Effects of Mining on Reindeer/Caribou Populations and Indigenous Livelihoods: Community-based monitoring by Sami Reindeer Herders in Sweden and First Nations in Canada

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Abstract

This paper explores the effects of human disturbances associated with mine development in the Arctic on habitat and populations of reindeer/caribou (both Rangifer tarandus*), and implications for reindeer husbandry and caribou hunting of indigenous Sami people in Sweden and First Nations in Canada. Through three case studies, we illustrate how Cree and Naskapi communities develop community-based geospatial information tools to collect field data on caribou migration and habitat changes; and how Sami reindeer herders use GIS to gather information about reindeer husbandry to better communicate impacts of mining on reindeer grazing areas. Findings indicate impacts on use of disturbed habitat by reindeer/caribou, on migration routes, and northern livelihoods. The three cases present novel methods for community-based environmental monitoring, with applications in hazards mapping, and denote the active engagement of indigenous communities in polar environmental assessments, generating community-oriented data for land use management decisions. They also illustrate how technology can lead to better communication and its role for empowerment.*

Keywords: *mining, disturbances, reindeer, caribou, Sami, First Nations, community-based environmental monitoring, communication, local and landscape level*

1. Introduction

The caribou of North America and semi-domesticated and wild reindeer of Eurasia (both *Rangifer tarandus*) inhabit highly variable environments[1] and act as keystone species shaping circumpolar socio-ecological systems.[2] Reindeer husbandry and the harvesting of caribou and wild reindeer are strongly linked to the cultural identity and social and economic well-being of

[1] Wolfe et al. 2000
[2] Simberloff 1998; Taillon et al. 2012

many northern societies.[3] However, over the last decades, most reindeer/caribou populations have experienced declines.[4]

Mineral exploration and extraction are increasing in polar regions.[5] The resulting disturbances on reindeer/caribou are broad and vary across subspecies, space - winter and summer grazing areas-, and time, including seasons (e.g., pre-calving, calving season) or phases of mining activity.[6] Increased human presence and linear human infrastructure associated with mining development, such as roads, railway tracks, power lines, can encroach upon migration paths and lead to a direct and indirect loss of or fragmented habitats.[7,8] Studies show that reindeer/caribou avoid industrial sites, buildings, and move away from aircrafts.[9] Mining activities increasingly occur near calving grounds[10] where reindeer/caribou females are most sensitive to human disturbance.[11] The nutritional or stress cost of responding to human disturbance may have cumulative implications for individual fitness and population productivity.[12] Human-caused disturbances can also modify interspecific interactions, such as predation rates.[13] All disturbances also have implications for caribou hunting practices and reindeer husbandry, and thus for the culture, identity, and traditional ways of life of Arctic communities.[14] To date, mining development across polar regions has required national, federal and territorial regulatory approval enabled through project-specific environmental and social assessments.

This paper documents and analyzes novel methods and tools integrating indigenous knowledge (IK) with Geographic Information Systems (GIS) allowing Sami communities in Sweden, and Cree and Naskapi First Nations in Canada to monitor the effects and assess the risks of human disturbance associated with mining on reindeer husbandry and caribou hunting, and to communicate their land use requirements. We discuss empirical work from Quebec, where Cree and Naskapi First Nations combine rugged GPS-equipped handheld computers with touch-screen software (CyberTracker) and develop a GeoPortal to collect field data on changes in caribou behavior, migration and habitat brought about by mining in the Eastern James Bay and around Schefferville. Then, empirical work from northern Sweden is discussed, where Sami reindeer herders use a participatory GIS (pGIS) to gather and compile information about reindeer husbandry to communicate the impacts of mining and associated developments around Jokkmokk on reindeer grazing areas and migration paths. In doing so we explore the potential for using community mapping and pGIS to gather and analyze geographical information on human-

[3] Kofinas et al. 2000; Kofinas & Russel 2004; Hummel & Ray 2008; Vistnes et al. 2009
[4] Vors & Boyce 2009; Festa-Bianchet et al. 2011
[5] Klein 2000
[6] Dyer et al. 2001; Weladji & Forbes 2002; Weir et al. 2007
[7] Skogland & Grøvan 1988; Cameron et al. 1992; Bradshaw et al. 1997; Dyer et al. 2002; Nellemann et al. 2003; Weir et al. 2007; Skarin 2012
[8] Vistnes et al. 2004; Kneeshaw et al. 2010
[9] Wolfe et al. 2000 ; Vistnes & Nelleman 2001; Cameron et al. 2005; Reimers et al. 2007; Skarin 2012
[10] Cronin et al. 1998; Vistnes & Nelleman 2001; Haskell et al. 2006; Taillon et al. 2012
[11] Cameron et al. 1979, 1992; Dau & Cameron 1986; Nelleman & Cameron 1996,1998; Nellemann et al. 2001; Weir et al. 2007
[12] Cameron et al. 2005
[13] James & Stuart-Smith 2000; Wittmer et al. 2007
[14] Sandström et al. 2003; Forbes et al. 2009; Peoples of Aklavik 2009; Royer & Herrmann 2011; Les Amis du Mushuau-nipi 2012; Ungava 2013; Facebook groups: *What local people – För ett gruvfritt Sápmi*; *Gruvfritt Jokkmokk*; *Urbergsgruppen*

environment interactions over time and space in land use conflict settings, and to empower indigenous communities to participate in decision-making, both as contributors and as users of knowledge.

2. Study areas and people

2.1. Sami, Cree, and Naskapi socio-ecological systems linked with reindeer/caribou

The caribou is divided into five subspecies, one of them being the woodland caribou (*Rangifer tarandus caribou*), which is the only caribou present in Quebec. Woodland caribou is further divided into three ecotypes: the forest-dwelling caribou inhabiting the boreal ecosystem, the migratory caribou which inhabits the tundra, and the mountain caribou.[15] There are two large herds of migratory caribou in Québec: the Rivière-George (RG) herd and the Rivière-aux-Feuilles (RAF) herd (Figure 1).

Due to a decline in the distribution and abundance forest-dwelling caribou[16] was designated as a threatened species in Canada in 2002 and a vulnerable species in Quebec in 2005.[17] The two migratory caribou herds which until recently were considered very healthy with an estimated population of 1,013,000 animals in 2001[18], have shown important changes in distribution and abundance during the last decades.[19] The RG herd has suffered a dramatic decline from about 800,000 heads in 1993 to 385,000 in 2001 and 27,600 in summer 2012.[20] Similarly, the RAF herd shows a decline, even though it is less pronounced than that of the RG herd.[21]

Caribou have been very important to IP in northern Quebec, including the Cree, Naskapi, Innu, and Inuit; and this relationship continues to the present day.[22] The Cree of Eeyou Istchee number approximately 18,000 people[23] and constitute a subpopulation of the greater Cree Nation. They are spread out over nine villages (Figure 1). Eeyou Istchee is located inside the James Bay territory of Quebec, which is part of the Canadian Shield, and thus rich in minerals (e.g. gold, silver, copper). The Cree are historically a semi-nomadic, kinship-based group pursuing a subsistence way of life based on hunting, fishing, and trapping. They have had hunting territories since the 18th century, which the Hudson's Bay Company later incorporated into a system of beaver preserves and registered traplines.[24] The traplines – family hunting territories which are used year round – still compose the territorial units into which the Cree territory is divided, and are still used today by family hunting groups for the practice of traditional subsistence activities.[25]

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[15] Courtois et al. 2003
[16] Ibid; Schaefer 2003; Hins 2009
[17] COSEWIC 2006; MRNF 2007
[18] Courtois et al. 2003
[19] Couturier et al. 2010
[20] Porter 2011; MRN 2012
[21] Taillon et al. 2012
[22] Speck 1935; Morantz 1979; Feit 1982; Scott 1986
[23] GCC 2012
[24] Tanner 1983
[25] Carlson 2008

The majority of the 1028 people of the Naskapi Nation live in the village of Kawawachikamach, which is located close to Schefferville in north-eastern Quebec. The caribou has a special status for the Naskapi culture and caribou hunting is of great importance to them. The Naskapi have built rich knowledge about the caribou, including the animal's eating habits, behaviour in different contexts such as rut or injury, physiological characteristics, diseases, and migration routes.[26]

Figure 1: Caribou distribution in northern Quebec/Labrador (Canada)

Reindeer (*Rangifer t. tarandus*) are well adapted to their natural northern, subarctic and arctic habitats. They exist in the wild and in differing degrees of domestication, the latter being especially common in northern Fennoscandia and Northwest Russia. Reindeer habitats display high seasonal variability; reindeer must pursue selective feeding, requiring high mobility and high-energy expenditures. Reindeer husbandry is of importance to Sami traditional livelihood activities and cultural identity.[27] In Sweden, laws and statutes have directed reindeer herding practices from the late 19th century.

Sami reindeer husbandry can take place on 55% (226,000 km^2) of the boreal biome in Sweden, but the land is always shared with other land users (Figure 2).[28] Reindeer husbandry in Sweden is organized into 51 Reindeer Herding Communities (RHCs). A RHC is a geographic area as well as an economic and administrative cooperative. It oversees reindeer husbandry and represents its members. Every reindeer herder/owner is usually registered as a firm. Most RHCs are further divided into self-organized and flexible winter groups (*siidas*) where some herders work together all year and some re-group before moving to winter grazing areas. Each RHC is large enough to encompass all grazing lands required for annual sustainable reindeer husbandry. The boundaries of each RHC are long and narrow, following river valleys, connecting seasonal grazing lands through a series of migrations paths. Migration from summer lands down to winter lands usually takes place in November-December and the return migration takes place in April, in time for calving in May. A viable and resilient reindeer husbandry system depends on landscapes that have biological connectivity at multiple scales. Barriers in the landscape caused by other land use represent obstacles to sustainability.

Figure 2. Map of Sápmi and present-day RHCs in Sweden

2.2. The Jokkmokk mining conflict in northern Sweden

Jokkmokk Iron Mines AB (JIMAB), a fully owned subsidiary company to the British-based Beowulf Mining, was created in February 2012 for mining in the Jokkmokk area in northern Sweden. JIMAB obtained an exploration license for test drilling for their proposed mining site Kallak which is located on a peninsula along the River Lilla Luleälven, on the grounds of the Jåhkågasska Tjiellde RHC. The peninsula contains major reindeer migration routes as well as areas used for resting, gathering, and grazing. Jåkhågasska has 26 registered reindeer firms with more than 70 members and is permitted to have 4,500 reindeers. Sirges is the neighbouring RHC

[26] Speck 1935; Marquis 2009
[27] Delaporte & Roué 1986; Forbes et al. 2006; Tyler et al. 2007; Rees et al. 2008; Bostedt & Lundgren 2010
[28] Sandström et al. 2014

to the north. It is the largest Sami RHC in Sweden with more than 100 reindeer firms and more than 400 registered members. Its winter herd comprises of 15,500 reindeers.

Since early 2012, several complaints were filed by the two Sami villages and the network "No Mines in Jokkmokk" to the Mining Inspectorate of Sweden against JIMAB. They claimed, among others: drilling on a non-valid work plan, violating the time schedule for test-drilling, test-drillings in areas with no prior permission, disrespecting driving restrictions.[29,30]

In summer 2012, JIMAB applied for extended test mining at the Kallak site with an environmental impact analysis stating that the loss of grazing grounds would be minor for RHC Jåhkågasska Tjiellde, no hazard for the reindeers and no disturbance for reindeer resting areas on the peninsula. RHC Sirges would not be directly affected by the test-mining, even though the ore would be transported on a present road that is located within the borders of Sirges.[31,32] Test-mining was conducted in the summer of 2013.

Regarding transportation of mined ore, JIMAB proposed several options including the construction of a new railroad from Kallak directly to the railroad point Porjus, as well the upgrade and use of existing roads and railroads. All alternative transportation routes would cross the four RHCs of Jåhkågasska, Sirges, Slakka skogsameby and Unna Tjerusj.[33]

Protest by Jåkhågasska Tjiellde and Sirges RHCs, locals and activists against mining at Kallak is ongoing since July 2013, and mining exploitation on Sami grounds in Sweden got attention from the Swedish Sami Parliament.[34] In northern Sweden there are 31 concession permits and 269 exploration licenses for the Norrbotten county and 69 concessions and 273 exploration licenses for the Västerbotten county.[35] These numbers show the range of mining interests in that area, where all exploration sites are in reindeer grazing areas. National politics are divided between those who call for a revision of the Swedish Minerals Act to give priority to "long term interests" such as reindeer husbandry over "short term interests" such as mining, and those who call for reindeer husbandry to step back for the benefit of mining.[36]

2.3. The Plan Nord and mining development in northern Quebec

The Plan Nord was launched in 2011 by the Quebec government.[37] Investments of CDN$80-billion over 25 years were intended to develop infrastructure to foster industrial activities – forestry, mining, hydroelectricity, tourism, and bio-food sectors – in Quebec's boreal, arctic and subarctic territories. The Plan Nord covers 1.2 million km^2, an area occupied by six Indigenous

[29] Wik Karlsson, Petition, April 5, 2012; Wik Karlsson, Petition, January 11, 2012.
[30] Persson & Lauritz, Decision no. BS 40-1658-2011, BS-40-26-2012.
[31] Eriksson 26 June 2012.
[32] Boman 2012; Eriksson 24 April 2013; Lindgren 2013.
[33] Vikström 2013.
[34] The Washington Post 2013; Zerpe & Westin 2013.
[35] *Norrbotten undersökningstillstånd*; *Norrbotten koncessionslicenser*; *Västerbotten undersökningstillstånd*; *Västerbotten koncessionslicenser* 2013.
[36] The Swedish Government 2013; Rehnfjell 2013; Abresparr 2013.
[37] Quebec 2011; Following elections in September 2012, the Quebec Liberal Party was replaced by the Partie québécois at the head of the province. The Parti québécois did not entirely reject the Plan Nord, but rather made minor changes to it, and changed its name for "Le Nord pour tous" (North for all).

Nations – the Inuit, Innu, Cree, Naskapi, Algonquin, and Atikamekw. To mitigate social and environmental impacts, 50% of the Plan Nord territory will be put under environmental protection and sustainable resource use.[38] Concerns have been raised with regards to the Plan Nord. [39]

Mineral resource development in northern Quebec requires major infrastructure development, as the area north of 49°N is mostly devoid of roads or railroads. Several mining projects are currently in development and the government has committed to pay for some of the necessary road infrastructure. For the Renard diamond mine of the Stornoway Corporation, located 350 km north of Chibougamau, a 240-km extension to Road 167 had to be constructed. The government of Quebec built the first 143 km, whereas Stornoway agreed to pay for the remaining 97 km. The road extension project, imposed on IP in a top-down manner, caused division within the Mistissini Cree community. Some Cree families have paired with a southern Quebec entrepreneur in a joint-venture company claiming the road-construction contract. The Mistissini Band Council also wanted to be attributed the contract, arguing they should have first say on any development project on the community's territory. Such within-community division could have been avoided if Cree people had been involved from the beginning in the decision-making process.

Mining in north-eastern Quebec is dominated by iron ore production concentrated in the subarctic 1,600 km long and 160 km wide Quebec-Labrador trough (Figure 3). Mining exploitation started in the 1950s with the establishment of the Schefferville town by the Iron Ore Company of Canada (IOCC). In 1980 IOCC scaled down operations before finally closing its Schefferville mining operations in 1983.[40] Since 2011, iron ore mining restarted in the Schefferville area: New Millennium Capital Corporation (NML) with TaTa Steel, through a joint venture company called TaTa Steel Minerals Canada Ltd. (TSMC) has a Direct Shipping Ore (DSO) project under construction at the site of former IOCC operations.[41] NML is also completing a feasibility study on a LabMag taconite iron ore deposit project near Schefferville, and a KeMag deposit project.[42] NML and the Naskapi Nation of Kawawachikamach (NNK) signed an Impact and Benefit Agreement (IBA) in 2010. Under a previous agreement signed in 2004, NNK became 20% owner of NML's LabMag deposit and obtained a gross overriding royalty interest based on the sale of products from the project. In 2011, TSMC and the Innu Nation of Matimekush-Lake John signed an IBA for the DSO project. The company Labrador Iron Mines Holdings Ltd.'s (LIM) owns 20 iron ore deposits at the site of the former IOCC operations.[43] Full-scale mining operations are underway since 2011. LIM signed an IBA with the NNK in 2010 and with the Innu Nation of Matimekush-Lake John in 2011, providing financial compensation for mining activities.

Figure 3: Mining in northern Quebec/Labrador (Canada)

[38] Quebec 2011
[39] Asselin 2011
[40] Bradbury 1984
[41] Schiller 2011
[42] Storey 2011
[43] Schiller 2011

3. Material and Methods

3.1. Community-based environmental monitoring (CbEM)

Integrating indigenous and scientific knowledge into ecosystem restoration and management is increasingly recognized as a valuable approach.[44] Modeling studies have shown that industrial development projects can remain profitable, after taking into account indigenous needs.[45] Decision-support tools are needed to help bridge indigenous and scientific knowledge. In polar regions there is a growing interest in community-based environmental monitoring (CbEM) where local knowledge and observations are thoroughly recorded and used to inform management processes and decisions.[46] This interest can be tied to: an increased recognition of IK and participatory research methods, an increased concern regarding the community-level impacts of environmental changes, an interest in building local capacity to monitor changes, and increased community control over resource management decisions.[47] Several Indigenous-led CbEMs across the Arctic in Europe and North America are currently underway.[48]

There are a number of advantages to CbEM, many of which are of particular relevance in Arctic communities: they can facilitate the integration of IK and science, a firm goal of polar resource management; they engage community members in the monitoring process, from indicator selection to data analysis; they generate results that are perceived as more rigorous and relevant by stakeholders, lending greater credence to subsequent management programs; they can be a powerful tool in land use conflict resolution; they represent a low-cost method of monitoring the Circumpolar North.[49] Although CbEM is promising, there are also obstacles that can impede successful development and application, such as: lack of funds, distrust between stakeholders, nonsystematic data collection, loss of interest by volunteers, and defining ownership of the data.[50]

In this paper, we selected three examples of CbEMs in northern Sweden and Quebec: the Sami RenGIS, the Cree GeoPortal, and the Naskapi CyberTracker.

3.2. Reindeer Husbandry Plans, and the RenGIS

Reindeer husbandry usually coincides with other diverse and overlapping as well as competing land use forms such as forestry, mining, hydro and wind power, recreation and infrastructure developments. The complex and unique land use in reindeer husbandry and its relationship and dependency of other land users' planning led to the idea behind the production of Reindeer Husbandry Plans (RHP). To improve communication about land use in reindeer husbandry, the Swedish Forest Agency, researchers and the reindeer herders initiated a process of developing RHPs in 2000[51]. The goal for a RHC to have a RHP was to provide clear and understandable information about habitat use and movement of reindeer across the landscape, which would

[44] Uprety et al. 2012
[45] Dhital et al. 2013
[46] Germain & Asselin 2010; Herrmann et al. 2012; Jacqmain et al. 2012
[47] Kofinas et al. 2002
[48] Parlee & Manseau 2005; Gordon et al. 2008; Herrmann et al. 2012; Gearheard et al. 2011
[49] Moller et al. 2004, Berkes et al. 2007; Dyck 2007; Sandström et al. 2012; Uprety et al. 2012
[50] Lefler 2010
[51] Sandström et al. 2003; Jougda et al. 2011

improve dialog and consultation procedures with other land users. In addition, a RHP should facilitate planning of the operational reindeer husbandry for the RHC.[52]

The process of producing RHP included the development of a custom-made participatory GIS (pGIS) termed RenGIS (ReindeerGIS in English). Figure 4 outlines the methods for the development of RHP. Working through a process of indigenous mapping[53], Sami reindeer herders digitized important grazing lands for each of the eight reindeer seasons combining their knowledge of land together with information from satellite images. The mapping of important seasonal grazing lands was followed by field inventories carried out by the reindeer herders. Information from GPS equipped reindeer contributed with detailed habitat use and movement information. Furthermore, the compilation of digital data about other land uses was incorporated into the pGIS.

Figure 4. The development process of a RHP

Currently the work with RHP involves over 350 Sami reindeer herders from 50 RHCs who carry out GIS mapping and field inventoring of an area of 225,000 km^2. In addition positions from >1000 GPS equipped reindeer contributes detailed information to the system about habitat use by reindeer.

The reindeer herders themselves use their pGIS for visualization, assessment and support for communication as their contribution to the land use planning process both with a local and a landscape perspective. The system has been used in consultation with forest companies for harvest planning, and in environmental impact assessments with mining and wind power companies.

3.3. The Cree GeoPortal of Eeyou Istchee

In 2009, the Cree Trappers Association (CTA) and engineering professionals engaged in a research partnership and pioneered a community-based geospatial information tool that incorporates Cree knowledge with information and base maps, vector and satellite images to assist Cree hunters in documenting their observations of environmental changes that they encounter on the land as they travel, hunt, trap or fish: the Climate Change GeoPortal of Eeyou Istchee. Whenever a hunter observes a change, he reports the position and shares his observations (including photographs) with the CTA administrator of the GeoPortal. Observations are then integrated into a GIS and mapped. The types of observations mapped are divided into 5 themes: land, water, weather, wildlife, and infrastructure.

3.4. CyberTracker for Naskapi caribou monitoring

CyberTracker is a GPS with a customizable touch screen interface designed to simplify field data collection, enabling rapid and accurate recording of observations.[54] Selecting particular icons leads to additional screens with new icons to collect more information. These series of screens eventually lead back to the beginning once all the required data have been filled and a GPS point

[52] Ibid.
[53] Chapin et al. 2005; Dove 2006; Green 2008
[54] CyberTracker Software Ltd, http://www.cybertracker.org

is recorded. The device allows collecting systematic, geo-referenced data that can be downloaded to a central database and represented in map formats.

As part of the project "Assessment of Climate Change Impacts on the Caribou, the Land, and the Naskapi Nation, and Identification of Priority Adaptation Strategies" a CyberTracker was developed and used by the Naskapi Nation to verify forest-dwelling caribou presence in collaboration with NML. Based on caribou monitoring needs, the interface was designed and installed on the CyberTracker (Figure 5). The caribou survey with the CyberTracker took place in April 2012.

In addition, a community workshop was held in February 2012 where Naskapi hunters and elders shared their observations on changes in caribou. During spring/summer 2012, 36 in-depth interviews have been carried out with elders and active hunters to record observed changes in caribou migration patterns, health, behavior, habitat, and the resulting impacts on subsistence hunting practices.

Figure 5: Screenshots of the CyberTracker interface for Naskapi caribou monitoring

4. Results

4.1. Mining development and effects for Sami reindeer husbandry in northern Sweden

The proposed Kallak mine is situated within the year-around-lands of Jåhkågaska Tjiellde. The Kallak area is also and especially an important winter and spring-winter land as identified in their RHPs. The actual mining site together with the accompanying industrial area and the impacted buffer zone would occupy the entire peninsula which also is surrounded by hydroelectric dams (Figure 6a). Additionally JIMAB is holding the license to explore in surrounding areas. Allowing for concessions in the Kallak area and resolving transportation issues would make further exploitation in the area more likely (Figure 6a).

Figure 6a. The Kallak mining site and year-around-lands of RHCs

The Kallak mining site is situated on and near a number of areas identified as key habitat areas in the RHPs by the RHCs (Figure 6b). According to current proposal the ore would be transported via trucks from the mining site in Kallak to Jokkmokk and then to Gällivare on the existing, but seldom used, railroad track (Figure 6a,b). The RHCs of Sirges, Slakka skogsameby and Unna Tjerusj are directly impacted by the transportation corridor which is planned through their year-around-lands (Figure 6a). The transportation plan calls for a heavy truck every 4 minutes and a train every 3 hours. Such heavy traffic both along the road and the train track would create a definite barrier to the reindeer migration routes used every fall and spring (Figure 6b). These migration routes blocked by the transportation corridor are an important area both for organized reindeer migration and for smaller groups of reindeer that move to and from the mountains to the forests on their own. All involved RHCs except Slakka skogsameby have completed their first version of their RHP and have experience using their RHP in land use negotiations. Additionally, the Sirges RHC has carried out site specific impact mappings for the area around Kallak and the proposed transportation corridor (Lars Ever Nutti pers comm).

Figure 6b: Impacts of the proposed Kallak mining site and transportation corridors on reindeer migration routes and key habitat areas

Until the comment period for the full application for concession the RHP mappings by the RHC has only played a minor rule.

Furthermore, the reindeer herders knowledge and the information in their RHP was not part of the consultant's work to compile an environmental impact statement leading to an incomplete description of how reindeer husbandry is carried out in the area in and around Kallak. The focus of this document was on a small area right around Kallak instead of on the RHC as a whole.

Finally, as part of the RHC statement to the company's application for full concession, RHP mappings and the knowledge of reindeer herders played a major role. This document contained a thorough description of both historic and present Sami use of the area. The bases for this document came from RHC's RHP including data from the delineation of grazing lands, field inventories and GPS data from reindeer. Furthermore, mappings of other land uses around the mine site and transportation corridor provided important pedagogical information in their statement. The negative effects on reindeer husbandry from the extensive hydroelectric development in 1965-1975 on all waters around the Kallak site have radically increased the vulnerability to further developments in the area. This is hardly mentioned in the company's application to full concession but a major component in the RHC's statement. For the first time in all documents produced during the different stages of the application process, the RHC's statement addressed impacts from the proposed development with a landscape perspective instead of addressing effects too locally. The final statement produced by the RHCs in October 2013 includes a thorough presentation of information about how reindeer husbandry is carried out in the area and the cumulative consequences of the proposed Kallak development addressing the landscape perspective. The work of the RHCs and their use of RenGIS represent a unique and useful example of how tools provided have empowered the RHCs in ways that could not happen before. The power of going from "just words" to mapped and documented knowledge effectively communicated is clearly demonstrated.

4.2. Mining development and effects on Cree and Naskapi caribou hunting grounds in northern Canada

In the Eeyou Istchee territory, the Cree community of Mistissini is directly impacted by the 240-km extension road, that had to be constructed to connect Chibougamau with the mining site, which goes through their traditional forest-dwelling caribou hunting grounds, disrupting the habitat (Figure 7). While the road extension will make Cree traplines more easily accessible, this positive outcome might be canceled out by the fact that large mammals tend to avoid roads[55] and mining sites.[56] The Cree Regional Authority recently started a project to increase awareness from Cree hunters not to kill the caribou because of their low abundance.

Figure 7: Impacts on Cree caribou hunting grounds of the extension of road 167 to reach a mine.

The iron-ore mines near Schefferville affect the GRH caribou, which migrate and occupy this area, through changes in habitat availability, movement patterns, and increased mortality through influences on predation and vehicle collisions. Transportation corridors include: a summer-use

[55] Laurian et al. 2012; Rudolph et al. 2012; Leblond et al. 2013
[56] Boulanger et al. 2012

road across the southern portion of the range of the GRH; a railway in western Labrador; an "all-weather" road from the railway to the mining sites through the range of the GRH. Caribou aerial surveys around the Schefferville mine demonstrated a quasi-absence of forest-dwelling caribou tracks around the mining sites and the transportation corridors (avoidance effect). The caribou avoid the vicinity of mines over a scale of several kilometres. Concerns over diminishing caribou population have been regular themes in community meetings where Naskapi elders reported that: "There is too much noise and shaking of the ground because of the mines. This is affecting the caribou. You don't see them anymore.", and "the caribou stopped coming around Kawawachikamach a couple of years ago, it is about the same time the drilling started", or "The caribou used to roam the streets of Kawawachikamach, now it stays only at the George River in the North", and "low-altitude flying of the mining companies affects the condition of the caribou herd" (NNK 2012).

The displacement and reduction of the available range due to human disturbance from mining activities, and other correlating factors, such as climate change, also reduces the use of high-quality foraging areas.[57] This has health consequences for the caribou, as Naskapi hunters reported: "We used to measure the fat of the caribou by fingers. In the past it was tick like 4 fingers, but now it is about 2 or 3 fingers. The body condition of the caribou changed", and "the body weight of the caribou is reduced".[58] Decreasing health, in turn can decrease reproductive rates.[59]

According to observations by the Naskapi hunters, mining activity, together with other effects, such as climate change, predation, sport hunting (stopped in 2012), and resulting habitat alteration can also be causes for population fragmentation. Several elders noted: "30 years ago there used to be one big herd - 100,000, 200,000. Now there are small groups - 200, sometimes 250. Maybe because of the mining or the outfitters. Maybe they get no food anymore.", and "There was lots of caribou in the past [1980s]; there used to be thousands and thousands of caribou in one big herd. Now a big group is hundred or something."[60]

Reduction in the abundance of caribou has consequences for traditional hunting practices: "It takes longer to hunt caribou; fewer caribou are killed in the community."[61] As caribou consumption reduces, people rely more on store-bought food, which may affect their health.[62] The Naskapi are adjusting hunting practices and methods to better match the changing caribou migration patterns and range use: "People have to use bush planes now for caribou hunting."[63]

Of concern to the Naskapi, and other First Nation and Inuit communities, is also the mining exploration and exploitation near the calving grounds, the Raglan nickel mine near Kangiqsujuaq, which results in dislocation of calving areas. Legal protection of calving grounds in Quebec prohibits human activities that can potentially affect caribou habitat only from 15 May

[57] Wolfe et al. 2000; Vistnes & Nelleman 2001; Haskell et al. 2006; Reimers et al. 2007
[58] NNK 2012
[59] Nelleman et al. 2003
[60] NNK 2012
[61] Ibid.
[62] Royer & Herrmann 2011
[63] NNK 2012

to 31 July. Consequently, we agree with Taillon[64], who recommend a year-round protection of calving grounds of migratory caribou from habitat changes as result of human disturbances that could hinder caribou from accessing and using calving grounds.

5. Discussion

In the following we discuss results that emerge from the impacts common to all three cases, and we try to get a deeper understanding of the strengths and weaknesses of three different methods of reindeer/caribou CbEM.

5.1. Area of impacts versus barrier effects to range use and migration patterns of reindeer/caribou

In all three case studies, our results reveal that even though the actual mine occupies a "small area", it causes impacts over an expansive area. Transportation corridors perpendicular to migration routes create physical barriers and force reindeer to be moved by truck instead of normal foot migration. Transportation corridors and roads create behavioral barriers that prevent caribou from crossing them. Linear corridors, buildings, and increased presence of humans, alter reindeer/caribou habitat characteristics and thereby reduce the use of high-quality foraging areas. Therefore, we would argue that when dealing with a species that moves over large areas it is necessary to address issues with a landscape perspective. Hence, mapping and considerations of all resources at stake in the area becomes essential.

5.2. Diverse effects add to mining impacts on reindeer/caribou populations and require mapping of cumulative impacts

Even though multiple human disturbances affect reindeer/caribou populations and multiple parts of their ecosystem, mapping is often carried out primarily through a sector-by-sector approach by focusing on one impact at a time. Potential cumulative effects are thus not dealt with, and management does not account for other stressors, and mitigation measures are not proven effective. Managing each impact in isolation is insufficient to conserve species in fragile ecosystems. The impact of mining has to be put in the proper context. The case studies from Sweden and Canada commonly show that diverse effects, such as hydroelectric development, forestry activities, roads, increasing predator numbers, climate change, exacerbate the impacts of mining on reindeer/caribou populations and habitat. Therefore, we argue that it is not the impact of the mine alone, but the cumulative and interactive impacts that need to be considered when assessing reindeer/caribou populations. Hence, it is important to highlight the importance of systematic community mapping of all possible interactions and cumulative impacts in order to understand the species' vulnerability in the context of multiple stressors, and identify areas that are "double exposed" such as migration routes or calving grounds.

5.3. Impacts of mining are case specific

While we are looking to broaden this discussion beyond our three study communities, we must be cognizant of the numerous contextual elements of each case and community that will limit the external validity of our results. There is seldom a general solution or description of impacts of mining and related infrastructure in polar regions, and thus it is impossible to make a universal statement concerning mining impacts always occurring over a x+ km radius around the mine.

[64] Taillon et al. 2012

Instead, as results from our three cases in Sweden and Canada have demonstrated, mining related impacts, their direction, and the priority of the problems are case-specific. Hence, we argue that it is important to analyze the particulars for the issue.

5.4. Strengths and weaknesses of the different CbEMs

Often the complex and unique land use forms of reindeer/caribou-people socio-ecological systems are not well understood by other land users with whom the land is shared. RenGIS, Cree GeoPortal and Naskapi CyberTracker have proven to be tools that can empower communities through data collection that can be used to inform processes and thus facilitate stakeholders' involvement in planning. All three CbEMs have shown potential to considerably improve a knowledge-based dialogue between the mining sector, and the reindeer husbandry sector/ caribou-related subsistence activity sector in several ways:

- improved understanding of how the different sectors of mining, reindeer husbandry/caribou-based livelihoods affect each other;
- more effective communication on how traditional subsistence activities – caribou hunting/reindeer husbandry, and use of reindeer/caribou by indigenous communities operate;
- improved communication through mapping about the cumulative effects with a landscape perspective;
- improved understanding of how to mitigate adverse impacts of mining and related infrastructure development;
- increased learning and interacting opportunities for members of the community as well as for researchers;
- effective integration of IK and western science;
- bridging communication, and increased respect and trust among the participants; and
- improved relationships between the mining sector and local communities, regarding the consultation process and its outcome, measured in terms of increased consideration given to each other's needs.

Based on our case study from Sweden we argue that a different type of communication, i.e. face to face meetings, is required at the prospecting stage, between involved parties (RHCs, prospecting/mining company, and other concerned actors). We stress that exploration companies active in indigenous areas must take extra consideration regarding the rights of the Indigenous Peoples. Exploration work can only be possible after direct consultation with the indigenous communities regarding environmental impacts as well as social implications. These questions must be highlighted at an early stage in the process and not in the latest stage as is still often the case today.

Challenges can also be identified in the CbEMs, such as guaranteeing long-term community participation (CyberTracker, GeoPortal) and a regular use (RenGIS). Education and training are necessary to use RenGIS. CyberTracker is limited in that it handles only pictorial information, because its goal is to enable non-literate people to contribute observations. CyberTracker does not reduce the time between data acquisition and delivery to the final users, such as the managers, scientific personnel, and the general public. As the data cannot be downloaded centrally onto a single PC, the information manager will have the laborious task of compiling the

data, and the more PDA users there are collecting the same sequence of data, the more dispersed the information will be.

5.5. Outcomes of pGIS tools employed in all three reindeer/caribou CbEMs

A major outcome common to all three cases, is the capability of pGIS to improve communication between all actors and boost communities' confidence.[65] For Sami reindeer herders, as well as for Cree and Naskapi caribou hunters, pGIS maps represent tools to communicate with decision-makers.[66] In all three cases, pGIS allows communities'/reindeer herders' voices to enter directly into the decision-making process concerning the utilization of their land resources and concerning options to lessen impacts of human disturbances due to mining. The pGIS in the three reindeer/caribou CbEMs are unique in that all of the actual data collection and compilation is carried out by the end-user — the caribou hunters and the reindeer herders themselves — rather than by outside experts. They can be used in many other circumstances to increase trust in and knowledge about fundamental land use premises for different stakeholders.

6. Conclusion

This paper highlighted the use and application of three new approaches to CbEM in polar regions - RenGIS, Cree GeoPortal, and CyberTracker - that combine IK with GIS allowing Sami,Cree and Naskapi communities in northern Sweden and Canada to predict, monitor, and communicate the impacts and assess the risks of mine development on habitat and populations of reindeer/caribou and indigenous livelihoods through the regular use of their environment, documenting observations and experiences in context, as they happen. The data collected by the Sami RHCs showed that transportation corridors would significantly affect reindeer husbandry as they create linear barriers perpendicular to reindeer migrations routes and cross reindeer key and core habitat areas. The data collected by the Crees showed that the road to the mine crosses the traditional caribou hunting grounds of Cree families, disrupting the habitat. Naskapi hunters observed avoidance behavior of caribou around the mining sites and the transportation corridors, and population fragmentation. In all three case studies, other effects (e.g., hydroelectric development, roads, climate change) exacerbated the impacts of mining on reindeer/caribou. Observed negative effects on reindeer/caribou populations indicate problems for the entire natural system of the area.

Based on our results, we argue that reindeer/caribou are keystone species, and that the reindeer/caribou system could be used as an indicator of a biologically functioning, and connected landscape.

The data collected by Sami herders and Cree and Naskapi hunters using RenGIS, Cree GeoPortal, and CyberTracker provide detailed, dynamic, geo-referenced information addressing issues both at the local level and with a landscape perspective which is necessary when communicating the complex land use form of reindeer husbandry and caribou hunting in the Arctic. They also allow for a deeper understanding of human–environment relationships over time and space that could otherwise not be collected.

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[65] Chapin et al. 2005
[66] McCall & Minang 2005

As demonstrated in this paper, the RenGIS, Cree GeoPortal, and CyberTracker have proven to be: (i) successful examples of IK, polar science and engineering collaboration; (ii) tools that can improve a knowledge-based dialogue between the mining sector and the local communities, thereby fostering an improved understanding of how the different sectors of mining, reindeer husbandry and caribou-based livelihoods affect each other; (iii) tools for more effective communication on how traditional subsistence activities operate in the Arctic; (iv) tools for better identification of options to lessen the negative impacts of mining and related infrastructure development; (v) tools that allow arctic communities' voices to enter directly into the decision-making processes concerning the utilization of their land resources; (vi) new tools in the field of indigenous mapping in polar regions; and (vii) approaches for meaningful engagement of IP in polar research. The data know-how and successful adoption of the newly developed geo-spatial information tools by the Sami, the Cree and the Naskapi demonstrate their potential as useful tools for other societies across polar regions for a variety of applications including hazards research, or arctic wildlife monitoring, and as tools that provides the possibility of enhancing information exchange, decision-making, conflict resolution and co-learning.

Acknowledgements

OURANOS, Aboriginal Affairs and Northern Development Canada, the Quebec Centre for Biodiversity Science, Le Groupe Hémisphère and TaTa Steel (New Millennium Iron Corp. "NML") kindly provided funding for the 'Naskapi Climate Change and Caribou Project' and Thora Herrmann's and Natalie D'Astous' work. Financial funding for Per Sandström's work was provided by Swedish Research Council Formas through the PLURAL project. Karin Granqvist is grateful to the Department of Philosophy and History of Technology, KTH Royal Institute of Technology, Sweden, for financial support. We thank Marc Girard for his contribution to this paper.

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