Estimates of wolverine density from mark-recapture DNA sampling, Aberdeen Lake, Kivalliq Region, Nunavut, 2013-14

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Summary

This report presents results for a wolverine (*Gulo gulo*) DNA mark-recapture study in the Kivalliq region, Nunavut conducted to establish baseline population abundance and density estimates for long term regional monitoring. Wolverine is an important cultural and economic resource traditionally harvested by Inuit. We used genetic analysis to identify individual wolverines from hair samples collected noninvasively by a science-driven study design and logistics facilitated by local hunters. From late March through early May 2013 and 2014 we sampled a grid of 209 posts baited with caribou (*Rangifer tarandus groenlandicus*) meat and scent lures spaced in 4x4 km (16 km^2) cells for three 10-day sessions in a 3,344 km^2 area north of Aberdeen Lake. In total we detected 21 (9F:12M) individual wolverines over two years of sampling, including eight individuals identified in 2013 and recaptured in 2014. Spatially explicit capture-recapture (SECR) methods were used to estimate density and average number of wolverines on the grid at any given time. Average or resident wolverine density was 2.36 wolverines/1,000 km^2 (SE = 0.34) in 2013 and 1.66 wolverines/1,000 km^2 (SE = 0.29) in 2014. Estimates of superpopulation size (number of wolverines within the effective sampling area) were 21 (CI=18-26) in 2013 and 14 (CI=11-19) in 2014. Superpopulation estimates were close or slightly above the number of unique wolverines detected on the sampling grid for each year, which suggests sampling was effective in detecting all the wolverines on the grid as well as the immediate surrounding area.

Simulations of sampling designs (post spacing and grid size) suggest that increasing post spacing while reducing the number of posts sampled can increase wolverine sample size and precision of the estimate. Wolverines in the area exist at low densities and are being exposed to increasing levels of human activity, with existing or proposed mining and subsistence harvest. Our results contribute to baseline data for wolverine ecology in the eastern mainland Arctic tundra and can be used to generate regional population estimates for future monitoring. The estimates can be used to evaluate current harvest, can provide a quantitative basis to establish future sustainable harvest limits and will support inputs to the Nunavut Impact Review Board (NIRB) review process. This collaborative research project with the Baker Lake Hunters and Trappers Organization (HTO) has provided valued training, employment and technical skills transfer to HTO members. Our results suggest that by involving local hunters, DNA based surveys offer a practical and cost-effective method to monitor wolverine populations in tundra situations. For better understanding of wolverine population in the area, we recommend long term monitoring by involving local HTOs and industry. This study demonstrates the efficiency of joint research projects to inform management.

Key words: *Gulo gulo*, wolverine, DNA, density estimates, Aberdeen Lake, Kivalliq, Nunavut, population, spatially explicit capture-recapture.

ᖃᔅᓯᐅᓇᓱᒋᔭᐅᓂᖕᒋᑦ ᖃᕝᕕᒎᖅᔪᐃᑦ ᐅᓄᖅᑎᒋᓂᖕᒋᑦ ᐃᒪᐃᑦᑐᒥᑦ, ᓇᓗᓇᐃᒃᑯᑦᑎᖅᓯᐊᓪᓚᓚᐅᕐᑐᓂ-ᐱᓯᒃᑲᓂᖅᐸᒃᑐᓂ DNA-ᖏᑎᒍᑦ ᖃᐅᔨᓴᖅᓯᓂᕐᒥᒃ, ᖃᒪᓂᕐᒥ, ᑭᕙᓪᓕᕐᒥᐅᓂ, ᓄᓇᕗᒥ, 2013-14

ᐅᓂᒃᑲᐅᓯᐅᓂᖓ

ᑖᓐᓇ ᐅᓂᒃᑲᐅᓯᖅ ᓴᖅᑭᑎᑦᑎᕗᖅ ᖃᐅᔨᒪᔭᐅᓕᖅᑐᓂᒃ ᖃᕝᕕᒎᖅᔪᖕᓄᑦ (*Gulo gulo*) DNA-ᖕᒋᓐᓄᑦ ᓇᓗᓇᐃᒃᑯᑦᑎᖅᓯᐊᓪᓚᓚᐅᕐᑐᓂ-ᐱᓯᒃᑲᓂᖅᐸᒃᑐᓂ ᖃᐅᔨᓴᕐᓂᓇᔭᐅᔪᒥᒃ ᑭᕙᓪᓕᕐᒥᐅᓂ, ᓄᓇᕗᒥ ᐱᓕᕆᐊᖑᓚᐅᖅᑐᒥ ᐋᖅᑭᒃᓯᒪᓕᖅᑎᑦᑎᔪᒪᑐᓂ ᐅᓄᖅᑎᒋᓂᖕᒋᓐᓂ ᖃᔅᓯᐅᓂᖕᒋᓐᓄᑦ ᐅᓄᖅᑎᒋᓂᖕᒋᑦ ᖃᓄᕐᓗ ᐱᑕᖅᑲᐅᖅᐸᒃᑎᒋᓂᖕᒋᓐᓄᑦ ᖃᔅᓯᐅᓇᓱᒋᔭᐅᓂᖕᒋᑦ ᐊᔪᖕᖓᑲᓪᓚᒃ ᐊᕕᒃᓯᒪᓂᓇᔭᐅᔪᒥ ᓇᐅᑦᑎᖅᓱᖅᓯᓂᐊᖅᑐᓂ. ᖃᕝᕕᒎᖅᔪᐃᑦ ᐱᒻᒪᕆᐅᕗᑦ ᐃᓕᖅᑯᓯᑐᖅᑲᒃᑯᑦ ᑰᓇᐅᔭᓕᐅᕋᓯᖕᓂᖅᓱᒍᓪᓗ ᐊᑐᖅᑕᐅᕙᒃᖢᑎᒃ ᐃᓕᖅᑯᓯᑐᖅᑲᖅᑎᒍᑦ ᐊᖑᔭᐅᕙᒃᑐᑐᖅᑲᐅᓪᓗᑎᒃ ᐃᓄᖕᓂᑦ. ᐊᑐᓚᐅᖅᐳᒍᑦ ᑎᒥᖕᒋᓐᓂᓖᖅᑐᒥᒃ ᖃᐅᔨᓴᖅᓯᓂᕐᒥᒃ ᓇᓗᓇᐃᓯᔪᒪᓪᓗᑕ ᐃᓛᒃᑰᖅᑐᓂᒃ ᖃᕝᕕᒎᖅᔪᓂᒃ ᒥᖅᑯᖕᒋᓐᓂᑦ ᖃᐅᔨᓴᒐᒃᓴᑎᒍᑦ ᑲᑎᑕᐅᓚᐅᖅᑐᑎᒍᑦ ᐸᒡᕕᓵᓇᔪᖅᑲᙱᒋᔾᔪᓂ ᖃᐅᔨᓴᖅᓯᓂᒃᑯᑦ-ᑲᔪᓯᑎᑕᐅᔪᒥᑦ ᖃᐅᔨᓴᕐᓂᓇᔭᐅᔪᒧᑦ ᐋᖅᑭᒃᓱᖅᑕᐅᓯᒪᔪᒧᑦ ᐱᓕᕆᔾᔪᑎᒋᔭᐅᔪᓄᓪᓗ ᑕᒪᓐᓇ ᑲᔪᓯᑎᑕᐅᓪᓗᓂ ᓄᓇᓕᖕᒥᐅᓂᑦ ᐊᖑᓇᓱᒃᑎᓂᑦ. ᒫᑦᓯᒥᑦ ᓄᖑᕈᔪᓕᕐᓂᖕᖓᓂᑦ ᒪᐃᒧᑦ ᐱᒋᐊᓕᕋᕐᓂᖕᖓᓄᑦ 2013-ᒥᑦ 2014-ᒥᓗ ᖃᐅᔨᓴᐃᓚᐅᖅᐳᑦ ᐋᖅᑭᒃᑕᐅᓯᒪᔪᓂᒃ 209-ᓂᒃ ᓇᑉᐸᖅᑎᖅᑕᐅᓯᒪᔪᓂᒃ ᓇᓇᔾᔨᖅᓯᒪᓪᓗᑎᒃ ᑐᒃᑑᑉ (*Rangifer tarandus groenlandicus*) ᓂᕐᑭᖓᓂᑦ ᑎᐱᓕᖕᓄᓪᓗ ᓇᓇᐊᓄᑦ ᐅᖓᓯᒌᒃᑎᒋᓂᖅᑲᖅᓗᑎᒃ 4x4 ᑭᓗᒦᑕᓂᒃ (16-ᓂ ᑭᓗᒦᑕᓂᒃ^{2}) ᐃᓂᓂ ᐱᖓᓱᓄᑦ 10-ᓄᑦ ᐅᓪᓗᓄᑦ ᐱᓕᕆᓂᐅᔪᓄᑦ ᐃᓂᒥ ᐊᖏᓂᖅᑲᖅᑐᒥ 3,344 km^{2}-ᓂᒃ ᐊᒡᒍᐊᓂ ᖃᒪᓂᐅᑉ ᑲᑎᔾᔪᒋᑦ ᖃᐅᔨᓴᖅᑲᓚᐅᖅᐳᒍᑦ 21-ᓂᒃ (9F:12M) ᐃᓛᒃᑰᖅᑐᓂᒃ ᖃᕝᕕᒎ 3 ᔪᖕᓂᒃ ᐊᕐᕌᒎᖕᓂ ᒪᕐᕉᖕᓂ ᖃᐅᔨᓴᕐᓂᖅᑎᓪᓗᑕ, ᐃᓚᒋᔭᐅᓪᓗᑎᒃ 8 ᐃᓛᒃᑰᖅᑐᑦ ᓇᓗᓇᐃᖅᑕᐅᓚᐅᖅᑐᑦ 2013-ᖑᑎᓪᓗᒍ ᐱᔭᐅᒃᑲᓐᓂᖅᑐᑎᒡᓗ 2014-ᒥ. ᐃᓂᒃᑰᑦᑎᐊᖅᑎᔾᔪᒋᑦ ᐱᔭᐅᓯᓂᖅ-ᐱᔭᐅᒃᑲᓐᓂᖅᓯᓂᕐᓗ (SECR) ᐊᑐᖅᑕᐅᔪᓐᓇᖅᑐᓂᒃ ᐊᑐᖅᑕᐅᔪᖅᑲᓚᐅᖅᐳᖅ ᖃᐅᔨᔾᔪᑕᐅᓇᓱᒃᖢᑎᒃ ᖃᔅᓯᐸᓘᓂᖕᒋᓐᓂᒃ ᖃᓄᖅ ᐅᓄᖅᑎᒋᓪᓗᑎᒃ ᑲᑎᔾᔪᒋᓪᓗ ᖃᔅᓯᐅᓂᓇᕙᒃᑕᖕᒋᑦ ᖃᕝᕕᒎᖅᔪᐃᑦ ᑕᒫᓂ ᓈᓴᐃᕝᕕᐅᔪᒥ ᖃᖓᑐᐃᓐᓇᒃᑯᑦ. ᐃᒪᓐᓇᐅᒐᔪᓚᐅᖅᐳᖅ, ᐅᕝᕙᓘᓐᓃᑦ ᖃᕝᕕᒎᖅᔪᐃᑦ ᐅᓄᖅᑎᒋᓂᖕᒋᑦ 2.36-ᖑᖅᑲᑦᑕᓚᐅᖅᐳᑦ /1,000 km^{2} (SE = 0.34) 2013-ᒥ ᐊᒻᒪᓗ 1.66-ᖑᓪᓗᑎᒃ ᖃᕝᕕᒎᖅᔪᐃᑦ/1,000 km^{2} (SE = 0.29) in 2014. ᖃᔅᓯᐅᓇᓱᒋᔭᐅᓂᖕᒋᑦ ᑕᕝᕙᓂᑦᑕᐃᓐᓇᖅ ᐅᓄᖅᑎᒋᓂᖕᒋᑦ (ᖃᔅᓯᐅᓂᓇᔾᖏᑦ ᖃᕝᕕᒎᖅᔪᐃᑦ ᑕᒫᓂ ᐊᑐᖅᑕᐅᔪᒥ ᖃᐅᔨᓴᕝᕕᒃᑖᕝᕕᐅᕙᒃᑐᒥ) 21-ᖑᓚᐅᖅᐳᑦ (CI=18-26) 2013-ᒥ 14-ᖑᓪᓗᑎᒡᓗ (CI=11-19) 2014-ᒥ. ᐃᓂᒋᔭᐅᔪᒥ ᖃᔅᓯᐅᓇᓱᒋᔭᐅᓂᖕᒋᑦ ᖃᓂᒃᓴᓚᐅᖅᐳᑦ ᖁᑦᑎᖕᓂᖅᓴᐅᕗᖅᔪᒃᓱᑎᒡᓗᓐᓇᓐᓂᑦ ᖃᔅᓯᐅᓂᐊᖅᓯᖕᓂᑦ ᐃᓛᒃᑰᖅᑐᑦ ᖃᕝᕕᒎᖅᔪᐃᑦ ᖃᐅᔨᔭᐅᔪᑦ ᖃᐅᔨᓴᖅᕕᐅᔪᒥ ᐃᓂᒥ ᑕᒪᐃᓐᓄᑦ ᐊᑐᓂᑦ ᐊᖅᑯᒍᒋᔭᐅᔪᓄᑦ, ᑕᒪᒃᑯᐊᓗ ᑕᑯᑎᑦᑎᓪᓗᑎᒃ ᑕᒪᓐᓇ ᖃᐅᔨᓴᕐᓂᓇᔭᐅᔪᖅ ᑲᔪᓯᓂᖅᑦᑎᐊᓚᐅᕐᓂᖕᖓᓂᒃ ᖃᐅᔨᔾᔪᑕᐅᓪᓗᓂ ᑕᒪᐃᓐᓂᑦᑎᐊᖅ ᖃᕝᕕᒎᔪᖕᓂᒃ ᑕᒫᓂ ᖃᐅᔨᓴᕝᕕᐅᔪᒥ ᐊᒻᒪᓗᑦᑕᐅᖅ ᑕᒪᑐᒪ ᖃᐅᔨᓴᕝᕕᐅᔫᑉ ᖃᓂᖏᔭᖓᓂ ᐃᓂᒥ.

ᐊᑐᖅᑕᐅᙳᐊᕐᓂᖕᒋᑦ ᖃᐅᔨᓴᖅᓯᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᓇᓱᖅᑐᑦ (ᓇᑉᐸᖅᑎᖅᑕᐅᓯᒪᔪᑦ ᐊᑯᑦᑐᓈᖅᑕᐅᓯᒪᓂᖕᒋᑎᒍᑦ ᐱᓕᕆᕝᕕᐅᔪᓪᓗ ᖃᓄᖅ ᐊᖕᒋᑎᒋᓂᖕᒋᑎᒍᑦ) ᐃᒪᓐᓇᐅᑦᑰᔨᑎᑦᑎᕗᑦ, ᐊᖕᒋᓪᓕᒋᐊᖅᑎᑦᑎᓂᖅ ᓇᑉᐸᑦᑎᑦᑕᐅᓯᒪᔪᑦ ᐊᑯᓐᓂᖕᒋᓐᓂᒃ ᑕᐃᒪᐃᓕᖅᓂᕐᒥᓂᓗ ᐅᓄᕈᓐᓃᖅᑎᑦᑎᒋᐊᖅᑐᑎᒃ ᖃᔅᓯᐅᓂᓇᔾᖕᒋᓐᓂᒃ ᓇᑉᐸᖅᑕᐅᓯᒪᔪᑦ ᖃᐅᔨᓴᕝᕕᐅᔪᑦ ᐊᖕᒋᓪᓕᒋᐊᖅᑎᑦᑎᔪᓐᓇᖅᐳᑦ ᖃᕝᕕᒎᔪᐃᑦ ᖃᐅᔨᓴᖅᑕᐅᓂᖕᒋᓐᓄᑦ ᓱᓕᓂᖅᓴᐅᓗᑎᒡᓗ ᖃᔅᓯᐅᓇᓱᒋᔭᐅᓂᖕᒋᑦ. ᖃᕝᕕᒎᔪᐃᑦ ᑕᐅᕙᓂ ᐃᓂᒦᑦᑐᑦ ᐅᓄᙱᑦᑐᑯᓘᑦᑐᑎᒃ ᐱᑕᖅᐳᑦ ᓴᖅᑭᕝᕕᐅᕙᓪᓕᐊᓪᓗᑎᓗ ᐅᓄᖅᓯᕙᓪᓕᐊᔪᓄᑦ ᐃᓄᖕᓂᒃ ᑕᐅᕙᓃᑦᑐᖅᑲᓕᖅᐸᖕᓂᖕᖓᓂᒃ, ᐱᑕᖅᑲᖅᐸᕐᑮᖅᑐᓄᑦ ᐱᓕᕆᐊᖑᒪᓂᐊᖅᑐᓄᓪᓘᓐᓃᑦ ᐅᔭᕋᖅᓂᐊᖅᕕᐅᔪᒪᔪᓂ ᐊᖑᓇᓱᒃᐸᖕᓂᓇᔭᐅᔪᒥᓗ ᐆᒪᔾᔪᑎᒋᓂᐊᖅᑐᒋᑦ. ᖃᐅᔨᔭᕗᑦ ᖃᐅᔨᓴᖅᓂᖕᒋᑦ ᐃᑲᔪᖅᐳᑦ ᑐᙵᕕᓴᐅᔪᒥ ᑎᑎᕋᖅᑕᐅᓯᒪᔪᓂᒃ ᖃᕝᕕᒎᔪᐃᑦ ᖃᓄᐃᓕᖓᓂᖕᒋᓐᓄᑦ ᑲᓇᖕᓇᖅᐸᓯᖕᒥ ᐅᑭᐅᖅᑕᖅᑐᒥ ᓇᐹᖅᑐᖅᑲᖅᑐᒥ ᑕᒪᓐᓇᓗ ᐊᑐᖅᑕᐅᓇᖅᓱᓂ ᐋᖅᑭᒃᓯᔾᔪᑕᐅᓗᓂ ᐊᕕᒃᓯᒪᓂᓇᔭᐅᔪᓂ ᖃᔅᓯᐅᓇᓱᒋᓐᓈᓂᕐᓂᒃ ᓯᕗᓂᒃᓴᒥ ᓇᐅᑦᑎᖅᓱᖅᓯᓂᐅᔪᒫᖅᑐᒧᑦ. ᖃᔅᓯᐅᓇᓱᒋᓐᓈᓂᑦ ᐊᑐᖅᑕᐅᓐᓇᖅᐳᑦ ᖃᐅᔨᓴᖅᓯᒪᓂᐊᑐᓂ ᒫᓐᓇ ᐊᖑᓂᓇᔭᐅᕙᒃᑐᓂᒃ, ᐱᑎᑦᑎᔪᓐᓇᖅᐳᑦ ᖃᔅᓯᐅᓂᖕᒋᓐᓄᑦ ᑐᙵᕕᒋᔭᐅᓂᐊᖅᑐᒥᒃ ᐋᖅᑭᒃᓯᒪᓕᖅᑎᑦᑎᔪᒪᑐᓂ ᓯᕗᓂᒃᓴᒥ ᖃᔅᓯᖏᕈᓐᓇᕐᓂᖕᒋᓐᓄᑦ ᐃᓱᓕᑦᑕᕝᕕᐅᓇᔭᖅᑐᓂᒃ ᐃᑲᔪᖅᑐᐃᓂᐊᖅᑐᓂᓗ ᐅᖅᑲᐅᓯᐅᔪᓂᒃ ᓄᓇᕗᒻᒥ ᐊᕙᑎᓕᕆᓂᖅᑯᑦ ᑲᑎᒪᔩᖑᑎᑕ ᖃᐅᒥᖅᑭᐊᖅᓯᒃᑲᓐᓂᖅᓯᓂᖅᑯᑦ ᐊᑐᖅᐸᒃᑕᖕᒪᓂᒃ. ᑕᒪᓐᓇ ᐱᓕᕆᖅᑎᑮᒃᔪᓂ ᖃᐅᔨᓴᖅᓯᓂᖅᑯᑦ ᐱᓕᕆᐊᖑᔪᖅ ᐱᓕᕆᖅᑲᑎᒋᔭᐅᓪᓗᓂ ᖃᒪᓂ'ᑐᐊᕐᒥᐅᓄᑦ ᐊᖑᓇᓱᒃᑐᓕᕆᔩᑦ (HTO-ᑯᑦ) ᐱᑎᑦᑎᖅᑲᑦᑕᖅᓯᒪᕗᖅ ᐱᐅᒋᔭᐅᑦᑎᐊᖅᑐᒥᒃ ᐊᔪᕈᓐᓃᖅᓴᖅᑎᑦᑎᓂᕐᒥᒃ, ᐃᖅᑲᓇᐃᔭᖅᑎᑦᑎᓂᕐᒥᒃ ᐱᓕᕆᔾᔪᑎᓄᓪᓗ ᓅᑎᑦᑎᓂᕐᒥᒃ ᐊᖑᓇᓱᒃᑐᓕᕆᔨᒃᑯᑦ ᐃᓚᒋᔭᖕᒋᓐᓄᑦ. ᖃᐅᔨᔭᕗᑦ ᐃᒪᓐᓇᐅᖅᑰᔨᑎᑦᑎᕗᑦ, ᐃᓚᐅᑎᑦᑎᓂᖅ ᓄᓇᓕᖕᒥᐅᓂᒃ ᐊᖑᓇᓱᒃᑎᓂᒃ, DNA=ᒥᒃ ᑐᙵᕕᑖᑦ ᖃᐅᔨᓴᕐᓃᑦ ᒪᓂᒪᑎᑦᑎᕗᑦ ᐊᑐᖅᑕᐅᑦᑎᐊᕈᓐᓇᖅᑐᓂᒃ ᐊᑭᑐᓗᐊᙱᑦᑐᓂᓗ ᐊᑐᖅᑕᐅᔪᓐᓇᖅᑐᓂᒃ ᓇᐅᑦᑎᖅᓱᖅᓯᓂᐊᕐᓗᓂ ᖃᕝᕕᒎᖅᔪᐃᑦ ᖃᔅᓯᐅᓂᓇᔾᖕᒋᓐᓂᒃ ᓇᐹᖅᑐᖅᑲᖅᑐᒥ. ᐱᐅᓂᖅᓴᒃᑯᑦ ᑐᑭᓯᐅᒪᔪᒪᑐᓂ ᖃᕝᕕᒎᖅᔪᐃᑦ ᖃᔅᓯᐅᓂᖕᒋᓐᓄᑦ ᑕᐅᕙᓂ ᐃᓂᒥ, ᐃᒪᓐᓇᐅᖅᑰᔨᓇᓱᖅᐳᒍᑦ, ᐊᑯᓂᐅᔪᒥᒃ ᓇᐅᑦᑎᖅᓱᖅᓯᖅᑯᔨᓗᑕ ᐃᓚᐅᑎᓪᓗᒋᑦ ᓄᓇᓕᖕᓂ ᐊᖑᓇᓱᒃᑐᓕᕆᔨᑭᓴᐅᔪᑦ ᑰᓇᐅᔭᓕᐅᕋᓯᖕᒋᐅᖅᑯᓗ. ᑕᒪᓐᓇ ᖃᐅᔨᓴᖅᓂᖅ ᑕᑯᑎᑦᑎᕗᖅ ᑲᔪᓯᓂᖅᑲᑦᑎᐊᕆᐊᖃᕐᓂᖕᒋᓐᓂᒃ ᑲᑐᔾᔭᐅᓪᓗᑎᒃ ᖃᐅᔨᓴᖅᓂᖕᒋᑦ ᐱᓕᕆᐊᖑᔪᑦ ᑐᓴᖅᑎᑦᑎᔪᒪᓂᐊᖅᑐᓂ ᐊᐅᓚᑦᑎᔨᒋᔭᐅᔪᓂᒃ.

ᐅᖅᑲᐅᓯᓪᓗᐊᑕᐃᑦ: *Gulo gulo*, ᖃᕝᕕᒎᖅᔪᒃ, DNA-ᖑᓂᖃᖅᑕᐅᔪᖅ, ᖃᓄᖅ ᐱᑕᖅᑲᖅᑎᒋᓂᖕᒋᑎᒍᑦ ᖃᔅᓯᐅᓇᓱᒋᔭᐅᓂᖕᒋᑦ, ᖃᒪᓂᕐᒥ, ᑭᕙᓪᓕᕐᒥ, ᓄᓇᕗᒻᒥ, ᖃᔅᓯᐅᓂᓇᔾᖕᒋᑦ, ᐃᓂᒥᒃ ᐊᑐᓪᓚᓇᒡᓗᓂ ᐱᓯᖅᑲᑦᑕᖅᓂᖅ-ᐱᒃᑲᓐᓂᖅᓯᖅᑲᑦᑕᖅᓂᖅ.

Itqurnarutait qakvingnik aulaniqaqtunik talvani naunaitkuhiqhimayunik - nanigiaqtauhimayunik Idjuhianik pukugianganik, Aberdeen Lakemi, Kivalliq Aviktuqviangani, Nunavut, 2013mi-14mun

Naittumik

Uvani iniqhimayunik titiraq aituihimayuq naunairutikharnik qalvingnik (*Gulo gulonik*) IDJUHINGNIK aulaniqaqtunik talvani naunaitkuhiqhimayunik - nanigiaqtauhimayunik qauyihaidjutikharnik talvani Kivallirmi aviktuqviangani, Nunavunt aulatitivakhimayut naunaiyaiyaangat amigaitilaangit aulavingitlu nallautiqhimayut hivutunigaalukmik atuqtangitni aviktuqvingmi munagihimaaqtunik. Qalviit akhurnaqtuq pitquhiliqinikkut maniliurutikharnik hanaqidjutikhaq pitquhiliqinikkut anguyauvakhimayut Inungnin. Atuqhimaanginaqtugut idjutikhangit ihivriudjutikharnik ilitagiyaanganik kituliqaak qalviit talvanga nuyait pukuktauhimayunik ilaungitunik talvanga nallunaqtunik ilituqhainiaqhimayunik qauyihaidjutikharnik havakhimayut naunaitkutingniklu uqagiikhimayunik nunalaani anguniaqtuliqiyikkungit. Nuungutiqviangani Qiqaiyaqvia talvunga Qiqaiyaqluarvia 2013mi 2014milu katitiqtuivakhimayut naunaitkutikharnik nunam nayugaani taima 209nik napaqutinik niriniaqhimayunik tuktunik (*Rangifer tarandus groenlandicusnik*) niqinik naidjutingniklu inikhalikhimayut taima 4 X 4nik ungahiktilaarutiqakhutik (16nik kilaamiitanik^{2nik}) nayugviinik taima pingahunik 10nik - ubluanik aulatitivakhimayut taima 3,344nik ungahiktilaarutiqakhutik kilaamiitanik^{2nik} hanigaini tununganirmi Aberdeen Lakemin. Tamaat katitiqhimayunik munagipluta pivakhimayugut 21nik (9F:12M-nik) qalvingnik talvuuna malrungnik ukiunganik katitiqtuivakhimayugut naunairutingnik, ilauplutik aitnguyut qalvingnik ilitagiyauhimayunik talvuuna 2013mi piyauvaffaaqtunlu talvuuna 2014mi. Ungahiktilaangit nanigiaqtauhimayut nanigiaqtauffaaqhimayutlu (SECR) atuqtangit atuqtauvakhimayut nallautigianganik ungahiktilaanganik qaffiutilaangitlu nampait qalviit talvani nayugaani talvaniitkaluaqtun. Naunaiqhimayut nayugaingit qalviit ungahiktilaarutikhangit imaatun itun 2.36 qaviingit/1,000 km^2 (SE = 0.34) in 2013 unalu 1.66 qalviit/1,000 km^2 (SE = 0.29) 2014mi. Nallautiqhimayuq anginirmik amigaitilaangat angikliyumiqhimayut (qaffiuyut qalviit talvani ihuatqiyauyumik atuqtauhimaaqtun ihivriuqtauyaangat nayugaini) imaatun itun 21 (CI=18-26) 2013mi unalu 14 (CI=11-19) 2014mi. Anginirmik amigaitilaangat nallautiqhimayut aadjikiivyaktun mikiumik angiyut nampait avaliqangitunik qalviit munagiyauhimayut ihivriuqtauvakhimayut talvani nayugaani ukiuk tamaat, taima ihumaliurutiqaqtun ihivriuqtauhimayut ihuagiyauvakhimayuq munagiyaangat tamainik qalvingnik talvani nayugaani taimaitutun qillaminuaq hanigaqaqtunik nayugaini.

Havagiikhimayut ihivriuqtauyukharnik havakhimayut (napaqutit hanigaingit nayugait amigaitilaangat) ihumaliurutiqaqhimayuq taima amigaiqyumiqtitiyukhat napaqutait nayugait taima ikikliyumigianganik napaqutait ihivriuqtauvikhat amigaikyumiqtitiniaqtun naunaitumik nallautiqhimayunik. Qalviit talvani nayugaini aulayut taima ikitun nayugainik tautungnarniaqtunlu amigaikyumiqhimayut taima inuit hulilukaakvingitni, aulahimaaqtunik tukhiqtauhimaaqtunlu uyaraqhiuqtunik anguniaqhimaaqtuniklu. Naunaiyagiikhimayut ihivriudjutit aituihimayut taima nayugaingit naunaitkutikharnik qaviit nayugait talvnai kivataani nunami Ukiuktaqtuniitunik nunami atuqtaugiaqaqtunik aulatitiyaangat aviktuqvingniitunik inugaingit nallautiqhimayut hivunikharni munagiyauyaangat. Tamna nallautiqhimayut atuqtaugiaqaqtun ihivriugianganik aulayut anguniaqtauvakhimayut, tunigiaqaqtun qafffiutilaaqharnik naunaiqhimayut hivunikhaptingni anguniarutikharnik ikayuutiniaqtuqlu ihumagiyauyut talvanga Nunavut Ayungnautiqaqqan Ihivriuqtukharnik Katimayiit (NIRB) ihivriuqtukharnik aulavikhangit. Una havaqatigiikharnik ihivriuqtunik talvani Qamanittuaq Anguniaqtuliqiyikkut (HTO) tunihimaaqpaktun ayuiqhautikharnik, havaktitivakhutiklu ayuittiarutikharnik qaritauyaliqidjutikharnik nuutigianganik HTOkutnun ilauyunun. Ihivriuqhimayaqut naunairutiit ihumaliurutiqaqtuq taima iluatitilugit nunalaani anguniaqtit, Idjuhikhangit (DNA) naunaiqhimayut ihivriudjutikhangit aituihimaarniaqtun naunaitumik akituvalaangitumik hanaqidjutikharnik munagiyaangat qalviit amigaitilaangit nunami aulayunik. Taima ihuatqiamik ilitugidjutikharnik qalvingnik amigaitilaanganik talvani nayugaini, ihumayugut hivutunirmik munagidjutikharnik taima ilautitilugit HTO-kut havagviingitlu. Una ihivriudjutikhaq naunaiyaivakhimayuq ihuagiyauhimayut havaqatigiikhutiklu ihivriuqtaunikkut havaaqhat ilitugipkaiyaangat munagiyauyunik.

Naunaitun tainiit: *Gulo gulo*, qalvik, IDJUHIIT (DNA), Ungahiktilaarutiit nallautiqhimayunik, Aberdeen LakeMI, Kivalliq, Nunavut, amigaitilaangit, ungahiktilaangit nayugait anguyauvakhimayut – anguyauffaaqpakhimayutlu.

Estimation de la densité de la population de carcajous basée sur les échantillons d'ADN provenant de l'opération de marquage-recapture près du lac Aberdeen, région du Kivalliq, Nunavut, 2013-2014

Sommaire

Ce rapport présente les résultats d'une étude de l'ADN à la suite d'une opération de marquage-recapture de carcajous (gloutons) dans la région du Kivalliq au Nunavut. Cette opération fut menée afin d'établir l'indice d'abondance et la densité de la population aux fins de monitorage à long terme. Le carcajou représente une ressource économique et culturelle traditionnellement récoltée par les Inuits. Nous avons fait appel à l'analyse génétique pour procéder à l'identification individuelle des carcajous à partir d'échantillons de poils recueillis de manière non invasive selon une stratégie scientifique et avec l'aide logistique des chasseurs locaux. De la fin mars au début mai en 2013 et 2014, nous avons disposé 209 pièges appâtés avec de la viande de caribou (*Rangifer tarandus groenlandicus*) et des leurres odoriférants répartis sur des parcelles de 4 km x 4 km (16 km^2) durant trois périodes de 10 jours chacune, couvrant une zone de 3 344 km^2 au nord du lac Aberdeen. Au total, nous avons recensé 21 (9F:12M) carcajous au cours des deux années d'échantillonnage, y compris huit individus identifiés en 2013 et capturés à nouveau en 2014. Des méthodes de capture-recapture spatialement explicites ont été utilisées pour estimer la densité et la population moyennes des carcajous dans chaque parcelle à tout moment. La moyenne de carcajous résidents était de 2,36 individus par 1 000 km^2 (SE = 0.34) en 2013 et de 1,66 carcajou par 1 000 km^2 (SE = 0.29) en 2014. Les estimations de superpopulation (nombre de carcajous au sein de la zone d'échantillonnage) étaient de 21 (CI=18-26) en 2013 et de 14 (CI=11-19) en 2014. Les estimations de superpopulation se situaient près ou tout juste au-dessus du nombre de carcajous individuels détectés dans la parcelle d'échantillonnage chaque année, ce qui suggère que l'échantillonnage s'est avéré efficace pour détecter tous les carcajous de la parcelle ainsi que dans la zone limitrophe.

Des simulations concernant le concept des échantillonnages (espacement des pièges et superficie des parcelles) donnent à penser que le fait d'accroitre l'espace entre les pièges tout en réduisant leur nombre pourrait augmenter le nombre d'échantillons et améliorer la précision des estimations. La population de carcajous dans la région est de faible densité et sera de plus en plus exposée à une activité humaine en croissance compte tenu de la présence de mines existantes ou proposées ainsi que de la récolte de subsistance. Les résultats obtenus contribuent à l'établissement de données de base sur l'écologie des carcajous dans la région est de la toundra arctique continentale et pourront être utilisés pour générer des estimations de la population de la région dans le cadre de monitorages à venir. Les estimations peuvent être utilisées pour établir les limites de récolte durable et serviront à appuyer le processus d'examen de la Commission du Nunavut chargée de l'examen des répercussions (CNER). Cette recherche, réalisée en collaboration avec l'organisation des chasseurs et trappeurs (OCT) de Baker Lake, s'est avérée une occasion d'offrir de la formation, de l'emploi et d'un transfert de compétences techniques aux membres de l’OCT. Nos résultats tendent à démontrer que l’implication des chasseurs locaux dans les enquêtes basées sur l’ADN constitue une approche à la fois pratique et économique pour procéder au suivi des populations de carcajous dans la toundra. Afin de mieux comprendre la population de carcajous dans la région, nous recommandons un monitorage à long terme qui implique tant les OCT que l’industrie. Cette étude démontre l’efficacité de projets de recherche mixtes pour renseigner la bonne gestion.

Mots-clés: *Glouton*, carcajou, ADN, estimation de la densité, lac Aberdeen, Kivalliq, Nunavut, population, capture-recapture spatialement explicite.

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1.0 INTRODUCTION

In Nunavut, the wolverine (*Gulo gulo*) is listed both as a furbearer (Schedule 5.2) and big game (Schedule 5.1) under the Nunavut Land Claims Agreement (NLCA). This non-hibernating, resident, solitary carnivore of Arctic tundra is an important cultural and economic resource traditionally harvested by Inuit. Nunavut represents the north-eastern edge of wolverine distribution in Canada. There is no precise population estimate yet for wolverines within the territory of Nunavut, nor is there any quantitative limit on their harvest by Inuit. Nevertheless, wolverine densities are believed to be moderate in the western mainland but low on the Arctic islands and in the eastern mainland (Slough 2007; Species at Risk Committee 2014). Inuit observations and recent reports suggest that wolverine numbers in Nunavut are either stable or slightly increasing (Awan et al. 2014; COSEWIC 2014). They also appear to be expanding their range eastward and northward (Awan et al. 2012; COSEWIC 2014).

The Committee on the Status of Endangered Species in Canada (COSEWIC) listed the wolverine as “Special Concern” across the Canadian range in 2014 (COSEWIC 2014). The species was also recently petitioned for listing under the US Endangered Species Act (Stewart et al. 2016). Primary threats to wolverine persistence identified by COSEWIC include habitat fragmentation and loss due to development and climate change. While this is true for most parts of the species’ southern range, the range fragmentation and habitat loss issues that affect southern populations may have limited effect so far on wolverines in Nunavut. However, there has been an increase in wolverine-human conflicts associated with recent mineral development projects, and there are indications of recent declines in wolverine numbers in the central barrens (Boulanger and Mulders 2013ab; Agnico Eagle Mines 2014; Species at Risk Committee 2014). Such scenarios can be expected to increase in Nunavut with the amount of development projects growing over time (NIRB 2012).

Arctic climates and ecosystems are changing at some of the fastest rates on earth (McLennan et al. 2012). It is believed that wolverines are demographically vulnerable and susceptible to impacts from climate change (Inman et al. 2012) and it has been suggested that species adapted to cold, snowy environments are particularly vulnerable to the impacts of predicted warming trends on the snowpack (McKelvey et al. 2011). Climate change impact is preeminent in the southern part of the wolverine range, and this impact is expected to increase northward (Inman et al. 2012). McKelvey et al. (2011) hypothesized that the geographic extent and connectivity of suitable wolverine habitat in western North America will decline with continued global warming. However, Webb et al. (2016) described that wolverines may be more flexible in their habitat selection and likely developed local adaptations depending on habitat type and resource availability. Various studies (Copeland et al. 2010; Peacock 2011; McKelvey et al. 2011) highlighted wolverine's requirement of snow cover for reproductive dens and identified wolverines obligate association with persistent spring snow cover for successful reproductive denning. Magoun and Copeland (1998) noted that at least 1 m of snow, distributed uniformly or accumulated in drifted areas, should be present throughout the denning period (February until May). Peacock (2011) believed that location of wolverine reproductive dens under deep snow provides insulating warmth to newborn kits and protection against predators. How climate change might influence spring snow cover and affect larger ungulates remains uncertain (COSEWIC 2014).

The wolverine is both a scavenger and predator throughout its range, caching food in boulder fields, snowbanks, or bogs for later use (Banci 1987; Mulders 2000; Mattisson et al. 2016). Within the Arctic ecosystem, caribou is an important species sustaining much of the tundra biodiversity, and trends in their numbers are important in the structure and functioning of the tundra ecosystem (Gunn et al. 2011). Wolverine diet analysis studies on the tundra (Mulders 2000; Awan et al. 2012; Mattisson et al. 2016; L'Hérault et al. 2016) revealed that wolverines rely predominantly on migratory caribou (*Rangifer tarandus*) and wolverine reproduction is limited by winter food availability (Persson 2005). The recent decline in caribou abundance in parts of the wolverine's range in the Canadian north (Gunn et al. 2011; Adamczewski et al. 2015) is expected to have some effect on wolverines in Nunavut. However, such potential effect is difficult to identify or quantify since we do not know how resident wolverine population may respond demographically to variation in prey abundance (Dalerum et al. 2009). Nunavut contributes substantial numbers to the national harvest and ecological data for tundra wolverine are sparse, especially in the north-eastern edge of distribution. Similar to other northern parts of the wolverine range, the Nunavut mainland is comprised of large undisturbed areas situated away from communities harvesting range. These areas with no or limited harvest act as reservoirs or refugia (source) to maintain or repopulate hunted populations (sink) of wolverines around the communities (Mulders 2000; Cardinal 2004; Krebs et al. 2004; Golden et al. 2007; Species at Risk Committee 2014; Gervasi et al. 2016). As these areas become more accessible due to resource development and increased use of highly efficient four-stroke snowmobiles by local hunters, populations of wolverines become more susceptible to overharvesting and disturbance. Given the current situation, there is a need to estimate the number of wolverines and monitor their trend, particularly in a changing Arctic.

The wolverine is an elusive species, occurring at low densities (Mulders 2000; Royle 2011; Boulanger and Mulders 2013ab), maintaining large home ranges (Mulders 2000; Dumond et al. 2012), and having long dispersal movements (Inman et al. 2012). Various techniques have been used to estimate wolverine population abundance or trends. In Arctic Alaska and southern Yukon, Magoun (1985) and Banci (1987) estimated wolverine density using telemetric monitoring. Landa et al. (1998) estimated minimum population size by monitoring natal dens in Scandinavia. Recently, researchers have used deoxyribonucleic acid (DNA) from hair collected at bait sites in the central barrens in the Northwest Territories (NWT) and in Alberta to estimate wolverine density (Mulders et al. 2007; Boulanger and Mulders 2008; Boulanger 2012; Boulanger and Mulders 2013ab; Fisher et al. 2013). Lofroth and Krebs (2007) and Royle et al. (2011) generated density estimates of wolverines captured on motion-detection cameras in British Columbia and southeast Alaska, respectively. Both aerial (Becker 1991; Becker et al. 1998; Golden et al. 2007) and ground (Golder 2007) snow track surveys were also used in open habitats in Alaska and NWT to index wolverine abundance and density estimates. However, Mulders et al. (2007) described that wolverine abundance indices obtained through snow track surveys are prone to observer bias and are affected by variable snow conditions, and error rates are difficult to assess. Boulanger and Mulders (2008) conducted the DNA-based mark-recapture studies in the Canadian Arctic at Daring Lake and the Ekati and Diavik mines in the Lac de Gras region. They estimated a density for females from 2.7 to 6.2 and for males from 1.3 to 4.5 wolverines/1,000 km² in 2003–2006. However, in Nunavut, we lack crucial information about their abundance and ecology, hampering justification and management of its harvest (Lee and Niptanatiak 1993).

Similar to other large carnivores, live-capture and tracking of the elusive wolverine which occurs at naturally low density in the remote tundra is expensive and time-consuming (Dumond et al. 2012). The NLCA established Hunters and Trappers Organizations (HTO) and Regional Wildlife Organizations (RWO) with specific roles and authorities, and through these organizations Inuit are co-partners in Nunavut wildlife management, including wildlife research. In Nunavut, harvest of wolverine and other furbearers for clothing and income is a seasonal and traditional activity, where opportunity for other employment is chronically scarce. Further, Inuit community concerns over wildlife handling gave rise to a need to adapt a culturally acceptable, non-invasive approach based on DNA-analysis with a field method that can benefit from Inuit hunter’s relevant skills and capacities (Inuit Tapiriit Kanatami 2016), while providing local employment and training. Furthermore, Boulanger and Mulders (2008) and (Golder 2007) argue that DNA-based methodologies are more powerful and robust for monitoring wolverine populations than track count methodologies. Recent studies have demonstrated that the hair-snagging sampling technique in a mark-recapture framework is feasible for wolverine and grizzly bear (*Ursus arctos*) in the tundra habitat (Mulders et al. 2007; Dumond et al. 2012, 2015), this was the approach selected in the present study to estimate density and monitor wolverine populations in the Kivalliq region.

1.1 Objectives

The primary objective of this project was to estimate wolverine population size and density utilizing Inuit hunter's relevant skills and capacities to develop a community-based monitoring protocol through a combination of culturally acceptable (non-invasive) scientific methods and hunters knowledge. This project is intended to be the basis for long-term monitoring of the species.

The specific objectives of the study were:

- Estimate wolverine population size and density within the Aberdeen Lake study area;
- Establish baseline wolverine population data which can be used for long-term population monitoring;
- Consider alternative designs to increase power to detect change in future sampling efforts; and
- Provide field work training, technology skills transfer and employment to HTO members and increase collaboration between government and resource users.

2.0 METHODS

2.1 Study Area

The study area was located north of Aberdeen Lake about 120 km northwest of Baker Lake (64° 48.715N, 98° 51.282W), and includes 3,344 km^2 in the Southern Arctic Ecozone and Back River Plain ecoregion (Fig. 1). The study area selection was based upon wolverine sightings, harvest pattern information collected from local hunters and elders, and opinion of knowledgeable biologists.

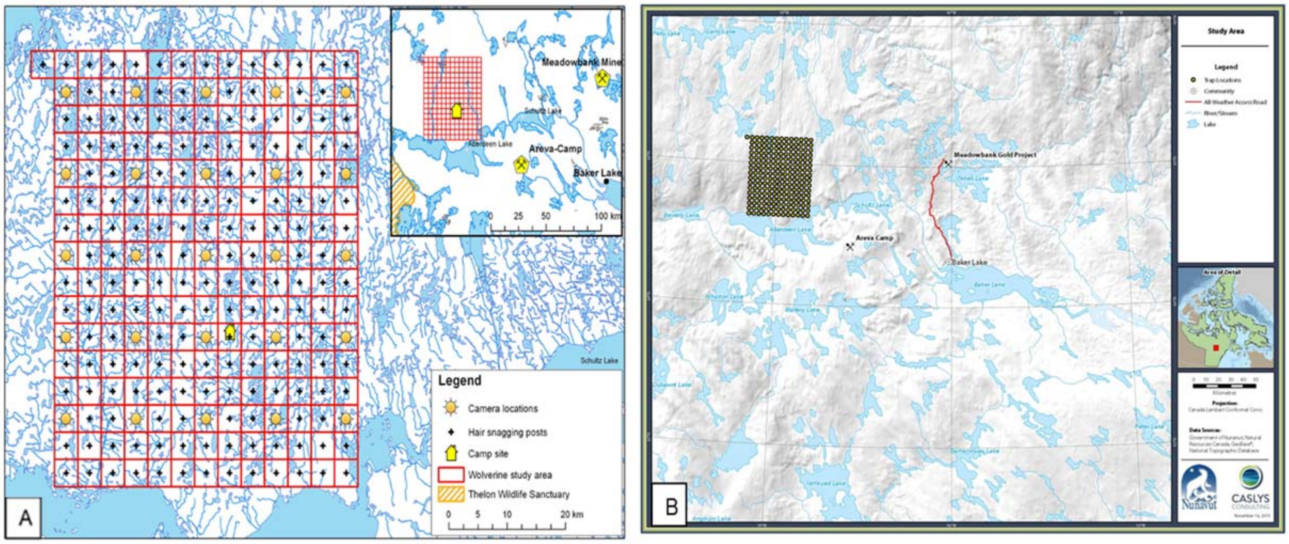


Figure 1. The Aberdeen Lake wolverine study area (A) and DNA grid in relation to Baker Lake and mining areas (B).

The ecoregion is marked by cool summers and very cold winters. The mean annual temperature is approximately -10.5°C with mean summer and winter air temperatures of 5.5°C and -26.5°C, respectively. Mean annual precipitation ranges from 200–300 mm. Elevation in the study area ranged from sea level to 300 m. The Back River Plain ecoregion is classified as having a low Arctic ecoclimate. The vegetation is characterized as shrub tundra, consisting of dwarf birch (*Betula nana*), willow (*Salix* spp.), northern Labrador tea (*Rhododendron tomentosum*), Dryas spp., and

Vaccinium spp. The ecoregion has high mineral potential (Ecological Stratification Working Group 1995).

We obtained snowfall data from the Environment Canada weather station in Baker Lake. Monthly snowfall in 2014 was 63% below average and 53% less than 2013 (Fig. 2). In 2014 there was little or no snow at higher elevations and spring thaw occurred early and rapidly.

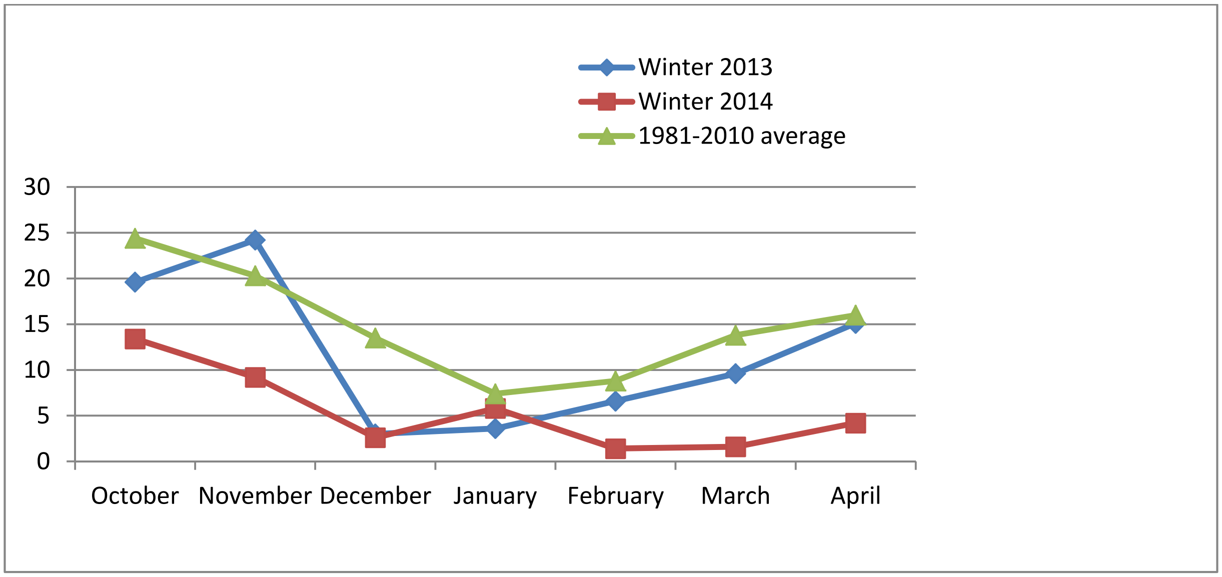


Figure 2. Monthly snowfall (cm) in Baker Lake, NU.

The Ahiak caribou herd migrates annually through the study area (Campbell et al. 2014). Muskoxen (*Ovibos moschatus*) also provide important food items for wolverine. Other prey species may include rodents, Arctic hare (*Lepus arcticus*), Arctic ground squirrels (*Spermophilus parryii*), voles and lemmings (*Muridae*), ptarmigan (*Lagopus* spp) and migratory bird species (Mulders 2000; Samelius et al. 2002; Dalerum et al. 2009; Awan et al. 2012). Other carnivores in the area included Arctic fox (*Vulpes lagopus*), red fox (*V. vulpes*), wolf (*Canis lupus*), and grizzly bears.

Hunters from Baker Lake and other Kivalliq communities have been harvesting wolverines and other furbearers from the study population. Moderate to heavy subsistence wolverine harvest occurs around the study area (mostly southeast of the grid) from November to May with a peak in March and April when the wolverine fur is in prime condition, days are longer and snowmobile travel is easier. The average annual reported wolverine harvest for Baker Lake (2010-2012) was 14 (range 11-18), biased toward males (73%) and sub-adults comprise 67% of the reported harvest. The majority of wolverine harvest occurred northwest of Baker Lake along the Thelon River and Schultz Lake area (Awan and Szor 2014). Since the study area is located on the northern periphery of wolverine distribution with ongoing subsistence harvest for fur, we predicted low wolverine density in the study area. Wolverines in the study area potentially are being exposed to increasing levels of industrial development. The operational Meadowbank Gold Mine is located approximately 110 km east of the study area, with a 110 km all-weather access road from mine to community of Baker Lake (Fig. 1B). Meadowbank Gold Mine is planning to expand its operations about 50 km further northwest of its Meadowbank mine. Another exploration camp, with proposed Areva uranium mine is located about 40 km southeast of the study area (Fig. 1B), although this mine is currently not proceeding.

2.2 Field methods

We conducted DNA sampling north of Aberdeen Lake during spring 2013 and 2014 following the non-invasive procedure developed by Mulders et al. (2007) for tundra wolverines. This study was designed to involve local hunters in the collection of samples, with three Baker Lake HTO members hired as part of the field research team. The DNA grid (Fig. 1A) was sampled from March 31st to May 7th in 2013 and March 28th to May 5th in 2014. During this time, 209 bait posts were sampled in a systematic sampling grid with 4x4km grid cells, each hosting a post in the cell centre. Each hair snare bait post consisted of a ~1.6m long and 10x10 cm post wrapped with barb-wire and anchored in packed snow (Appendix 1). Bait (~250g caribou meat) and a combination of commercial lures (Beaver Castor and Long Distance Call, O'Gorman Lures, Montana, USA) were attached to the top of the post with haywire. A GPS position of each bait post was recorded. Each post was visited 3 times at about 10-day intervals using snowmobiles. At each visit, all visible hairs were collected and the wood post was cleaned using a propane torch to remove any remaining hair. Each individual clump of hair was removed from the post and placed in labeled individual coin envelopes (post number, location on post and date) for storage. A fresh set of bait and lures was installed after every check. The number of caribou, muskoxen, and other prey species sighted or wildlife signs observed were recorded during the post set-up and while driving between posts to check for hair samples.

Twenty-five motion triggered digital cameras (Reconyx PC-800 Hyperfire Professional IR, Holmen, WI) were installed facing bait posts within the sampling grid to capture wolverine activity (Fig. 1A). The cameras documented wolverine sightings date and time of the visit, time spent at the hair snagging post, and captured images of other animals visiting the post. We considered only camera events when they captured wolverine approaching and departing from the post.

Upon the end of each field season, the samples were sent to Wildlife Genetics International (WGI), Nelson, BC for individual wolverine identification. From 2013 samples, we analyzed two samples per collection event (post/session combination) when there was more than one sample of suitable quality available. If possible, we selected the two samples from different sides of the post and used a minimum quality threshold of one guard hair root or five underfur hair samples. In 2014, all potential wolverine samples that contained at least one guard hair root or five underfur were analyzed. DNA was extracted using QIAGEN DNeasy Tissue kits, aiming to use 10 clipped guard hair roots, when available. Individual wolverines were identified using a ZFX/ZFY gender marker and the seven microsatellite markers, as applied to other wolverine projects in the tundra (Mulders et al. 2007; Dumond et al. 2012).

Due to low snow depth and an early melting season in 2014 a subset of posts (approximately every 3rd column of posts) was sampled in the 3rd session, 65% of posts were flat on the ground during the third session checkup and had strands of hair rather than large clumps of hairs trapped in the barbwire. Because of this, data were summarized in terms of wolverine numbers as a function of active detectors. In addition, approximate paths of wolverines based upon unique post detections per session were plotted.

2.3 Estimates of wolverine density and population size

2.3.1 Baseline model analysis

Spatially explicit capture-recapture (SECR) methods (Efford 2004, Efford et al. 2004, Efford et al. 2009, Efford 2011) were used to estimate density and population size of wolverines. Spatially explicit methods model both the first and subsequent detections of wolverines at posts, while accounting for the spatial configuration of posts in the landscape. The detection and redetection locations of wolverines on the grid partially identify a partial sample of where wolverines traversed both on and off the grid during sampling. Spatially explicit methods basically attempt to estimate the most likely spatial patterning and movement of wolverines on the grid from detection histories observed across the grid. More precisely, the detection probabilities of wolverines at their home range center (g_0), spatial dispersion of movements (σ) around the home range center, and density are estimated. An assumption of this method is that wolverine's home range can be approximated by a circular symmetrical distribution of use (Efford 2004). The actual shape and configuration of the sampling grid is used in the estimation process. This accounts for the effect of study-area size and configuration on the degree of closure violation and subsequent density estimates.

To avoid bias in estimates, a sex-specific detection and scale model was initially run to determine the effective sampling area of the grid and the dimensions of the SECR mask (a grid of points that lie on the grid and surrounding area in which density is estimated). The estimate of effective sampling area is proportional to the scale of movement (σ) estimated by the SECR model. This step indicated that the grid area needed to be buffered by 30 km to ensure non-biased estimates. A SECR mask of points spaced at 2 km intervals was overlaid on the study area and the 30 km buffer area around the study area. The SECR model then estimated density for each mask point.

For the baseline SECR analysis, a set of sex and year-specific SECR models were run to assess sex and year-specific movement and detection rate parameters. The basic approach was to first model variation in g0 and σ to obtain a base model for 2013 and 2014. The most supported base model was then used to obtain a parsimonious model that described yearly and sex-specific variation in density. Models were evaluated in terms of relative support information theoretical model selection, using sample size adjusted AIC_c scores (Akaike Information Criteria) to define the most parsimonius model (lowest AIC_c score; Burnham and Anderson 1998).

These estimates were then used to assess sampling efficiency and wolverine movements. Density and superpopulation estimates were then derived from the most supported SECR model (Efford and Fewster 2013). These were assessed in terms of precision as well as whether the number of wolverines in the area was sufficient for monitoring purposes. SECR analyses were conducted using the package *secr* (Efford 2014b) in the R software program (R Development Core Team 2009). Map plots were created using QGIS software (QGIS Foundation 2015).

2.3.2 Inference about spatial and temporal trends in wolverines

2.3.3 Temporal trends

The support of models that assumed that density did not change between years was compared to the support of models that estimated year-specific variation and sex/year-specific variation in density to assess dominant forms of variation in density during the surveys.

2.3.4 Spatial trends

The baseline SECR models were used to determine whether the distribution of wolverines on the grid could be described by its habitat features. For this analysis, the SECR mask was populated with remote sensing habitat covariates based upon a 1 kilometer buffer around each SECR mask centroid. The 1 km buffer effectively sampled the area that each mask centroid sampled therefore providing a way to associate density with habitat features. The ecological land classification (ELC) of the Kivalliq region (Campbell et al. 2012) and Northern Land Cover remote sensing habitat maps were considered for the analysis. Unfortunately, the ELC map only covered half of the study area and therefore the Northern Land Cover was used for the analysis. Northern Land Cover classes were pooled down to classes for SECR analyses based upon the mean proportion of each class in the wolverine grid SECR mask area (Table 1). In general, the Northern Land Cover classes were not that precise. For example, class 26 in Table 1 indicated that a pixel could be “Lichen-shrubs-herb bare soil or rock outcrop”, which indicates a wide range of potential habitat attributes.

Table 1. Northern Land Cover classes and the spatially explicit capture-recapture (SECR) pooled classes and their occurrence on the wolverine grid and 30 km buffer zone. The proportion class is the overall proportion that each class occurred on the study area as indicated in the SECR mask.

Northern Land Cover class	SECR pooled class	Proportion class
28-Low vegetation cover (bare soil rock outcrop)	bare	7.9%
39-Recent burns	burn	4.3%
1-Evergreen forest (>75% cover)—old	forest	0.3%
13-Mixed evergreen-deciduous open canopy (25–60% cover)	forest	0.0%
14-Mixed deciduous (25–50% coniferous trees; 25–60% cover)	forest	0.0%
3-Deciduous forest (>75% cover)	forest	0.0%
4-Mixed coniferous (50–75% coniferous)—old	forest	0.0%
6-Mixed deciduous (25–50% coniferous)	forest	0.0%
7-Evergreen open canopy (40–60% cover)—moss-shrub understory	forest	0.2%
8-Evergreen open canopy (40–60% cover)—lichen-shrub understory	forest	0.0%
9-Evergreen open canopy (25–40% cover)—shrub-moss understory	forest	0.1%
18-Herb-shrub-bare cover mostly after perturbations	herb	0.0%
23-Herb-shrub	herb	7.2%
41-Low vegetation cover	herb	1.8%
35-Lichen barren	lichen_barren	38.5%
26-Lichen-shrubs-herb bare soil or rock outcrop	lichen_shrub	3.9%
36-Lichen-shrub-herb-bare	lichen_shrub	11.3%
38-Rock outcrop low vegetation cover	rock	1.6%
15-Low regenerating to young mixed cover	shrub	0.1%
16-Deciduous shrub land (>75% cover)	shrub	0.2%
19-Shrubs-herb-lichen-bare	shrub	0.0%
21-Sparse coniferous (density 10–25%) shrub-herb-lichens cover	shrub	0.2%
22-Sparse coniferous (density 10–25%) herb-shrub cover	shrub	1.3%
24-Shrub-herb-lichen-bare	shrub	0.1%
25-Shrub-herb-lichen-water bodies	shrub	0.9%
37-Sparse coniferous (density 10–25%) lichens-shrub-herb cover	shrub	1.2%
20-Wetlands	water	0.1%
43-Water bodies	water	18.5%
45-Snow/ice	water	0.0%

The dominant pooled SECR landcover was lichen_barren (Fig. 3). During the surveys water bodies would be frozen and therefore represent a viable wolverine habitat type which was considered in the SECR analysis.

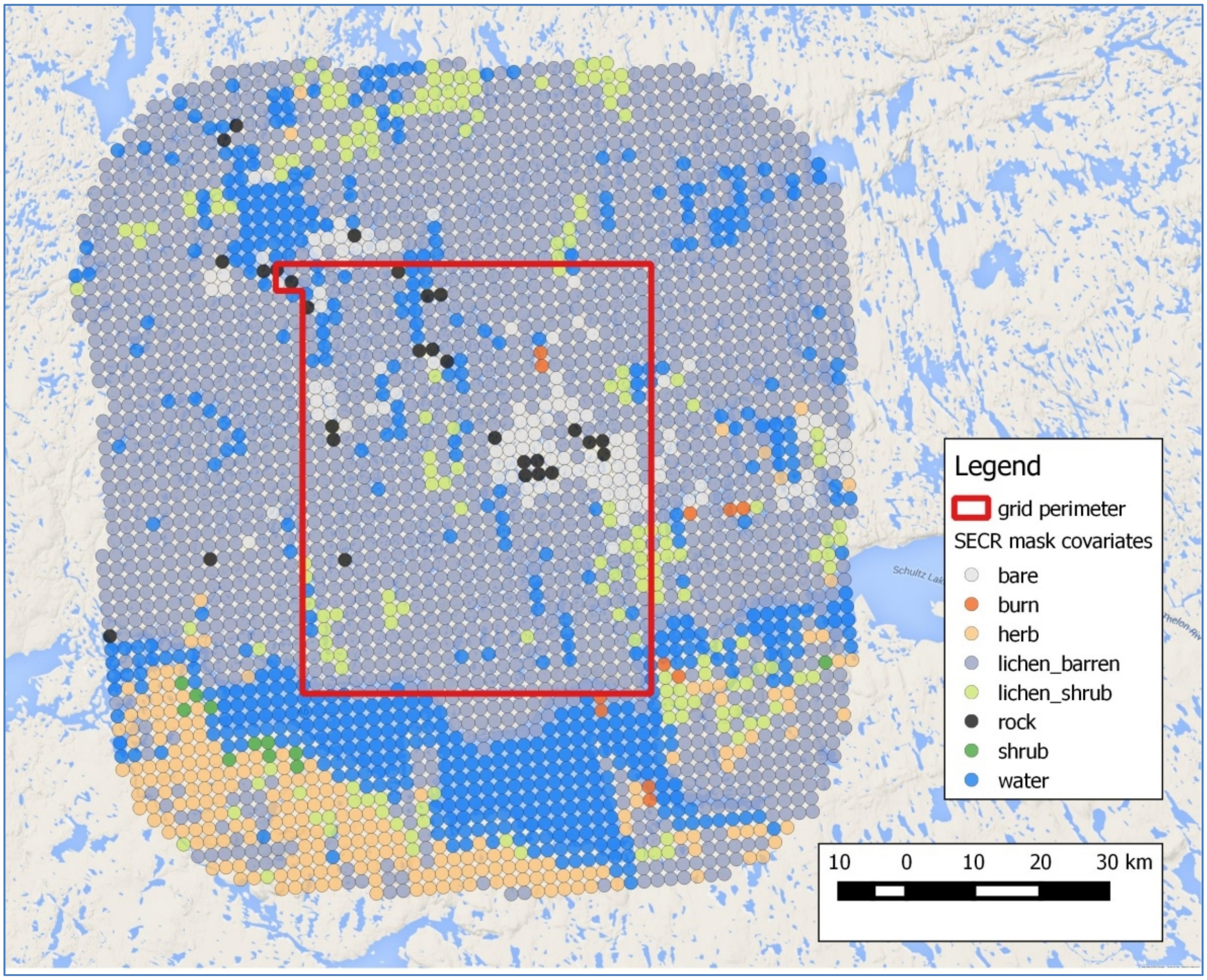


Figure 3. Dominant pooled Northern Land Cover habitat types classified on the SECR mask based on a 1 km buffer around each centroid point. Each mask point was classified by proportion of each habitat type and dominant habitat type (habitat type with the highest proportion).

The distribution of SECR classes as indicated by proportions of landcover in each 1 km buffer in figure 4. There was a range of coverage of each pooled landcover class with lichen_barren being the dominant class within the study area (Fig. 4).

Baker Lake hunters harvest wolverines in and around the study area, so an additional distance from Baker Lake covariate was added to the analysis to test whether proximity to Baker Lake affected wolverine density. The main rationale for this covariate was that harvest pressure might reduce wolverine density and harvest pressure was assumed to be higher in areas that were closer to Baker Lake.

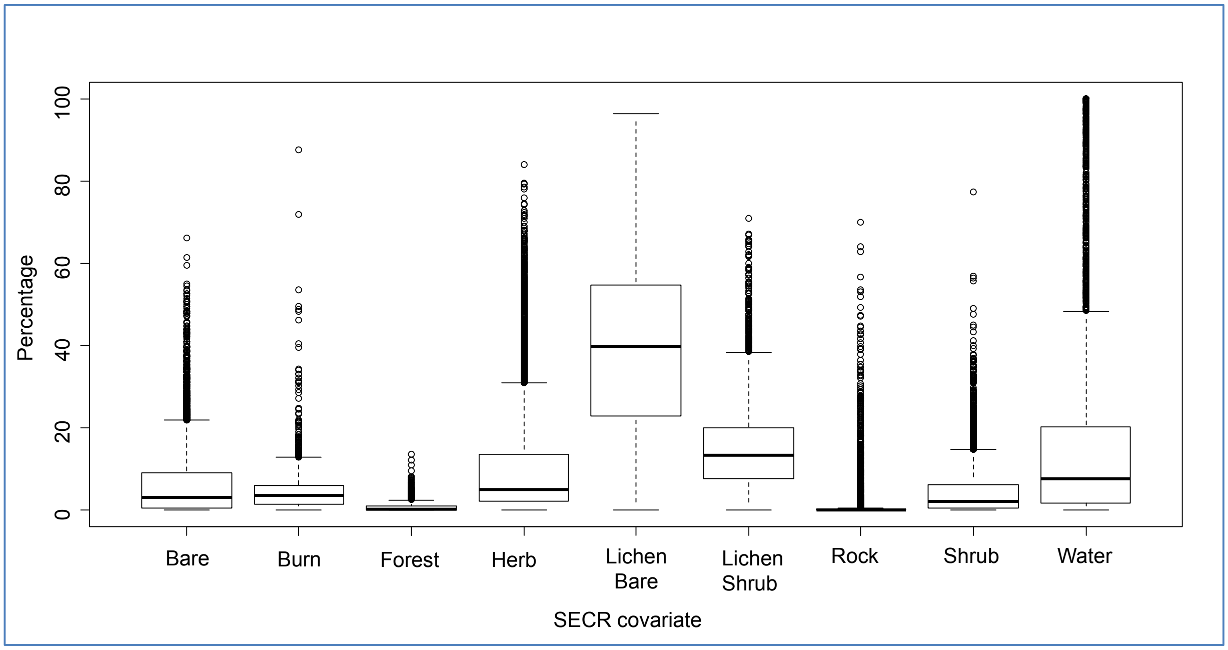


Figure 4. Distributions of the percentage of pooled landcover types in 1 km buffers around each SECR mask covariate. The bar in each box indicated the median proportion, box boundaries indicate the 25th and 75th percentiles. The limits indicate up to the 95th percentile. Points beyond the 95th percentile are indicated by individual points.

The SECR habitat covariates were added to the density term for each of the habitat classes. The support of these models was compared to a constant density model (which assumes homogenous density across the study area) to determine if any of the SECR habitat covariates was associated with wolverine density.

2.3.5 Pradel robust design open and closed model analysis

The Pradel model (Pradel 1996) robust design (Pollock and Otto 1983) in program MARK (White and Burnham 1999) was used to obtain estimates of local population size and trend from the mark-recapture data set. The Pradel model estimates apparent survival (ϕ - deaths and emigration), rates of addition (f - births and immigrants) and population rate of change (λ) from multiple year data sets. Population rate of change (λ) for the Pradel model is simply the population size in one year divided by the population size in the previous year. It is also equal to apparent survival (ϕ) plus rates of addition (f) for a given year. The relative fit of models was evaluated using the Akaike Information Criterion (AIC) index of model fit. The model with the lowest AICc score was considered the most parsimonious, thus reducing estimate bias and optimizing precision (Burnham and Anderson 1998). In general, any models with a ΔAICc score of less than 2 are considered equal.

2.3.6 Simulation study of alternative grid sizes

One of the potential issues identified in 2013 was the low numbers of wolverines encountered in the grid area. This was likely due to the relatively small size of the study grid combined with lower densities of wolverines in the region. Such outcome likely reduced estimate precision and therefore our ability to monitor wolverine trends. One of the dominant questions was whether it would be possible to increase grid size to increase the population of wolverines susceptible to sampling while retaining sufficiently high capture probabilities. Grid size might be increased by increasing post spacing while reducing the number of posts sampled to therefore keep the amount of sampling effort at a feasible level.

To explore these options, a set of simulations was conducted using the 2013 data where grid size was increased by increasing post spacing from 4 km to 8 km while reducing the total number of posts. Simulations were then conducted to assess the relative bias and precision of density estimates. Simulations were conducted using the *secrdesign* (Efford 2015) package in the R statistical analysis program.

3.0 RESULTS

3.1 Summary of data

In 2013, 321 hair samples were successfully analyzed which belonged to 18 individual wolverines (8F:10M). In 2014, 207 hair samples were successfully analyzed, with 11 (3F:8M) individual wolverines identified, including eight identified during 2013 sampling. The number of new individuals detected was relatively similar for first two sessions in both years but detection of new individuals was lowest in the third session in 2014 (Table 2). The third session in 2014 only had 96 active posts, which may have reduced detections, however, inactivity of posts was accounted for in the SECR modelling process. The hair sample success rate dropped accordingly, from a weighted mean of 75% for 2013 to 70% for 2014. This drop was largely explained by the poor performance of 2014 third session samples, which had a 56% hair sample success rate, likely due to early thaw, which left flat posts on bare ground with fewer hairs. No individual from this study area matched to any individual from other Arctic datasets or study areas (D. Paetkau, WGI, unpubl. data).

In both years, about half of the wolverines (n = 12) were detected in more than one session. The number of detectors visited was quite high within each session suggesting that wolverines visited multiple posts within sessions.

Table 2. Summary statistics for 2013 and 2014 DNA mark-recapture sampling efforts at Aberdeen Lake, Nunavut.

Statistic (Year)	Session			
	1	2	3	Total
2013				
Individual detected (session)	9	8	15	32
New individuals (session)	9	2	7	18
Cumulative detected (session)	9	11	18	18
Frequencies of detection (individual)	9	4	5	18
Detectors visited (session)	56	64	97	217
Detectors available (session)	209	209	209	627
2014				
Individual detected (session)	8	7	8	23
New individuals (session)	8	2	1	11
Cumulative detected (session)	8	10	11	11
Frequencies of detection (individual)	4	2	5	11
Detectors visited (session)	51	58	28	137
Detectors available (session)	208	208	96	512

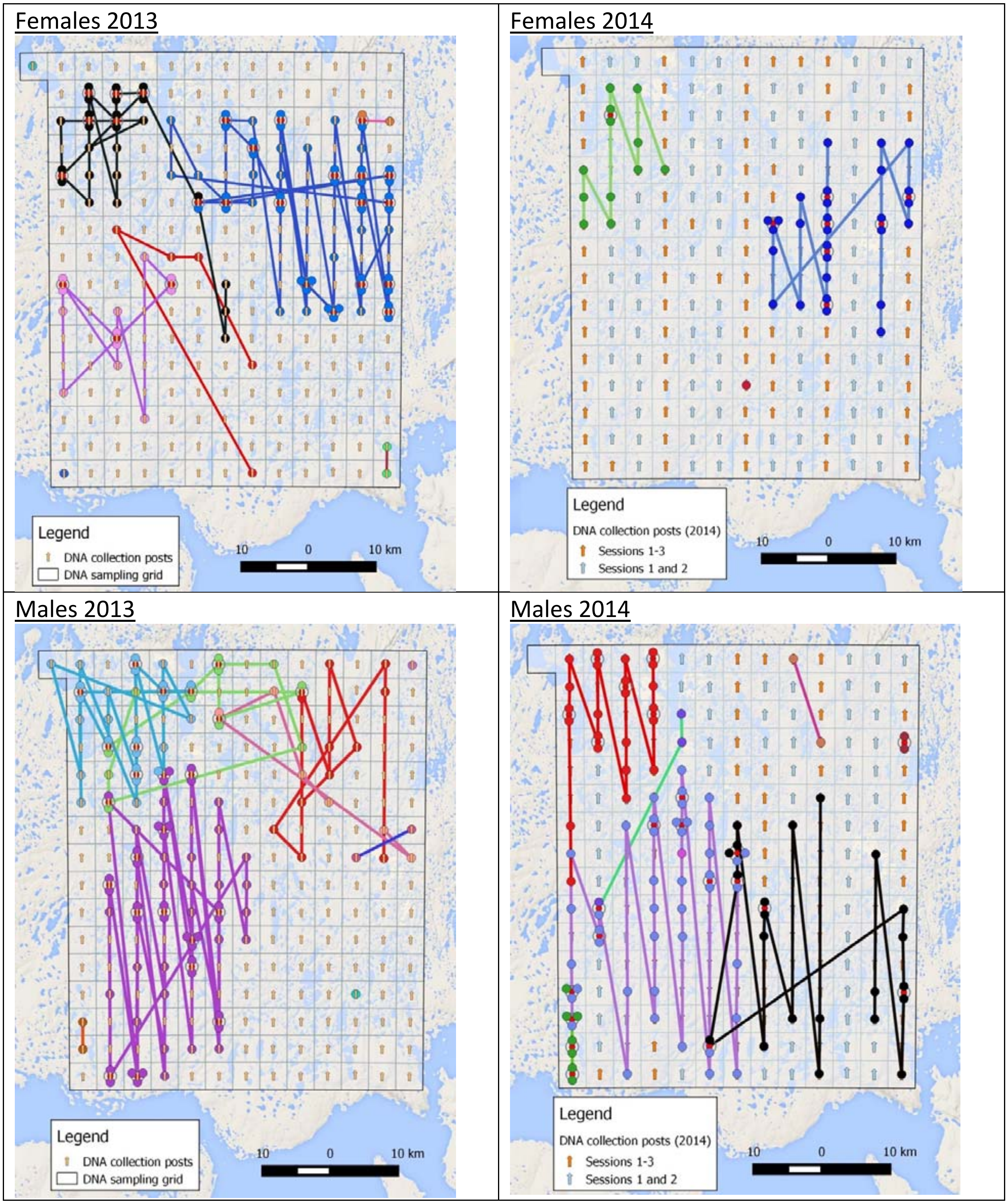
On the DNA sampling grid, nine females and 12 males were detected in 2013 and 2014. The majority of wolverines were detected in 2013 with an additional one female and two male wolverines detected in 2014. Most wolverines were detected multiple times with some wolverines being detected at up to 58 different post X session combinations over the three sampling sessions in 2013 (Table 3).

Table 3. Summary of the number of unique detections (combinations of unique posts where a wolverine was detected for each sampling session) by year and sex of wolverine.

Females	Detections (year)		Males	Detections (year)	
Individual	2013	2014	Individual	2013	2014
1-A08-B3	52	28	1-C06-A3	14	2
1-D12-A7	6	0	1-F01-A6	12	0
1-E09-A8	30	12	1-F07-D6	58	43
1-Y15-A5	2	0	1-G03-C6	0	3
2-E13-A7	0	1	1-G08-BO	0	1
2-G09-GR	12	0	1-I07-C5	1	0
2-K16-C2	2	0	2-G02-C4	29	23
3-L01-C3	1	0	3-A08-D4	2	2
3-Y03-B5	2	0	3-A13-D2	1	22
			3-B06-GR	7	0
			3-K14-D5	2	7
			3-Y01-A4	1	0

Many of the wolverines traversed a substantial portion of the sampling grid, with both male and female wolverines traversing similar distances (Fig. 5). Eight individuals (2F: 6M) were detected on the grid in both years (Table 3), apparently these were resident wolverines, and nine individuals (4F: 5M) in both years were detected only in one session, likely transient wolverines or individuals whose home range overlapped only the periphery of the grid (Fig. 6). The wolverines detected on the periphery of the grid were seldom detected, likely because their home range centers occurred off the sampling grid. In 2014, approximately every third column of posts was sampled in session three. This most likely did not have a large effect on estimates given that most wolverines were detected across at least 3–4 rows or columns of posts. Program SECR accounted for this difference by only considering the active sites for session three in 2014.

In 2013, approximate mean distances moved per session for females and males were 11.1 km (±0.86, n = 99) and 13.9 km (±0.91, n = 117), respectively. In 2014, approximate mean distances moved for females and males were 9.9 km (±0.99, n = 38) and 14.3 km (±1.09, n = 95), respectively. Estimated distances should be interpreted cautiously for a few reasons. First, the actual order of wolverine detections at posts within a given session is unknown and therefore the actual distance between detections will be approximate or minimum. Second, distances between detections could potentially be influenced by behavioural response to posts. Wolverines may change their movements after initial detection due to attraction to posts ("trap happiness"). Both of these factors are accounted for by the fitting of spatially explicit models. The metric that best describes movement is the SECR scale parameter (σ) and the associated detection function, all of which are estimated and described later in this report.



Females 2013

Females 2014

Males 2013

Males 2014

Figure 5. Detection location and approximate paths of wolverines using detections at unique posts across all sessions by sex and year. The paths for wolverines *are approximate* given that the order of detections within sessions is unknown. Multiple detections at single posts are staggered for easier interpretation. All posts were sampled for 3 sessions in 2013. Posts were sampled as noted in legend for 2014.

Plotting of mean detection location of wolverines by year (Fig. 6) suggests that despite the large areas traversed, wolverines displayed reasonable home range fidelity with relatively short distances between mean detection locations from each year. These mean detection locations do not necessarily indicate the home range center of wolverines given that they could only be sampled within the DNA grid.

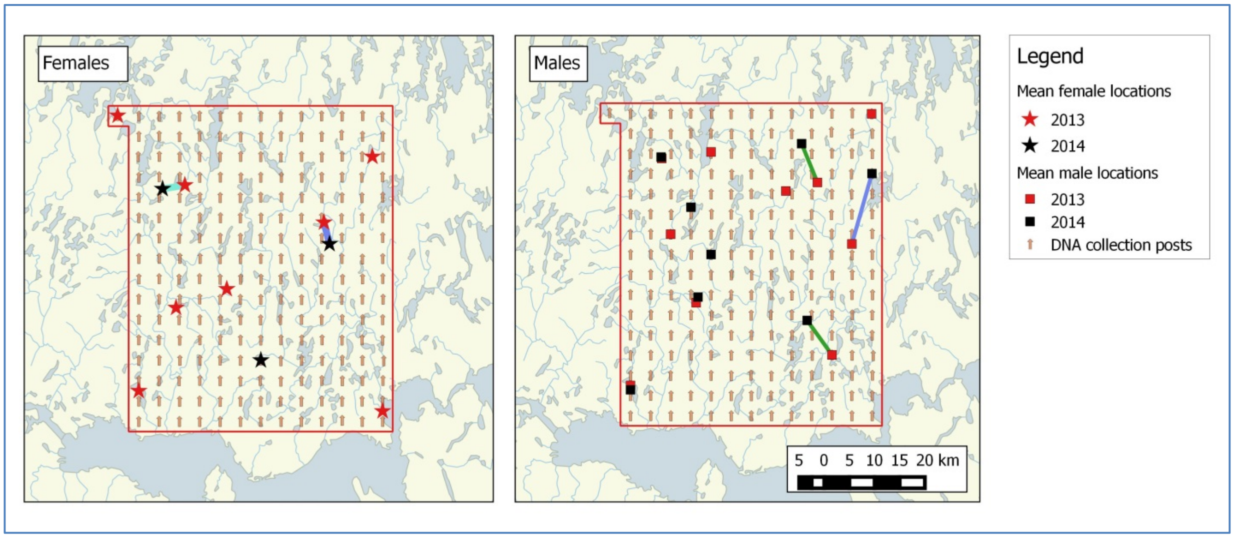


Figure 6. Mean detection locations of wolverines by sex and year. Multiple mean detection locations at the same post are staggered to facilitate interpretation. Mean locations of wolverines detected both years are connected by a colored line. In the case of males, all mean locations which overlap are from the same individual (detected in both 2013 and 2014).

3.2 SECR analysis

SECR model selection initially focused on determining the best model to describe sex and year-specific variation in detection probabilities and movements. The full combination of covariates was considered with only 4 models being more supported than a constant model (that assumed detection and scale of movement were similar for both sexes and years). Of the 4 models, a model that assumed constant detection across sexes and years but sex-specific scale of movement was most supported (Table 4, Model 1).

Table 4. SECR model selection for the Aberdeen Lake wolverine project. AIC_c = sample size adjusted Akaike Information Criterion, ΔAIC_c = the difference in AIC_c between the model and the most supported model, AIC_c weight = w_i, K, the number of model parameters and log-likelihood (*LL*) are given. Baseline constant models are shaded for reference with covariate models.

No	Detection (g_0)	Scale (σ)	AIC_c	ΔAIC_c	w_i	K	LL
1	constant	sex	2472.2	0.00	0.63	4	-1231.3
2	year	sex	2475.4	3.19	0.13	5	-1231.4
3	sex	sex	2477.4	5.23	0.05	5	-1232.4
4	constant	year	2477.5	5.33	0.04	4	-1233.9
5	constant	constant	2477.7	5.52	0.04	3	-1235.4
6	session	constant	2478.9	6.69	0.02	4	-1234.6
7	constant	sex*year	2479.4	7.20	0.02	6	-1231.8
8	year	year	2479.4	7.23	0.02	5	-1233.4
9	sex	year	2480.1	7.96	0.01	5	-1233.8
10	sex	sex*year	2480.2	7.98	0.01	7	-1230.4
11	year	sex*year	2480.2	8.00	0.01	7	-1230.4
12	sex	constant	2480.5	8.36	0.01	4	-1235.4
13	sex*year	sex	2482.1	9.93	0.00	7	-1231.4
14	sex*year	constant	2485.3	13.16	0.00	6	-1234.8
15	sex*year	sex*year	2485.9	13.73	0.00	9	-1229.2
16	sex*year	year	2486.9	14.68	0.00	7	-1233.8

Additional analyses were conducted to explore potential behavioural response of wolverines to sampling using the baseline non-behavioural response models in Table 4. Results from previous studies (Boulanger and Mulders 2013ab) suggest that wolverines display a “trap happiness” response to sampling. This is the case here with the large number of repeated detections (Table 3). Behavioural response models considered individual responses to sampling in which a wolverine changed detection probability (g_0) or movement (σ) after initial detection for the duration of sampling (symbolized as b) or for just the session after detection (symbolized as B). In addition, site-level behavioural response models were considered in which the detection of a site changed after the session it detected a wolverine for the duration of sampling (symbolized as k) or for just a single session after it first detected a wolverine (symbolized as K). Finally, models that considered individual and trap specific detection were considered (symbolized as bk or Bk). In this case, trap response would be specific to individual wolverines that had been detected at that site rather than all wolverines.

Model selection suggested the importance of the scale of movement changes for individuals detected at specific sites (Table 5, model 1). Basically, this model suggests that wolverines will change (increase movement) for sites that they have previously visited. This response occurs for specific wolverine/site combinations rather than for all sites. For example, a site that had not detected a wolverine would not have an increase in movement relative to its location.

Table 5. SECR model selection for the Aberdeen Lake wolverine project for behavioural response models. AIC_c = sample size adjusted Akaike Information Criterion, ΔAIC_c = the difference in AIC_c between the model and the most supported model, AIC_c weight = w_i, K, the number of model parameters and log-likelihood (*LL*) are given. Baseline non-behavioural models are shaded for reference with covariate models.

No	Detection (g0)	Scale (σ)	AICc	ΔAICc	w_i	K	LL
1	constant	sex+ animal/site (*bk*)	2431.53	0.00	1.00	5	-1209.5
2	site(*k*)	sex	2451.56	20.03	0.00	5	-1219.5
3	constant	sex+site(*k*)	2452.29	20.76	0.00	5	-1219.8
4	site transient(*K*)	sex	2460.41	28.89	0.00	5	-1223.9
5	animal/site (*bk*)	sex	2460.83	29.30	0.00	5	-1224.1
6	constant	sex+site transient(*K*)	2461.34	29.81	0.00	5	-1224.4
7	animal (*b*)	sex	2468.52	37.00	0.00	5	-1228.0
8	animal transient(*B*)	sex	2472.79	41.26	0.00	5	-1230.1
9	constant	sex	2472.2	40.65	0.00	4	-1231.3
10	constant	sex+animal(*b*)	2478.26	46.74	0.00	5	-1232.8
11	constant	sex+animal transient(*B*)	2483.19	51.66	0.00	5	-1235.3

Plots of detection functions for the behavioural response model (Table 5, model 1) indicates an increase in movements after initial encounter of posts by individual wolverines (Fig. 7). The actual change in overall movement would depend in this case on how many posts a wolverine had encountered given that post-specific encounters was modelled. The scale of the detection function relative to post spacing (approximately 4 km) suggests that the current post spacing is more than adequate to ensure detection of the majority wolverines on the sampling grid (as discussed later).

If a circular home range shape is assumed, it is possible to approximate home range size using estimates of σ based on initial detection. This home range size is equivalent to the 95% utilization distribution with home range radius (r) estimated as 2.45σ and home range area estimated as πr^2. Using this formula, estimates for home range size (based on Model 1 in Table 5) were 1,724 km^2 (CI=1,419-2,094) and 2,669 km^2 (CI=2,211-3,222) for females and males, respectively. Using these estimates, the home ranges of wolverines were relatively large compared to the overall size of the DNA sampling grid (3,344 km^2).

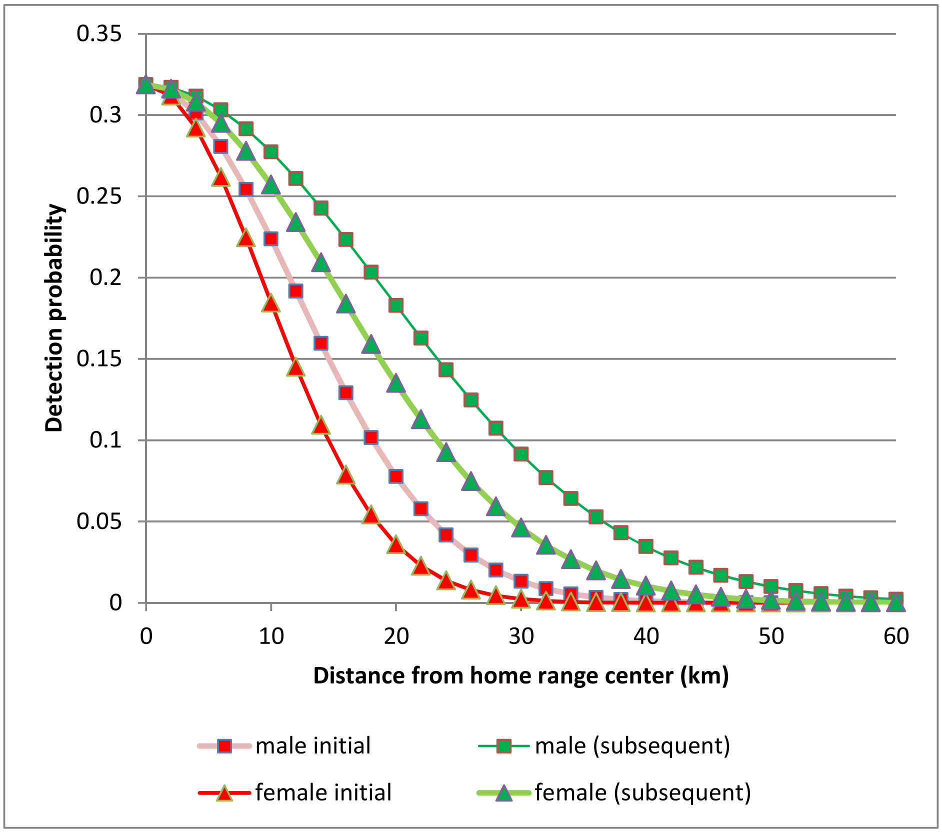


Figure 7. Detection functions for the most supported model for estimating wolverine densities in the sampling grid at Aberdeen Lake, Nunavut. This model assumes similar detection at the home range center but sex-specific scale of movement (σ) as well as a post and animal specific behavioural response in σ after the initial encounter of posts.

3.3 Estimates of population size and density

Estimates of the average number of wolverines on the sampling grid at a single capture time were derived from the most supported detection model for year and sex of wolverine (Table 5). In terms of SECR, the expected local population size for the DNA grid area is essentially an estimate of the number of home range centers occurring on the sampling grid (Efford and Fewster 2013). Estimates were 7.85 and 5.53 wolverines for 2013 and 2014, respectively (Table 6), which were less than the 18 and 11 individual wolverines detected on the grids in 2013 and 2014, respectively (Table 2). This suggests that many of the wolverines detected on the grid had home range centers off the grid, which is not surprising given the large home range sizes and the paths and locations of mean detection on the DNA grid (Figs. 5 and 6).

Interestingly, inclusion of the behavioural (bk) term on σ did not appreciably change estimates. For example, estimates based on a model without the bk term were 7.38 and 5.35 wolverines for 2013 and 2014, respectively.

Estimates were marginally precise for females but had acceptable precision for males and pooled sex estimates (as denoted by coefficients of variation of less than 20%). Density was obtained by dividing the average population size by grid area.

Table 6. Estimates of average population size (N) and density (wolverines per 1,000 km^2), average number of wolverines on the DNA grid, Aberdeen Lake, Nunavut, 2013-2014.

Sex/year	Estimate	SE	Confidence Limit		CV
Average N					
2013					
females	4.51	0.99	2.95	6.89	21.9%
males	3.34	0.53	2.46	4.55	15.8%
total	7.85	1.12	6.97	11.10	14.3%
2014					
females	3.36	0.93	1.97	5.73	27.8%
males	2.17	0.23	1.76	2.67	10.7%
total	5.53	0.96	6.97	11.10	17.4%
Density					
2013					
females	1.35	0.30	0.89	2.07	21.9%
males	1.00	0.16	0.74	1.37	15.8%
total	2.36	0.34	2.09	3.33	14.3%
2014					
females	1.01	0.28	0.59	1.72	27.8%
males	0.65	0.07	0.53	0.80	10.7%
total	1.66	0.29	2.09	3.33	17.4%

The population size of wolverines on the grid and surrounding area that was vulnerable to sampling was calculated by estimating the "effective sampling area" of the grid with SECR methods (Table 7). For closed models, this area is termed the "superpopulation" and is less well defined (Efford and Fewster 2013). Estimates of wolverines were close to or slightly above the number of unique wolverines detected on the sampling grid for each year. This suggests sampling was highly effective in detecting all the wolverines on the grid as well as the immediate surrounding area.

Table 7. Estimates of wolverines in the grid and surrounding area (the effective sampling area of the grid) using closed models and SECR models (sexes pooled) for 2013 and 2014, Aberdeen Lake, Nunavut.

Method	Estimate	SE	Confidence Limit		CV
2013					
SECR	21.20	2.07	17.50	25.70	9.8%
Closed N	18.52	1.29	18.03	26.16	7.0%
2014					
SECR	14.20	2.19	10.54	19.20	15.4%
Closed N	11.00	0.62	11.00	11.23	5.6%

3.4 Spatially explicit analysis of temporal trends and spatial variation in density

Spatial and temporal trends were investigated using SECR methods as well as the Pradel robust design method. SECR models were introduced into the analysis that considered temporal and spatial trends in the wolverine data set. Temporal trend models included year-specific and sex and year-specific variation in density. Of the models considered, a model with constant density was most supported (Table 8).

The most supported constant density model was then used as a base model for the spatial/density surface modelling analysis, which used the Northern Land Cover covariates (Table 1 and Figs. 3 and 4) to describe density variation on the sampling grid (Table 8). None of the density covariate models were more supported than the baseline constant density model. Distance from Baker Lake also was not supported as a distance covariate model.

Table 8. SECR model selection results for exploration of temporal and spatial trends in wolverine density in the sampling grid of Aberdeen Lake, Nunavut, 2013-2014. The most supported detection model (Table 4: g0(.) σ(sex+bk)) was used for all the density models. AIC$_c$ = sample size adjusted Akaike Information Criterion, ΔAIC$_c$ = the difference in AIC$_c$ between the model and the most supported model, AIC$_c$ weight = w$_i$, K, the number of model parameters and log-likelihood (*LL*) are given.

No	Density	AICc	ΔAICc	wi	K	LL
Temporal trends						
1	constant	2432.1	0.00	0.67	5	-1209.7
2	year	2436.7	4.55	0.07	6	-1210.4
3	sex	2451.1	18.99	0.00	6	-1217.6
4	sex*trend	2457.9	25.78	0.00	8	-1217.3
5	sex*year	2460.4	28.34	0.00	8	-1218.6
Spatial variation						
1	shrub	2434.4	2.32	0.21	6	-1209.3
2	bare	2439.4	7.30	0.02	6	-1211.8
3	rock	2439.5	7.40	0.02	6	-1211.8
4	forest	2440.2	8.10	0.01	6	-1212.2
5	water	2461.2	29.09	0.00	6	-1222.7
6	burn	2462.2	30.09	0.00	6	-1223.2
7	dom. Habitat	2470.1	38.03	0.00	12	-1213.3
8	lichen_shrub	2474.1	42.01	0.00	6	-1229.2
9	herb	2474.6	42.50	0.00	6	-1229.4
10	Sex*distance Baker Lake	2475.4	43.26	0.00	8	-1226.1
10	lichen_bare	2480.0	47.88	0.00	6	-1232.1

3.5 Pradel model analysis of demography

Model building for the Pradel model first focused on testing of a baseline detection model. Our models allowed full variation in several parameters: capture and recapture rate variation (Table 9: model 8), year and sex variation in detection and redetection (model 7), year and sex variation in detection probabilities (model 6), sex specific variation in detection rate (model 5) and no variation in detection rate (model 4). The model with no variation in detection rate was most supported (model 4). Using this model, sex-specific variation in apparent survival and additions was explored. Of the models considered, a model with sex-specific variation in apparent survival but constant additions was most supported (model 1).

Table 9. Pradel model analysis of 2013 and 2014 Aberdeen wolverine mark-recapture data. AIC_c = sample size adjusted Akaike Information Criterion, ΔAIC_c = the difference in AIC_c between the model and the most supported model, AIC_c weight = w_i, K, the number of model parameters and deviance are given. Baseline constant models are shaded for reference with covariate models. A (.) indicates the parameter was held constant. Otherwise, the covariate varied is indicated. Parameters are apparent survival (ϕ), rates of addition (f), capture probability (p) and recapture probability (c).

No	Model	AICc	ΔAIC_c	wi	K	Deviance
1	Φ (sex) f(.) p(.)	159.37	0.00	0.36	4	68.01
2	Φ (.) f(.) p(.)	159.39	0.02	0.36	3	70.36
3	Φ (.) f(sex) p(.)	161.58	2.22	0.12	4	70.23
4	Φ (sex) f(sex) p(.)	161.73	2.37	0.11	5	67.96
5	Φ (sex) f(sex) p(sex)	163.90	4.54	0.04	6	67.60
6	Φ (sex) f(sex) p(sex*year)	167.64	8.28	0.01	8	65.96
7	Φ (sex) f(sex) p(sex*year) c(year*sex)	171.24	11.87	0.00	11	60.55
8	Φ (sex) f(sex) p(sex*year*t) c(year*sex)	178.72	19.35	0.00	16	49.85

Model averaged estimates of apparent survival and additions were added to obtain estimates of overall change for males and females (Fig. 8), which further suggested a declining population. The primary drivers for this change was low apparent survival for both males and females. Low apparent survival could be due to high mortality or emigration from the study area (or both). In both cases estimates of overall change did not overlap suggesting that this decline was statistically significant.

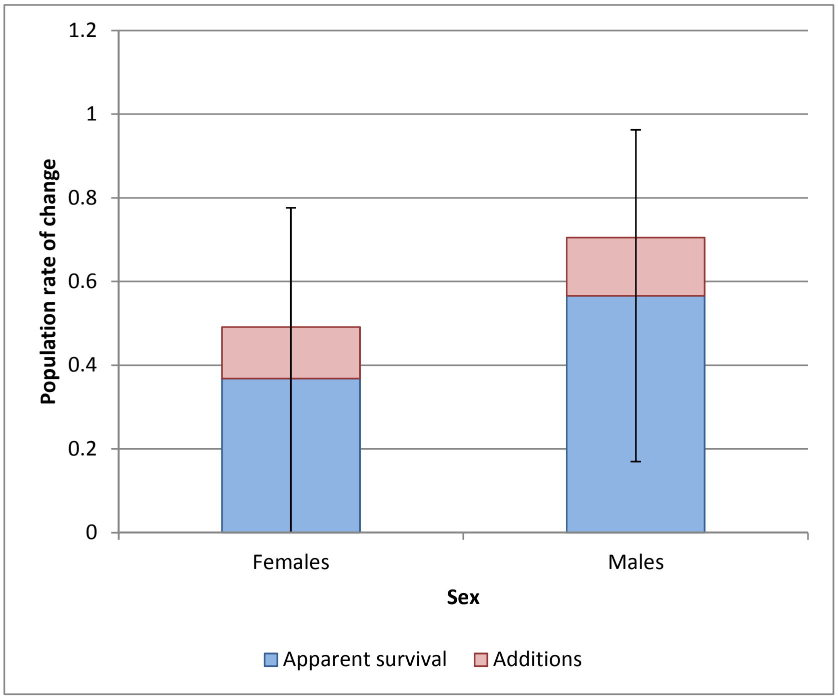


Figure 8. Model averaged estimates of apparent survival, rates of addition and population rate of change (apparent survival + rates of addition = population rate of change) for the 2013 and 2014 Aberdeen Lake wolverine study, Nunavut.

3.6 Simulation study of alternative grid sizes

Simulations in SECR design focused on single-year estimates of density, average population size, and population on the grid and surrounding area. The grid configuration was assumed to be expansions of the existing grid (4 km post spacing with 208 posts) by reducing the number of posts, while increasing post spacing up to 8 km (Fig. 9). The range of spacing of posts was based partially on rules of thumb for trap spacing for SECR studies based upon estimates of σ. In general, post spacing should be from 1.5σ to 2.5σ (Efford and Fewster 2013, Royle et al. 2014). Estimates of σ from this study were 9,563 m (CI = 8,676–10,054) and 11,900 m (CI = 10,831–13,074) for females and males, respectively, based on initial encounter of posts. In this case, conservative post spacing could be at least the value of σ for females (9.5 km). Given logistical constraints on field efforts, a post spacing of 5 to 8 km was considered for simulations.

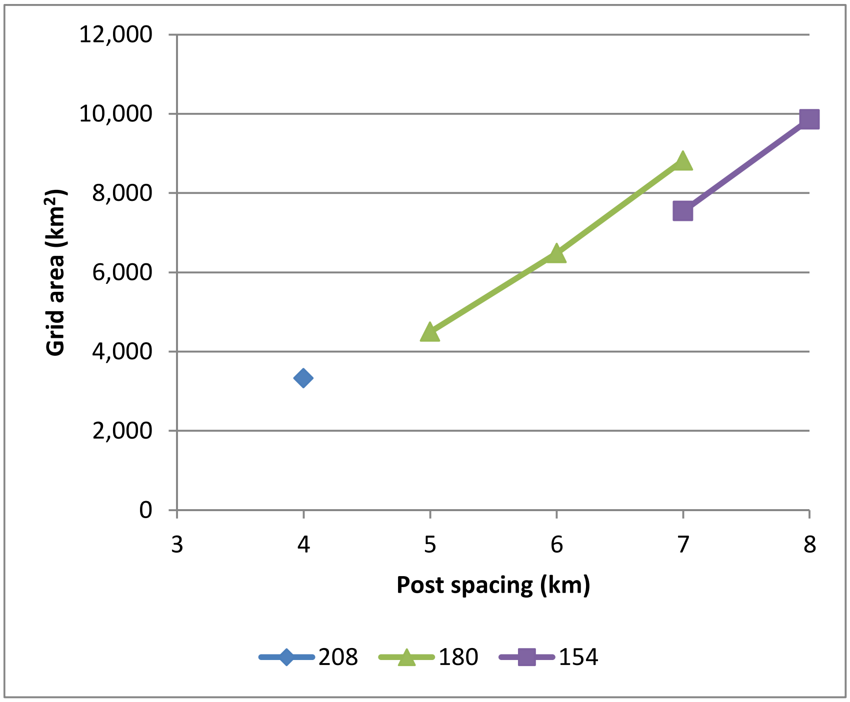


Figure 9. Grid areas (km^2) simulated as a function of the number of posts employed and post spacing. The existing study used 4 km post spacing with 209 posts.

Indicators of a successful design were a population size of wolverines on the grid and surrounding area of greater than 20 (based on 2014 densities) as well as an increase in relative precision compared to the present 4 km 209 post design. Using estimates of density and effective sampling area from 2014, estimates of the average number of wolverines on the grid and the grid and surrounding area were estimated. It can be seen that it would require at least a 6x6 km design with 180 posts to ensure that 20 wolverines were on the grid and surrounding area (Fig. 10).

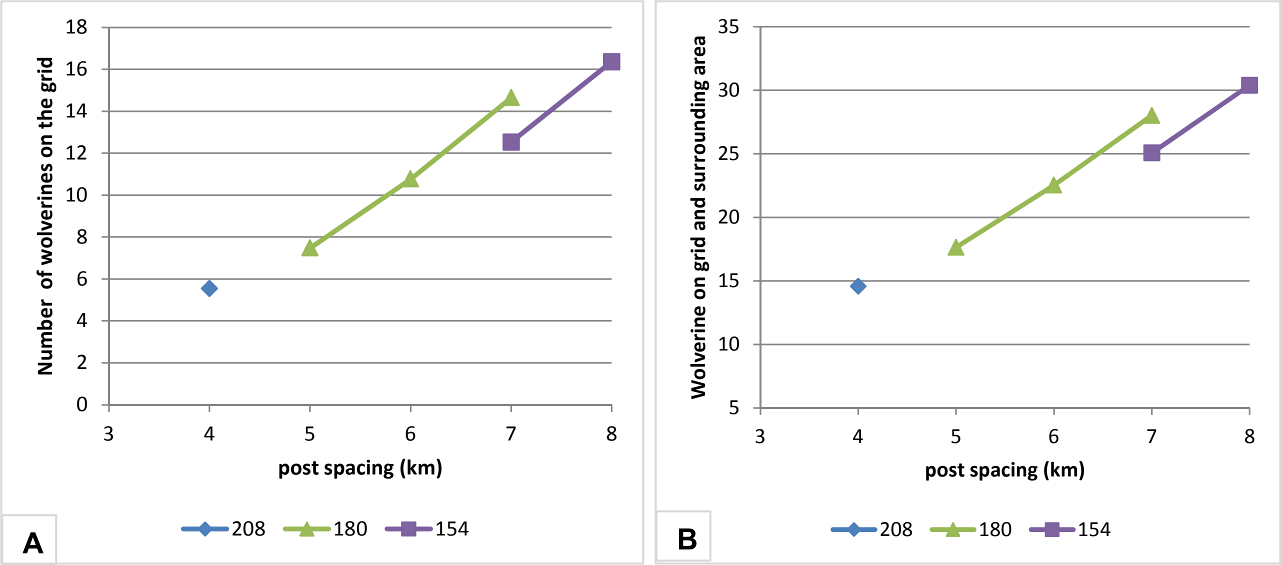


Figure 10. The estimated number of wolverines on the grid (A) and the number of wolverines on the grid and surrounding area (B) based upon estimates of density in 2014.

Results from the *secrdesign* simulations suggest that the precision of density estimates increased with grid size. This suggests that the main limiting factor for precision with this study is the number of wolverines likely to be sampled rather than the spacing of posts (Fig. 11). Increasing post spacing to increase grid size will increase estimate precision even if the number of posts sampled is reduced.

The actual estimates of precision pertain to a single year study and are therefore lower than from the current analysis that combined data from 2013 and 2014. For example, the estimate of coefficient of variation for the 2014 density estimates was 16.6% whereas simulated estimated precision was 32.0%. Therefore, simulation results should be interpreted in a relative manner. The main point of the simulations is that precision with larger post spacing increases relative to the present (4 km spacing) design.

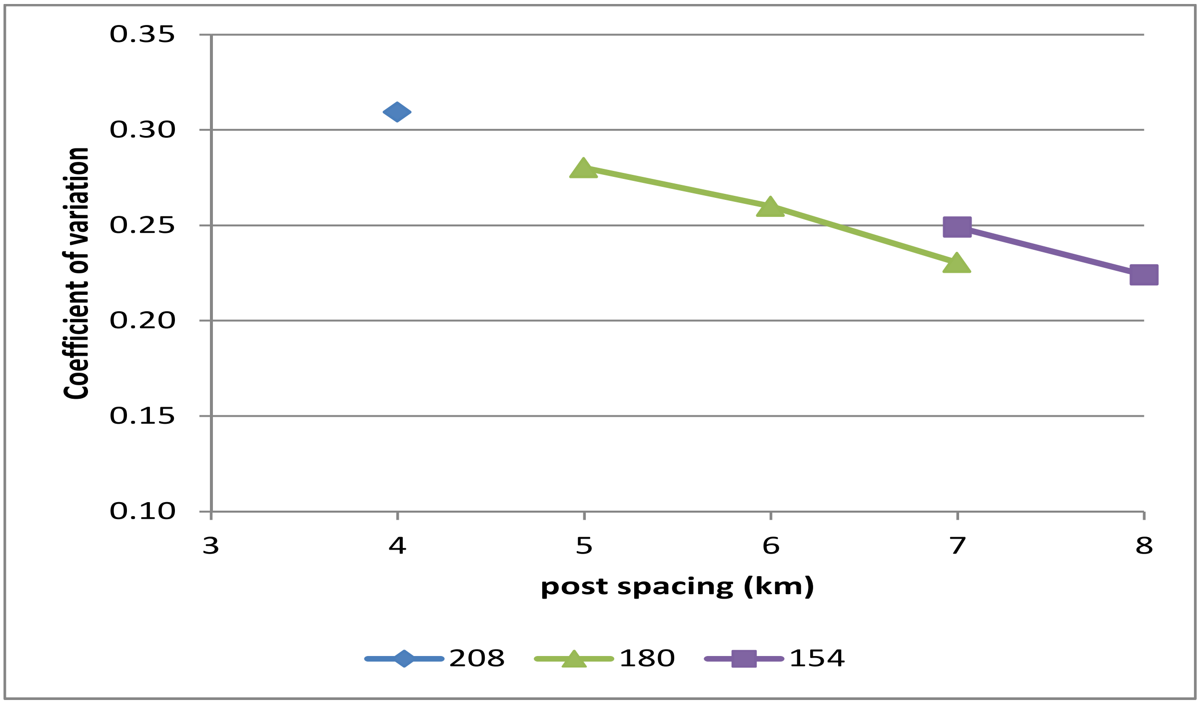


Figure 11. Estimated relative precision of density estimates from a single year study as a function of post spacing and the number of posts employed.

Camera data shows that wolverine visits to the bait post occurred on average 6 days (SD = 3, n = 49) after deployment. Based on the trigger cameras, while visiting the baited post wolverine spent on average 710 seconds (11.8 minutes) around the post (SD = 1125, n = 44). The wolverine visits to bait posts showed a clear pattern, with wolverines visiting posts often during night (42%, n = 48) or early morning hours (33%) with the least visits during the day (19%). Such nocturnal behaviour is also reported by Arnesen (2015) in Sweden, who observed significantly more visits during the night hours (68.9%) in comparison to day hours.

Ground-based survey is cost-effective way of study wolverines and it vigorously involved the local HTO and community. The land skills required for this type of field work were achieved by hiring five experienced hunters and HTO members (3 for the whole duration of the study and 2 as and when needed). They were very knowledgeable, actively participated in the field work and learned standardized wildlife survey techniques (sampling protocol, hair collection and data recording) and could potentially run this program in future years with minimal supervision and technical help. These trained HTO members are able to work as wildlife monitors at exploration/mining camps or participate in wildlife monitoring surveys. This seasonal employment to local hunters helps combat the high cost of living in the north and expensive maintenance of their hunting equipment to carry out subsistence harvesting activities. The study generated about 400 person-days of employment to local hunters and elders, the project helped to build a monitoring capacity in the HTO, and the baseline information collected within the socio-cultural framework will be used for future monitoring and for wolverine management. HTO board members reviewed and discussed the proposal and field methods in detail, provided guidance and obtained more awareness about the species status at the national and international level. The involvement of hunters and HTO in the study enhanced their interaction with the government and may be a mechanism to increase local involvement in wildlife management. The government staff learned land skills and more about how HTO/community members want to be involved in scientific studies and conservation in Nunavut. While working on the project, as hunters with immense experience, they act as stewards of the land on a daily basis and provided guidance to government staff and safely accomplished the field work. Some logistical and social gaps were identified during the field work that will be shared with other department researchers and will be addressed in future studies.

4.0 DISCUSSION

This study produced the first density estimates of wolverine in the Kivalliq region, Nunavut using a robust survey sample design and logistics facilitated by local hunters. Our average density estimate of 2.36/1,000 km^2 was low compared to other known values reported throughout the central Arctic. Despite low sample sizes, the precision of estimates from the combined 2013 and 2014 data sets were acceptable for the combined sex estimates (Table 6), most likely due to the large number of detections and redetection of wolverines. The estimated average number of wolverines on the grid was lower than the total of detections. This indicates that all resident wolverines were probably detected in DNA sampling, and also suggests that the grid is capturing wolverines using an area beyond the grid boundaries (as far as 30 km). The scale of movement by wolverines (based on repeated detections on the grid [Fig. 5] and the detection functions; [Fig. 7]) is relatively large compared to overall grid size.

The detection of site and wolverine-specific response in analyses is biologically intuitive. These models assume that a wolverine will change its scale of movement at a post that it has been detected at previously. This type of behavioural response model is much more exact in that it considers post and wolverine combinations based on previous encounter.

Within the 3,344 km^2 grid area, 2 females and 6 males were present on the grid for both years (Table 3) and this generated a density of 2.3 resident wolverines per 1000 km^2. Most of the individuals (n=9) were detected in one session only. It is likely that these were transient animals and this is consistent with COSEWIC (2014) that a sizeable proportion of the wolverine populations, normally sub-adults, are transient at any given time. This is also evident from the Baker Lake reported wolverine harvest (2010-2012) with high proportion of sub-adults (67%) and males (73%) in the harvest (M. Awan, DOE, unpubl. data). In 2015, Awan and Boulanger (in prep.) used the same methodology with 5x5 km cells and estimated 4.32 wolverines per 1000 km^2 in a study about 300 km south of the Aberdeen Lake study area. In the West Kitikmeot, higher densities were estimated (6.85/1,000 km^2 at High Lake in 2008 and 4.80/1,000 km^2 at

Izok Lake in 2012) by Poole unpubl. data (2013). However, both of these study areas were in the central Arctic characterized by generally higher productivity, and with no or occasional limited wolverine harvest. Krebs et al. (2004) reported substantially higher survival rates in non-harvested populations than harvested populations and significant differences in survival among habitats. Further, Gervasi et al. (2015) described that population properties, such as density or survival rates, often vary due to uneven spatial distribution of resources and mortality risks. Like grizzly bears, it has been generally assumed that wolverine densities are higher in the West Kitikmeot and lower to the north and east, and that population density is driven by productivity and seasonality (McLoughlin 2001). Inman et al. (2012) described that wolverine density estimates can vary among latitude and habitat type and comparison of wolverine density among studies must be made with caution because estimates may vary with study design and season. In North America, wolverine densities vary across ecological areas and habitat quality, to a maximum of about 5-10 wolverines/1,000 km^2 (COSEWIC 2014; Species at Risk Committee 2014). However, we expected wolverine density in the Aberdeen Lake area to be lower compared to central and western Arctic tundra habitat (western Kitikmeot and NWT) and taiga and mountain areas because of lower productivity on the eastern tundra (McLoughlin 2001; Rescan 2014).

Both SECR (Table 6) and Pradel model (Fig. 8) analyses resulted in lower estimates of abundance and density for 2014 compared to 2013. Consequently, the number of wolverines on the grid at any given time also declined between years as well as the superpopulation of wolverines on the grid and surrounding area. The difference between the two year estimates has a number of possible explanations. The Pradel model results suggest that low apparent survival rates are potentially driving the decline of wolverines in the area. In general, wolverines that were detected in both years (n = 8) showed reasonable fidelity to mean capture areas (Fig. 6) so we speculate that lower apparent survival is due to either low true survival or emigration of younger and breeding female wolverines to other areas. Like other mammals, high male-biased dispersal (Pusey 1987) and intersexual home range overlap is reported in wolverine populations (Vangen et al. 2001; Dalerum et al. 2007; Bischof et al.

2016). Others have reported long dispersal movements in yearlings from their natal area (due to competition of resources) before reaching sexual maturity (Copeland 1996; Mulders 2000; Vangen et al. 2001; Inman et al. 2012) and migration of wolverines from the areas with lower mortality to those with higher mortality (Gervasi et al. 2015, 2016). The average annual reported wolverine harvest for Baker Lake from 2010-2012 was 14 (range 11-18). It is likely that the Aberdeen Lake population is part of a source and sink dynamic, with emigration from the northwestern portion of the grid and adjacent areas replenish harvested animals closer to Baker Lake community. So this low apparent survival may likely be due, in part, to dispersing transient wolverines that spend only a portion of time on the grid, as also described by Mulders et al. (2007) in the central Arctic.

Various studies describe wolverine selection of deep snow for reproduction and den sites in rocky scree slopes, along eskers, within hard packed snowdrifts or under snow-covered boulders (Lee and Niptanatiak 1993; Magoun and Copeland 1998; Landa et al. 1998) and suggest that denning females were restricted to the areas having dense snow cover (≥1 m), distributed uniformly or accumulated in drifted areas, during the February to May denning period (Magoun and Copeland 1998; Copeland et al. 2010). McKelvey et al. (2011) hypothesized that snow depth may have a greater influence on wolverine denning than spring snow cover; thus, it is likely that less snow in the area in 2014 (Fig. 2) likely reduced the availability of reproductive den sites and altered the wolverine distribution in the area. This interpretation is supported by the detection of only three females in 2014 compared to eight females in 2013. Wolverine spatial patterns and variation with season and year on tundra is poorly understood, but denning philopatry has been reported in tundra breeding females (Lee and Niptanatiak 1996).

Observed decline and or inter-annual variability in abundance should be interpreted with caution. Indeed, the lower number of wolverine recorded in the 2014 (specifically in the third session) may be caused by the low snow quantity in the hilly areas (likely area of high density), which reduced sampling effort and detection, or emigration.

Moreover, due to less snow and early melting, 65% bait posts were lying down and with fewer hairs rather than large clumps of hairs trapped in barbwire, which caused a reduced DNA extraction rate for the third session (56%) due to insufficient DNA material for extraction.

Prey availability between years may contribute to changes in wolverine numbers, because the ungulate literature suggests that snow depth influences spatial and temporal distribution and use of habitat (Maher et al. 2012; Richard et al. 2014; Tablado et al. 2014), which affects distribution of predators (Hojnowski et al. 2012; Carricondo-Sanchez et al. 2016). The reasons for the apparent population decline/change from 2013 to 2014 are unclear, plausible explanations are weak and we have only one comparison (2013to 2014). This requires additional investigation to determine whether less snowfall and lower sampling coverage in 2014 may have contributed to this apparent decrease. While sampling effort was reduced, sampling was still reasonably systemic in 2014 with every third row being sampled in session three. However, if wolverine shifted their movements to areas that were not sampled by posts then it is possible that estimates were reduced due to shift in distribution of wolverines relative to posts on the sampling grid. This baseline result is a snapshot of wolverine status in early spring over two years. The apparent annual variation in density estimates highlights the need for continued monitoring to better determine spatial and temporal drivers of local abundance and how wild populations change over time (Harris et al. 2005; Mulders et al. 2007). Three study areas in the central Arctic in the NWT exhibited a decline in wolverine density of 35% to 61% between 2004–2005 and 2011 (COSEWIC 2014). Boulanger and Mulders (2013ab) believe that these declines were concurrent with declines in the Bathurst caribou herd and not related to mining activities.

Given the low wolverine density in the sampling grid area, the main challenge to future survey efforts will be detecting sufficient wolverines to allow estimates of trends. Previous simulation studies suggest that at least 20 (preferably 50) wolverines are needed on a sampling grid for adequate power to detect trends (Boulanger and

Mulders 2013b). The current 4 km post spacing oversamples the population as indicated by the large number of recaptures of resident wolverines.

Other studies in the Arctic tundra utilized 3x3 km (Mulders et al. 2007), or 5x5 km cell size (Boulanger 2012; Dumond et al. 2012). Considering the low density in the Kivalliq region and logistics this study used 4x4 km grid cell to examine whether sample size of wolverines on the grid, grid cell size spacing and other study design features were adequate to monitor wolverine trend in the region. Simulations of sampling designs (post spacing, grid size) suggest that increasing post spacing up to 7x7 km while reducing the number of posts sampled can increase sample size and estimate precision. Studies in West Kitikmeot have obtained precise estimates of wolverine population size with 5 km post spacing (Boulanger 2012). Increasing post spacing and overall grid size increases the distance between posts and therefore the overall amount of field effort. The main way to reduce field time would be to reduce the number of overall posts (from 208 to 154) concurrent with expanding cell size.

A future goal of this DNA sampling effort is to describe wolverine density across the contiguous portion of the Kivalliq region. In order to achieve this goal sampling should be spread widely across the region. From this study we obtained a precise wolverine density estimate for the grid area which may not be an adequate representation of wolverine densities in other parts of the region. To generate a second estimate of population size within the broader region a DNA grid around Henik Lake, about 300 km south of the Aberdeen Lake study area, was sampled in 2015-16, which estimated a higher density of wolverines (Awan and Boulanger in prep). For Kivalliq regional population estimates we will use combined data from these 2 study grids similar to the sub-grids approach proposed for the Kivalliq grizzly bear study (Boulanger et al. 2013). This type of simulation could be considered with discussion of likely sub-grid areas and overall field logistical constraints. The main advantage of the sub-grid approach is that it could contribute to an estimate of the overall regional population of wolverines rather than an estimate of wolverines on a single sampling grid.

The density surface modelling exercise did not detect associations of wolverine density with Northern Land Cover covariates or distance from Baker Lake. We suspect this was caused by the lack of resolution in the Northern Land Cover classification as well as the relatively small scale of the sampling grid. The large scale of movement of wolverines and subsequent larger scale of habitat selection may also be at play. Johnson et al. (2005) used wolverine locations from a radio telemetry study by Mulders (2000) in the Southern Arctic ecozone on the central barrens in the NWT. This work indicated a strong relationship between wolverine occurrence and sedge habitat, while wolverines were avoiding areas dominated by heath rock, heath tundra, and lichen veneer. We suspect that selection and distributions of densities of wolverines occur on a relatively large scale compared to the grid area. Non-invasive DNA sampling and SERC analyses have detected associations between barren-ground grizzly bear and habitat in the Tuktuyaktuk-Inuvik regions of the NWT (Boulanger et al. 2014) as well as with other wildlife species (Royle et al. 2013; Efford 2014a).

In summary, results from this study contribute to baseline data for wolverine ecology in the Arctic tundra and will be used to generate regional population estimates for future monitoring. This allows us to evaluate current harvest in the territory and will provide a quantitative basis to establish future sustainable harvest limits. A database containing “DNA fingerprints” of individual wolverine has been established which will be used for population delineation. This study data set will be used to further refine and optimize DNA sampling methods for future wolverine studies on the tundra. Wolverines in the region exist at low densities and are being exposed to increasing levels of human activity, with existing or proposed mining activity (Meadowbank Gold Mine, Areva). Wolverine is a culturally and economically important furbearer for Inuit. Like other wildlife species, the local wolverine harvest pattern shows that the bulk of wolverine harvest occurs northwest of Baker Lake (Awan and Szor 2014) and harvest of wildlife increased along the Meadowbank mine all weather access road (Agnico Eagle Mines 2014). We suggest genotyping of wolverine harvest samples from Baker Lake to include mortality data for future demographic analysis. There is currently no wolverine monitoring program executed at the Meadowbank mine, so potential effects of the mine and the all weather road are unknown. Based on the low density of wolverines in the area, we recommend multiple years DNA sampling to accurately determine population trend by involving the mine through NIRB and the Baker Lake HTO.

5.0 FIELD TEAM

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8.0 **APPENDIX 1:** Wolverine hair snagging posts.