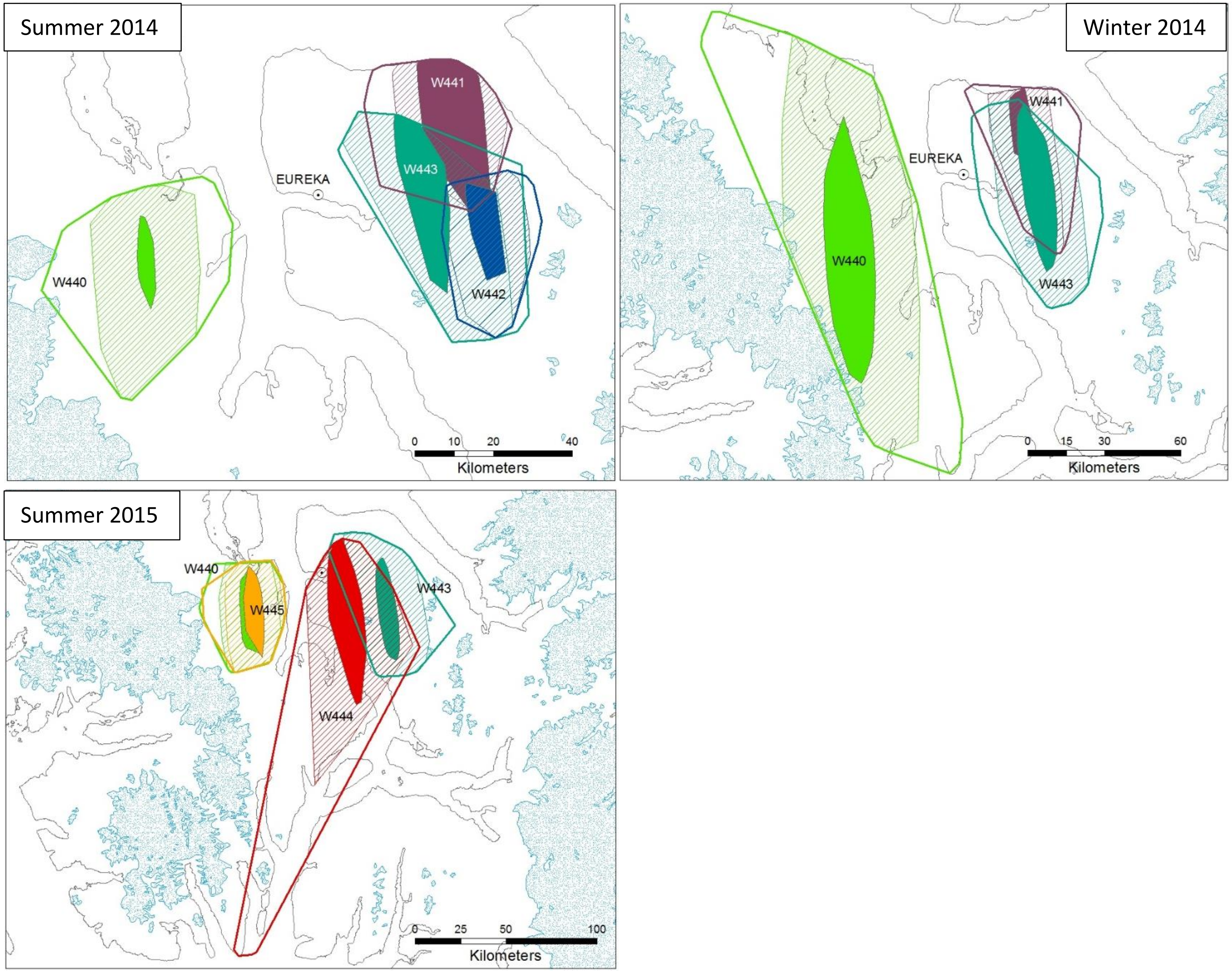

Figure 3. Home ranges for collared wolves in summer (Jun 1-Sep 30) and winter (Oct 1-May 31). Hollow outlines are 100% minimum convex polygons (MCPs), hatched areas are 95% MCPs, and solid areas are 50% MCPs. Stippled blue areas are glaciers and icefields.

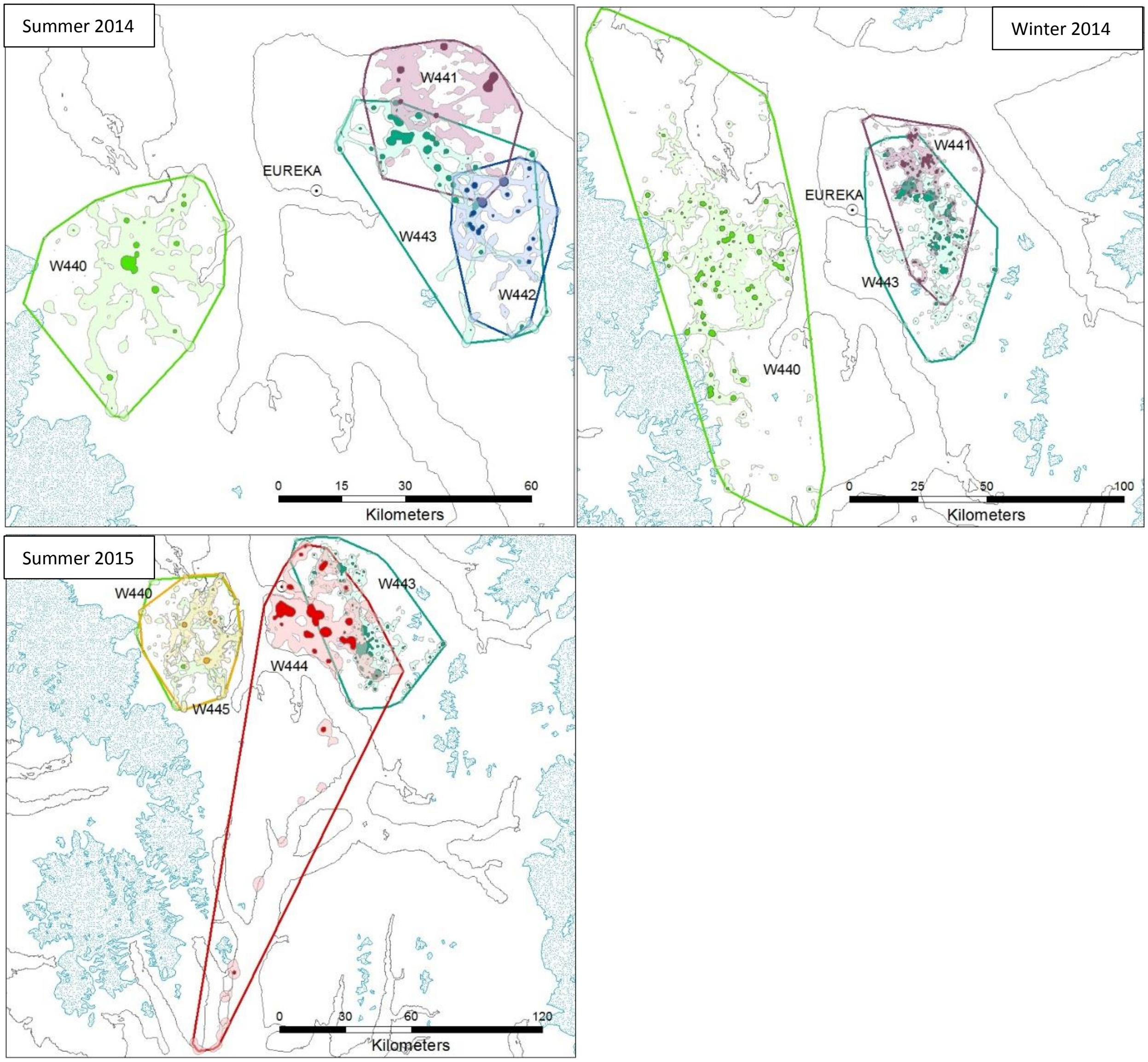

Figure 4. Home ranges for collared wolves. Hollow outlines are 100% minimum convex polygons , transparent polygons are 95% Brownian bridge movement model (BBMM) home ranges, and solid polygons are 50% BBMM core areas. Stippled blue areas are glaciers and icefields.

Overall, the space use of the wolves collared from 2014-2015 is that of a population maintaining territories year-round. The movements of W410 over winter 2009-2010 suggested that a large area was required to maintain the pack (Mech and Cluff 2011), although it may be that some of the long movements made by W410 (and presumably the pack) were forays off their territory. W444 visited some of the same areas off-territory as W410 had visited 5 years ago. Densities of prey may have been different during that study, but no quantitative estimates are available – especially for arctic hare. Mech (2005) did suggest that unusually early snow resulted in a muskox die-off in 1997, although muskoxen were again at high densities by 2006 (Jenkins et al. 2011). Muskoxen on south Ellesmere also experienced a die-off in the early 2000s and in 2005, from which the population has since recovered (Campbell 2006, Jenkins et al. 2011, Anderson and Kingsley 2015). The implications for predation dynamics are vastly different if wolves are territorial than if they exist in a nomadic state when not denning, and this could change depending on available prey resources.

Table 3. MCP and Brownian bridge movement model (BBMM) home range sizes for wolves collared from summer 2014 to summer 2015. Areas were calculated with a North Pole Lambert azimuthal equal area projection centered on the study area (latitude of origin 80°N and central meridian -92°W).

Wolf	Season	Collar Days	Collar Locations	100% MCP (km^2)	95% MCP (km^2)	50% MCP (km^2)	95% BBMM (km^2)	50% BBMM (km^2)
W440	Summer 2014	78	1832	1794	1182	77	621	24
	Winter 2014	212	5803	8803	6026	1457	1886	125
	Summer 2015	64	1519	2232	1719	396	705	21
W441	Summer 2014	93	2180	1111	816	506	392	16
	Winter 2014	71	1683	1867	1260	213	402	48
W442	Summer 2014	23	531	809	688	164	311	22
W443	Summer 2014	25	568	1798	1424	369	417	54
	Winter 2014	212	5808	2768	2125	618	826	122
	Summer 2015	122	2902	3301	2669	468	947	47
W444	Summer 2015	120	1247	9506	4728	1236	1750	210
W445	Summer 2015	118	2538	2124	1613	382	623	15

Wolf home ranges tend to be smaller in summer than in winter, since wolves are tied to den and rendezvous sites during the summer (Mech 1977). In North America, wolf territories range from less than 150 km^2 (Pimlott et al. 1969, Scott and Shackleton 1982, Fuller 1989, Mills et al. 2006) to larger than 1,500 km^2 in the boreal forest and tundra (Fuller and Keith 1980, Stephenson and James 1982, Oosenbrug and Carbyn 1982, Ballard et al. 1987, Hayes 1995, Ballard et al. 1997, Kuzyk 2002, Anderson 2012). The largest home range recorded was 13,000 km^2 in winter in Alaska (Mech 1970); the smallest was 18 km^2 in Algonquin (Ontario) in summer (Pimlott et al. 1969). Mech (1987, 1988) estimated home ranges could be greater than 2,500 km^2 for Ellesmere Island wolves.

Across their North American range, wolves generally occur at densities from 2 to 40 wolves per 1,000 km^2 (Paquet and Carbyn 2003 and references therein). Densities greater than 75 wolves/1,000 km^2 are sustained on the west coast of BC and Alaska (Tompa 1983, Darimont and Paquet 2000, Person 2001), and the highest reported wolf density was 1 wolf per 2 km^2 in a winter deeryard near Ontario's Algonquin Park, although this was only a temporary situation (Forbes and Theberge 1995, McRoberts and Mech 2014). Wolf density has not been investigated in the High Arctic, but Miller (1993) suggested based on limited anecdotal information that densities might be 0.3-0.5 wolves/1,000 km^2. In our study area of approximately 8,750 km^2 (based approximately on the 95% MCPs and including the area used by the uncollared Mt. Lockwood pack), based on fall pack counts in 2014 and an updated pack count for the

Eureka wolves in 2015, we estimate about 60 wolves, or about 7 wolves/1,000 km^2. The total number of wolves estimated includes pups at the end of summer, rather than when populations are at annual minimums in February/March (Mech 1970), although it also doesn't include an assumption of 10% lone wolves in addition to pack members (Fuller 1989). For comparison, the Alberta Rockies have 3-4 wolves/1,000 km^2 (Gunson 1995, Paquet et al 1996), and boreal Ontario has 4-8 wolves/1,000 km^2 (Kolenosky 1983). Densities on the barrenlands are generally around 2 wolves/1,000 km^2 (Parker 1972), although they can be as high as 90 wolves/1,000 km^2 where caribou congregate (Parker 1972) and in other areas may be lower than expected due to snowmobile-based hunting (Bergerud 1988).

Bergerud (1988) suggested that wolf densities above 6.5 wolves/1,000 km^2 were capable of limiting caribou populations. The wolf densities in our study area appear to be higher than this threshold, although whether it has any relevance to caribou persistence in the High Arctic is uncertain. Mech (1970) suggested that wolves may control prey populations when their densities are such that there is less than 11,000 kg of prey per wolf, as is the case on Isle Royale, but mass of prey per wolf has not been determined for the Eureka area yet.

Prey Surveys

Muskox

No muskox survey was conducted in 2015. An aerial survey of central Ellesmere is planned for March 2016 and would greatly inform our knowledge of prey distribution and abundance. The last survey was flown on central Ellesmere in 2006 and on Axel Heiberg Island in 2007 (Jenkins et al. 2011), and observations on Axel Heiberg are shown in Figure 4. Although there could be (and likely are) many interacting factors responsible for the apparent pattern of caribou in areas of lower wolf use and wolf use concentrated in high density muskox areas, it is a pattern worth investigating further.

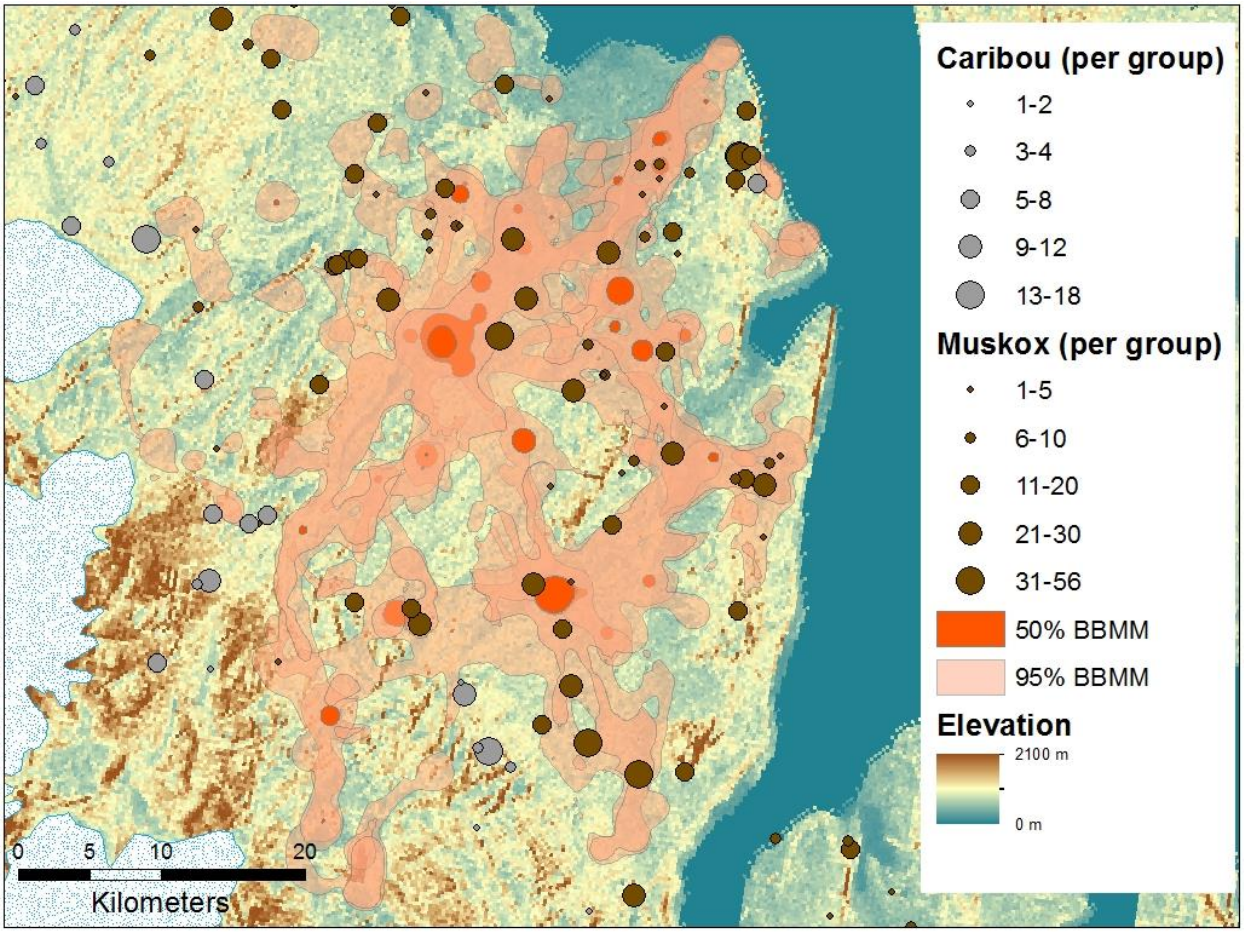

Figure 5. Distribution of muskox and Peary caribou groups observed in a May 2007 survey, shown with Brownian bridge movement model home ranges of W440 for summer 2014 and 2015 and W445 for summer 2015.

Arctic Hare

Each year, a ground survey is conducted for Arctic hares (Mech 2007). The survey consists of 2 people on ATVs, one ahead and one behind, driving the road to Skull Point and PEARL (Polar Atmospheric Environment Research Laboratory). Each surveyor counts the number of hares (adults and leverets) he or she sees on the way there and again on the way back, and the largest count is taken as the number of hares on the survey. The defined route along the road makes the survey repeatable, and it may provide some indication of widespread drastic changes in hare numbers, but it is an index and does not provide a population estimate.

The hare survey was not conducted in 2015, partly due to a reduced field season and partly because it was early in June. June hare counts, particularly with the altered sightability from patchy snow cover, would likely not be comparable to the July counts conducted in previous years. Quantifying hare abundance will be key to investigations of predator-prey interactions, as hares make up a substantial portion of the Arctic wolf diet, at least in summer (Mech 2007), and this remains an important data gap.

Kill Site Investigations

The early field season in 2015 prevented us from determining with certainty that many of the clusters we checked were not associated with prey remains. Snow persisted in gullies, on the lee side of hills, and in depressions in patterned ground and we could not definitively say some clusters were not associated with kill sites despite searching the area. We used the same cluster algorithm developed by Knopff et al. (2009) for cougar predation that we used in 2014, with clusters defined as 2 or more points within 175 m (Knopff et al. 2009) to locate potential kill sites. Cluster investigations were carried out mostly incidentally during capture activities and den searches, and are summarized in Table 4. W441, W442, and W443 all visited one muskox carcass; it had previously been detected when W442 was collared there on Sep 6, 2014. The two muskox carcasses that W440 visited were adult bulls within 50 m of each other, and the remains appeared to both be from the same time (kill site investigations in 2014 often revealed old muskox kills near the cluster kill sites, which was not the case here).

Table 4. Kill cluster investigations for summer 2015. Clusters were determined from the Knopff et al. 2009 algorithm, with the most recent clusters and those that might be den sites prioritized for investigation. Multiple visits to kill sites and dens resulted in several clusters for some sites.

Wolf ID	Date Range	Total Clusters	Clusters Checked	Clusters associated with kills (# of kills)	Clusters associated with dens (# of dens)
W440	Nov-Dec 2014	161	0		
	Jan-Feb 2015	139	0		
	Apr-May 2015	138	21	9 (2 muskoxen)	10 (2)
W441	Sep-Oct 2014	180	2	2 (1 muskoxen)	0
W442	Sep 2014	59	10	7 (1 muskoxen)	0
W443	Nov-Dec 2014	214	0		
	Jan-Feb 2015	201	0		
	Mar-Apr 2015	216	6	1 (1 muskoxen)	0
	May 2015	108	9	0	0

Since the satellite collars are also outfitted with accelerometers, we will be able to refine the kill cluster algorithm to more accurately identify kill sites. Even incorporation of basic accelerometer data (sum of activity over cluster locations) provides marked improvement over algorithms based only on location information (Moffatt 2012). Wolf behaviour at kill sites is different from behaviour at rendezvous sites, bed sites, and dens, however, so we expect to be able to further refine the kill cluster algorithm as the dataset for investigated clusters improves. Whiskers collected from captured wolves can also be analyzed for stable isotopes to determine the contribution of different prey types to the diet, but these analyses have not been completed to date.

Genetic Results

Genetic samples were taken from all collared wolves, and the 2014 samples were analyzed by Wildlife Genetics International under contract SC1410043. The blood blot filter paper cards were not effective for extracting DNA, and WGI recommends that future blood samples be on ordinary printer paper, which they have found works well for DNA extraction even after being stored at room temperature for decades. Additional samples were run for W441 and W442 due to low sample quality, but they still only amplified at 10 and 9 loci respectively; W440 and W443 amplified at 23 and 22 loci respectively.

Another 10 genotypes from the 2010 work were available for parentage analysis (more than 30 pup scats were collected in 2010 but amplified with little success), but the combinations of low sample size, low marker variability (observed heterozygosity = 0.60) and high consanguinity related to pack-based social structure (i.e. lots of full siblings) undermine the power to differentiate parent–offspring relationships from sibling relationships. Only 3 of the genotypes in the database are complete for the 22 loci, with some genotypes are missing as many as 9 markers. However, it was determined that W443 was not in a parent-offspring relationship with any wolves in the dataset, as there was no other individual with which he shared an allele at every marker. W440 shared alleles at all 15 markers with a wolf sampled in 2010, Individual 6 which, given the low genetic variability, can only be said to suggest a first-order (sibling or parent–offspring) relationship. Individual 6 is/was a Eureka wolf. Both W440 and Individual 6 share a weak 186 peak at allele o08, which had originally been dismissed as noise in the previous analysis of Individual 6. Combined with the movement data from W445 and W410, this strengthens the case that the wolves on the Fosheim Peninsula and Axel Heiberg Island function as one interisland population.

Incidental Reports

A shorter field season meant fewer incidental reports of wolves and less time discussing with other researchers in the area. Personnel at the Eureka weather station continue to report when the wolves move through and attempt to record pack counts and whether the collared wolf is visible. The collar is occasionally visible and noted by weather station staff or later seen in photographs.

Residents of Grise Fiord noted in early December 2015 that at least 2 wolves have been around the community for about a month. Another wolf was seen alone, and believed to be a third individual. This is unusual for Grise Fiord, where wolves usually move through and are not present for long periods.

An overflight on Lougheed Island in July 2015 counted about 110-130 Peary caribou, mostly on the north part of the island, no muskoxen, and 2 wolves on the south part of the island.

Management Implications and Future Work

The knowledge gaps in the muskox-caribou-wolf system have been brought up by the Peary Caribou Recovery Strategy Science Assessment Team (most recently at All Chairs Meeting in Yellowknife, Feb 17-19, 2015 and during Dec 2, Dec 8 2015 conference calls to review the knowledge assessment) and by COSEWIC during the Peary caribou status assessment (threat assessment conference call Sept 12, 2014). Certainly communities in the Northwest Territories, like Sachs Harbour and Ulukhaktok, and in the Kitikmeot, like Cambridge Bay, have mentioned increasing wolf populations as a threat to Peary caribou recovery (Peary Caribou Recovery Strategy consultations, Feb 26-28 and Mar 4-5, 2013 and All Chairs Meeting in Yellowknife, Oct 22-24, 2013, teleconferences Dec 2, Dec 8 2015). Although a classic apparent competition scenario could be present it has not been investigated to present (Miller 1993, confirmed at more recent Peary caribou Recovery Strategy discussions). The mechanism of caribou decline when muskoxen are abundant (a pattern that community members often notice and that is also known through Inuit qaujimajatuqangit) is unknown.

The 2 years of data on 6 wolves in 5 packs have already started to address some of these pressing questions. We have established that wolf populations in parts of the High Arctic exist at relatively high densities, comparable to the boreal forest and even approaching or exceeding Bergerud's (1988) wolf density threshold for caribou persistence (although the relevance of that threshold is unknown for Peary caribou in the High Arctic). We have also found that wolves remain on territories year-round. This means that there is not a time when wolf territories present a significantly lower predation risk due to wolves moving away. This could be an important factor in Peary caribou distribution and movement, particularly if they employ a 'spacing away' tactic to minimize predation risk, like woodland caribou. Wolves do not use their territories uniformly, however, so predation risk will still vary across the landscape.

Although previous locations from the collared wolf in 2009 showed movements between the Fosheim Peninsula and Axel Heiberg Island, the additional location information from the Eureka pack crossing to Axel Heiberg and the genetic similarity between W440 of Axel Heiberg and a previously genotyped Eureka wolf suggests that eastern Axel Heiberg Island and the northern Fosheim Peninsula form part of the same interisland population. The lack of locations south of the Sawtooth Mountains suggests that the mountain range may form more of a barrier than the frozen fiords and sounds, although long ice crossings are still not common.

From an ecosystem monitoring standpoint, the project continues to provide baseline information on den/territory occupancy, pack size, and litter size for wolves in an area of development interest. Although Canada Coal retracted its Nunavut Impact Review Board application to develop coal licenses held on the Fosheim Peninsula in 2013, the abundance of high-grade thermal coal at the surface, and potential for metallurgical coal, will likely continue to draw attention from developers as the arctic becomes increasingly accessible.

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