

Peary caribou (*Rangifer tarandus pearyii*) are small, light-coloured caribou inhabiting the Canadian Arctic Archipelago. Unlike barren-ground caribou, they do not undertake large predictable migrations, although sporadically they may move long distances in search of forage and they are known to include several islands within their home ranges. They associate in small groups year-round, and disperse for calving rather than aggregating on traditional calving grounds as barren-ground herds do. The tendency of Peary caribou to move long distances across areas like sea ice that would be seen as barriers to other species, combined with infrequent scientific monitoring and their remoteness from communities, have made it difficult to define meaningful population units for Peary caribou. Even basic life history information is lacking across much of the species range. Peary caribou are an important part of high arctic ecosystems, and are vital to the Inuit and Inuvialuit communities that harvest them for subsistence and maintenance of traditional skills and values. For some communities, like Grise Fiord and Resolute Bay, Peary caribou are the only caribou available. Other communities, like Cambridge Bay, Taloyoak, and Gjoa Haven, have access to barren-ground or Dolphin and Union caribou, but Peary caribou are prized for their thick fat deposits and delicious meat.

The strong cultural link between community members and caribou also manifests in community concerns for caribou during research activities. Community involvement is essential on surveys, and local experts are increasingly engaged to provide guidance on survey timing and ways to minimize disturbance. Invasive procedures like capture and collaring are not supported for caribou, for a number of reasons varying from concern of physical damage from the collar to the impact of handling on the animal's metaphysical state. Pursuit of scientific knowledge through non-invasive methods relying on community involvement and knowledge is therefore encouraged.

The recent advances in genetic analysis has led to rapid expansion and application of non-invasive techniques for surveying and researching wildlife, including rare species detection, identification of diet items, mating system, population structure, movements, and abundance (Mills et al. 2000, Manel et al. 2003, Waits and Paetkau 2005, Schwartz et al. 2007, Ball et al. 2010, Hettinga et al. 2012, Galpern et al. 2012b, Shafer et al. 2014).

Genetic methods have previously been employed to determine the recovery mechanisms of Peary caribou on northern Ellesmere after Robert E. Peary's expeditions and harvests of muskoxen and Peary caribou in the early 1900s (Petersen et al 2010). The current caribou population on northern Ellesmere Island is more closely genetically related to the population on central Ellesmere Island than to the animals harvested by Peary, suggesting recovery through immigration rather than recruitment alone (Petersen et al. 2010). The gene flow in the Arctic islands is also being increasingly scrutinized – McFarlane et al. (2014) found that caribou collected on Prince of Wales Island were genetically similar to Peary caribou on Ellesmere Island and the High Arctic Island, but caribou on Banks Island and on Victoria Island were genetically similar to barren-ground caribou in the Northwest Territories. These patterns of gene flow will likely continue to shift as species ranges and movement patterns alter in response to climatic drivers and anthropogenic activities.

The information on movement, relatedness, range use, dispersal, and population definition that this project will provide will be important in supplementing existing local knowledge in development of policy for caribou conservation and management. In February 2011, Peary caribou were listed under the Species At Risk Act as Endangered, due to a series of large-scale catastrophic die-offs. These die-offs occur unpredictably when freezing rain and melt-freeze events prevent access to forage. A federal Recovery Strategy is currently being drafted to address knowledge gaps and prioritize recovery actions and timelines. The Government of Nunavut is currently involved in developing a

territorial management plan for Peary caribou and also provides guidance on the federal Recovery Strategy. Results of this work are also anticipated to be helpful in determining land use practices, including mineral and petroleum extraction (notably coal licenses on the Fosheim Peninsula, Ellesmere Island), the proposed Napartulik Territorial Park on Axel Heiberg Island, and Qausuittuq National Park on Bathurst Island.

OBJECTIVES

1. *Gene flow in the Arctic Archipelago:* Characterize and spatially identify movement corridors, sex-biased dispersal, and landscape features blocking/facilitating movement, including inter-island movements.
2. *Population recovery process for Bathurst Island:* The most recent survey of Bathurst Island, May 2013, shows a substantial recovery from the die-offs in 1994-1997. Genetic samples collected in 1998 and in 2013-16 will allow us to determine whether caribou on the island are primarily descended from survivors of the die-offs, or whether caribou have recolonized Bathurst Island from other areas.
3. *Landscape genetics on Ellesmere/Axel Heiberg Islands:* Previous genetic analyses indicated caribou on northern Ellesmere are more closely related to animals on central Ellesmere than to animals that lived on northern Ellesmere prior to Peary's expedition, when hundreds of caribou were killed. This suggests that the population in the north was not able to recover quickly on its own, and was supplemented by animals moving up from central Ellesmere. Genetic analysis of samples from central and southern Ellesmere, and nearby Axel Heiberg, will provide more insight into these source-sink dynamics.
4. *Population definition:* Working with samples from across the High Arctic, phylogenetic and population genetic analyses will be done to delineate and characterize the main population units. These samples will also contribute to characterize the differences (and extent of genetic introgression) among Peary caribou, Dolphin-Union caribou and barren ground caribou. This is a longer-term objective.

This interim report provides an update on field activities in summer 2015 and 2016, which were undertaken to address the objectives above. It provides an update from the previous report, Anderson et al 2015, which covered the summer 2013 and 2014 fieldwork and preliminary analysis.

METHODS

Field Sampling

Detailed descriptions of field sampling protocol are provided in Anderson et al. (2015). The same pellet collection and swabbing techniques were used in 2015 and 2016, as well as collection of incidental tissue and bone samples when encountered.

COMMUNITY CONSULTATION AND INVOLVEMENT

Survey observers for the Devon Island and Prince of Wales/Somerset islands surveys (although we did not collect any samples for this project): Resolute - Debbie Iqaluk, James Iqaluk, Thomas Kalluk, Belinda Oqallak, PJ Attagootak, Saroomie Manik, Oolat Iqaluk; Taloyoak - Eric Saittuq, Robert Quqqiaq, Bill Ekalik; Grise Fiord - Etuangat Akeeagok, Aksakjuk Ningiuk, Jopee Kiguktak, Frankie Noah, Olaph Christianson, Simon Singoorie, Junior Kakkee; Arctic Bay/Iqaluit - Keesha Allurut. The assistance of Government of Nunavut summer student Etuangat Akeeagok, who had previously worked on the project in 2014, was again key to the success of the targeted pellet collection work, and James Iqaluk and Samson Simeonie also assisted with sample collection.

Consultation - Iviq HTA, July 18 2016 19:30-21:30, at Grise Fiord hamlet office. In attendance: Jaypetee Akeeagok (chair), Jopee Kiguktak, Amon Akeeagok, Imooshie Nutaraqjuk, Aksakjuk Ningiuk, Etuangat Akeeagok, Charlie Noah, Monasie (secretary-manager filling in for Terry Noah), Morgan Anderson. Update on on-going research and monitoring, including most recent results of the genetics work. Continued enthusiasm and support for the research and appreciation of the commitment to reporting the results back to the community.

Presentation – Qiqiktaaluk Wildlife Board meeting regarding caribou grounds, Jun 2-3 2016 in Iqaluit. The project was brought up briefly as a way in which communities and scientists can work together to understand caribou.

FIELDWORK 2015-16

Sample collection in 2015 was focused on Axel Heiberg and central Ellesmere islands, Byam Martin Island, Bathurst Island, and Melville Island. We conducted a reconnaissance flight by Twin Otter to Loughheed Island to determine whether there were sufficient densities of caribou and suitable landing areas to allow a ground-based collection effort. We collected samples on northern Bathurst Island east of the park boundary and north of Polar Bear Pass, with a drop-off and pick-up by Twin Otter at Airstrip Point. We collected samples by helicopter for one day on Byam Martin Island before being dropped off west of Rae Point on Melville Island and hiking out to Rae Point while collecting additional samples. Sample collection was incidental to other work on Axel Heiberg and central Ellesmere islands in July. Additional samples were submitted from May 2015 on southern Bathurst Island by Wildlife Officer Tabitha Mullin. Aksakjuk Ningiuk also contributed pellet samples from the south coast of Ellesmere Island.

Sample collection in 2016 was targeted on Axel Heiberg Island and Loughheed Island, using ground-based backpacking trips. Additional sample collection opportunities in Quttinirpaaq National Park (QUNP) and Qausuittuq National Park (QANP) did not return any samples. Caribou were seen in QANP during other work (primarily scouting trips and vegetation sampling on a separate project), but crews did not collect samples. No aircraft hours dedicated to this project were flown in either national park. Weather prevented additional targeted sample collection on Bathurst Island, either in QANP or at Polar Bear Pass NWA, in 2016, so no Bathurst Island samples were collected in summer 2016.

Additional sampling opportunities were expected during 2016 survey work on Devon (March 20-30), Prince of Wales and Somerset islands (Aug 4-20), but no caribou were encountered on Prince of Wales or Somerset island, and caribou were not seen in areas where the survey aircraft could land on Devon Island. Incidental samples from caribou harvested at Sor Fiord were collected from harvesters in Grise Fiord during the survey.

PLANS FOR FIELDWORK 2017

We plan to continue to collect samples incidentally, either from community members on the land, from animals they harvest, or from other crews working in the High Arctic, including Parks Canada staff in QANP and QUNP, although no specific targeted sample collection has been planned.

PRELIMINARY RESULTS

Field Sampling

We collected pellet, hair, and tissue samples from Bathurst, Byam Martin, Melville, and Ellesmere islands in 2015:

Southern Bathurst Island – May 2015 – Tabitha Mullin, 7 pellet samples, 1 tissue sample.
Southern Ellesmere Island – April 2015 – Aksajuk Ningiuk, 1 pellet sample.
Airstrip Point, Bathurst Island – July 25-27 2015 – Morgan Anderson, Samson Simeonie, James Iqaluk, 18 hair samples, 66 pellet samples.
Byam Martin Island – July 28 2015 - Morgan Anderson, Samson Simeonie, James Iqaluk, 20 hair samples, 40 pellet samples.
Rae Point, Melville Island – July 28-30 2015 - Morgan Anderson, Samson Simeonie, James Iqaluk, 26 hair samples, 1 pellet sample.

We collected pellet, hair, and tissue samples from Axel Heiberg, Ellesmere, and Lougheed islands in 2016:

Sor Fiord, Ellesmere Island – Mar 27 2016 – Terry Noah et al, 4 samples of fresh blood dried on printer paper.
Axel Heiberg Island – Jul 9 2016 – Morgan Anderson, Etuangat Akeeagok, 1 lower jaw and 1 lower leg.
Lougheed Island – Jul 28-29 2016 - Morgan Anderson, Etuangat Akeeagok, James Iqaluk, 23 pellet samples.

All samples were sent to the genetics lab at Trent University for analysis. Pellet swabs were sent to the lab but the pellets themselves are archived in the Igloolik Department of Environment research lab freezers for further analysis of parasites and disease, and as a back-up if swabs fail to provide sufficient genetic material.

Final Reports

Manuscripts are currently under review (see abstract in Appendix 1) and in preparation and will be provided to Parks Canada, CWS and the GN on completion. In addition, results were presented at the 14th Arctic Ungulate Conference in Røros, Norway, August 2015, by Micheline Manseau (*Landscape genetics and population trends of Peary caribou in the Canadian Arctic Archipelago*) and Cornelyia Klütsch (*Circumpolar meta-analysis of mitochondrial DNA reveals the complex phylogeographical structure and evolutionary history of Rangifer*).

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- Galpern P, Manseau M, Hettinga P, Smith K, Wilson P 2012a Allelematch: an R package for identifying unique multilocus genotypes where genotyping error and missing data may be present. *Mol. Ecol. Resour.* **12**, 771-778.
- Galpern P, Manseau M, Wilson PJ 2012b Grains of connectivity: analysis at multiple spatial scales in landscape genetics. *Molecular Ecology* **21**, 3996–4009.
- Galpern P, Peres-Neto P, Polfus J, Manseau M 2014 MEMGENE: Spatial pattern detection in genetic distance data. *Methods in Ecology and Evolution* **5**, 1116-1120.
- Hettinga PN, Manseau M, Arnason AN, Cross D, Whaley K, Wilson PJ 2012 Estimating size and trend of the North Interlake woodland caribou population using fecal-DNA and capture-recapture models. *Journal of Wildlife Management* **76**:1153-1164.
- Manel S, Schwartz MK, Luikart G, Taberlet P 2003 Landscape genetics: combining landscape ecology and population genetics. *TRENDS in Ecology and Evolution* **18**, 189-197.
- McFarlane K, Miller FL, Barry SJ, Wilson GA 2014 An enigmatic group of arctic island caribou and the potential implications for conservation of biodiversity. *Rangifer* **34**, 73-94.
- Mills LS, Citta JJ, Lair KP, Schwartz MK, Tallmon DA 2000 Estimating animal abundance using noninvasive DNA sampling: promise and pitfalls. *Ecological Applications* **10**, 283–294.
- Peakall R, Smouse PE 2012 GenAlEx 6.5: genetic analysis in Excel. Population genetic software for teaching and research – an update. *Bioinformatics* **28**, 2537-2539. (doi: 10.1093/bioinformatics/bts460)
- Petersen SD, Manseau M, Wilson PJ 2010. Bottlenecks, isolation, and life at the northern range limit: Peary caribou on Ellesmere Island, Canada. *Journal of Mammalogy* **91**, 698-711.
- Pritchard JK, Stephens M, Donnelly P 2000 Inference of population structure using multilocus genotype data. *Genetics* **155**, 945–959.
- Rousset F 2008. Genepop'007: a complete reimplementaion of the Genepop software for Windows and Linux. *Mol. Ecol. Resources* **8**: 103-106.
- Schwartz MK, Luikart G, Waples RS 2007 Genetic monitoring as a promising tool for conservation and management. *Trends in Ecology and Evolution* **22**, 25–33.
- Shafer AA et al 2014 Genomics and the challenging translation into conservation practice. *Trends in Ecology & Evolution* (online early view).

Waits LP and Paetkau P 2005 Noninvasive genetic sampling tools for wildlife biologists: a review of applications and recommendations for accurate data collection. *Journal of Wildlife Management* **69**, 1419-1433.

Appendix 1. Evolutionary reconstruction of Peary caribou supports the presence of a Pleistocene polar refugium for a large mammal species

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ABSTRACT

The potential of polar refugia during the Pleistocene requires reconsideration of the evolutionary histories of North American fauna and flora beyond the major refugia of Beringia and south of the Laurentide Ice sheet. Peary caribou (*Rangifer tarandus pearyi*), identified as a subspecies based on morphological characters, inhabits the Canadian Arctic Islands and Boothia Peninsula. Previous studies demonstrated incomplete lineage sorting of mitochondrial DNA interpreted as a Beringian origin. We used two molecular markers and Approximate Bayesian Computations testing the hypotheses of colonization out of Beringia into the Arctic Islands following the Last Glacial Maximum (LGM) or a divergence from Beringia significantly before the end of the LGM within a different refugium. The coalescent-based analyses rejected a recent Beringian origin with subsequent colonization, instead supporting a divergence of Peary caribou from Beringia ~100,000 years ago linking it to the last interglacial (125,000 – 75,000 years ago). Admixture on Banks Island with Beringian-derived barren-ground caribou is indicative of post-Pleistocene secondary contact; further supporting a divergent history of Peary caribou within a separated Arctic refugium. Increasing evidence of such refugia has significant implications on understanding the evolution of Arctic species, particularly in light of sensitivities and adaptive potential to a rapidly changing climate.