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# Historical Reindeer Corrals as Portraits of Human-Nature Relationships in Northern Finland

Sari Stark,[1,2] Outi H. Manninen,[1] Oona Ilmolahti[1] and Maria Lähteenmäki[3]

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ABSTRACT. Reindeer herding has been practised in northern boreal and subarctic regions of Fennoscandia for several centuries. The gathering and separation of reindeer for slaughter and calf marking are significant and cyclical activities of reindeer herding that are commonly carried out in reindeer corrals composed of circular-shaped fences of wood or stone construction leading into the corral. Using archaeological databases, we mapped historical reindeer corrals in northern Finland dating from the late 1800s to the 1960s for the entire reindeer herding area and characterized the legacies of their past use on present-day vegetation in Peräpohjola. In total, 94 corrals were located. Reindeer separations created a niche for novel plant communities with increasing graminoids in relation to dwarf shrubs and formation of a dense birch grove. Corrals have also preserved old rare trees left standing inside the corral to provide shelter for reindeer. The positioning of the corrals in the landscape was usually planned in a way that utilized man-made constructions and natural barriers, such as peatlands, and the typical behaviour of the reindeer in combination with both. When the wooden constructions had collapsed and decomposed, only the different vegetation indicates their past existence.

Key words: reindeer herding; northern Finland; boreal forests; reindeer corral; historical ecology

RÉSUMÉ. L'élevage des rennes est pratiqué dans les régions boréales et subarctiques nordiques de la Fennoscandie depuis des siècles. Le rassemblement et la séparation des rennes à des fins d'abattage et de marquage des veaux sont d'importantes activités cycliques de l'élevage des rennes. Elles s'effectuent généralement dans des enclos à rennes composés de clôtures circulaires en bois ou de constructions en pierre menant aux enclos. À l'aide de bases de données archéologiques, nous avons dressé la carte historique des enclos à rennes du nord de la Finlande de la fin des années 1800 jusqu'aux années 1960 pour l'ensemble de la zone d'élevage des rennes, puis nous avons caractérisé l'héritage de leur utilisation antérieure sur la végétation actuelle de Peräpohjola. Nous avons localisé 94 enclos en tout. Les séparations employées pour les rennes ont donné lieu à la création d'un créneau favorable à l'établissement de nouvelles associations végétales contenant plus de graminiformes par rapport aux arbustes nains et à la formation de boulaies denses. Les enclos ont également permis de préserver d'anciens arbres rares qui sont restés à l'intérieur des enclos en guise d'abri pour les rennes. En général, l'emplacement des enclos était planifié de sorte à tirer parti des constructions artificielles et des obstacles naturels, comme les tourbières, et du comportement typique des rennes à l'égard de ces deux caractéristiques. Une fois les constructions en bois effondrées et décomposées, seule la végétation différente témoigne de leur existence.

Mots clés : élevage des rennes; nord de la Finlande; forêts boréales; enclos à rennes; écologie historique

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## INTRODUCTION

Ecological investigations have demonstrated that past cultural activities and historical events exert lasting legacies on present-day ecosystem structures and processes (e.g., Kardol et al., 2007; Szabó, 2015; Valls Fox et al., 2015; Bürgi et al., 2017). These legacies have been recognized as an integral part of the natural environment (Balée, 2006) and an agent for increased heterogeneity and diversity across the landscape (Egelkraut et al., 2018a; Marshall et al., 2018; Rouet-Leduc and von Essen, 2019). Signs from past human activities that are still distinguishable in the environment provide unique insights into both the ecology of the ecosystems and the relationship between people and the environment across time. Analysing various historical legacies in the natural environment and the interconnectivity of people and natural environments belongs to the research field of historical ecology, which uses a multidisciplinary approach involving ecological field inventories, archaeological evidence, and historical records alike (Balée, 2006; Szabó, 2015; Hédl et al., 2021).

Historical legacies of past land use are also evident in northern boreal forests and subarctic tundra, although these ecosystems for many may seem to be natural rather

[1] Arctic Centre, University of Lapland, PO Box 122, FIN-96101 Rovaniemi, Finland
[2] Corresponding author: sari.stark@ulapland.fi
[3] Karelian Institute, University of Eastern Finland, Yliopistokatu 2, Joensuu 80101, Finland

than cultural landscapes (Hörnberg et al., 1999, 2006; Östlund et al., 2003; Räsänen et al., 2007; Josefsson et al., 2009, 2010; Staland et al., 2010; Freschet et al., 2014; Kamerling et al., 2017; Kuuluvainen et al., 2017; Normand et al., 2017; Egelkraut et al., 2018a; Rouet-Leduc and von Essen, 2019). In these areas with harsh climatic conditions, traditional livelihoods involved combining several methods of acquiring food and resources, including hunting, fishing, agriculture, and the herding of semidomestic reindeer (*Rangifer tarandus* L.). In northernmost Fennoscandia, reindeer herding was developed by Sámi in the fells of Sweden and Norway in the late Middle Ages, as described already in early historical records (Olaus, 1555; Linné, [1732] 2005; von Düben, 1873). The livelihood gradually spread to Finnish Lapland between the 1600s and the 1800s and was also adopted by the Finnish settlers (Kortesalmi, 2008; Turunen et al., 2018, 2020). Historical ecological studies have shown that high reindeer densities exert important legacies on present-day ecosystem structures and processes that may persist for a long time, even after grazing has ended (Josefsson et al., 2009, 2010; Freschet et al., 2014; Egelkraut et al., 2018a, b; Stark et al., 2019). Yet, since different regions experienced highly variable grazing patterns due to local management practices and historical events that modified reindeer numbers and migration routes, these legacies also vary in space and time depending on the practises that created them.

Remnants of reindeer corrals, pens, and fences are rare physical evidence of historical reindeer herding still visible in boreal forests and the subarctic area. Several historical records mention circular structures supposedly used for reindeer milking, calving, and slaughtering in boreal forests (Schefferus, [1674] 1963; von Düben, 1873; Itkonen, 1948) and above the tree line (Turi, [1910] 2011; Paulaharju, 1927), but the history of using corrals and fences in reindeer herding is still largely unknown. Reindeer corrals vary tremendously in size and structure, reflecting the unique historical development and practices of the area in which they are found. The location of reindeer corrals was based on several criteria; a major determinant was the natural movement of reindeer across the landscape (Korhonen, 2008; Kortesalmi, 2008). Fence structures were built by using the most abundant materials in the environment—wood in the boreal forest and stones and boulders in treeless tundra (Paulaharju, 1927; Norstedt et al., 2017). In addition to the circular pens and corrals, in the forested areas of northern Sweden, linear fences and barriers were used already about 300 years ago to restrict and guide reindeer movement (Norstedt et al., 2017). The characteristics of reindeer corrals have changed over time as a result of cultural transitions in reindeer herding, leading to a large variation across time in the size, location, and structural complexity of reindeer corrals (Korhonen, 2008; Kortesalmi, 2008; Norstedt et al., 2017).

In Finland, very little research has been conducted on reindeer corrals. Yet, reindeer herders have long used corrals in separation events to group animals for slaughter,

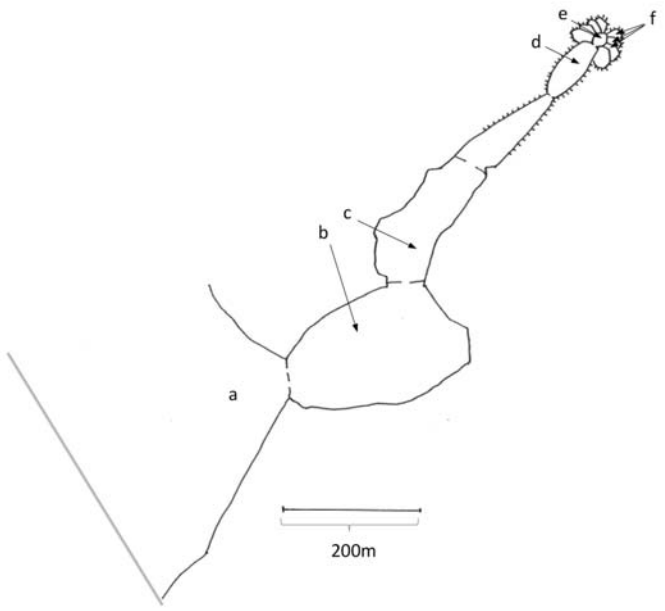


FIG. 1. The floor plan of the Saarivaara reindeer corral. a) Funnel shaped, tapering fence corridor (*siula*), b) Corral for feeding, c) Corral for watering, d) Main corral, e) Churn (*kirnu* or *kurra*), and f) Offices, pens (*konttori*). Reindeer are gathered inside *siula* and guided gradually through corrals to the churn, where reindeer owners separate the animals and pull them into the offices. The image is modified from a drawing by Jama and Laine (Strand et al., 1994).

calf marking, and counting them according to ownership (*ráttka* in Sámi, *poroerotus* in Finnish; Näkkäläjärvi and Pennanen, 2003; Korhonen, 2008; Kortesalmi, 2008). As a whole, the process comprises a series of activities, each of which has its own specific area and structure in the corral. Separation events start by gathering reindeer from the surrounding area (a process called *ohcu* in Sámi, *etto* in Finnish), eventually guiding the reindeer towards fences that are several kilometres long (*sivlá* in Sámi, *siula* in Finnish) that lead to the inner parts of the corral (Fig. 1a). In order to control their movement and maintain their welfare, reindeer are divided into smaller groups and gradually herded through corrals built for different purposes (Fig. 1b–d). The pressure caused by the reindeer increases towards the inner parts of corral as animals are packed into smaller spaces, reflected in the fence structures. Funnel-shaped fences built from tree trunks or boards are replaced by more solid structures constructed of large logs or stones and boulders in the innermost parts of the corral. The pressure caused by the reindeer is at highest when the herd starts to circulate during the actual separation process inside the churn (*njoarostangárdi* in Sámi; *kirnu* or *kaarre* in Finnish; Fig. 1e). This is the most hectic event of the separation, when herders recognize and capture their reindeer and pull them into smaller roundup fences known as offices (*kantuvra* in Sámi; *konttori* in Finnish), which are placed around the churn (Fig. 1f). In the offices, reindeer are counted, earmarked, and grouped according to their destination, and then released. The number of animals per separation event varies and has varied widely over time, numbering between 150 and 5000 reindeer or even as

many as 10,000 reindeer per corral depending on the region (Korhonen, 2008).

In the present study, we analyzed historical reindeer corrals dating from the late 1800s to the 1960s. We aimed to answer the following specific questions: 1) How many historical reindeer corrals can be located from existing archaeological inventory data and at what geographical distribution? 2) What type of vegetation can be found in these corrals and how does it compare with previous historical ecological studies from reindeer herding sites? 3) In which ways do the features of the reindeer corrals, such as their location and structure, depict an understanding of reindeer behaviour in its surroundings and from this, the human-nature relationship in the North? As is common in historical ecological studies, we used archaeological data, field inventories, and historical records as analytical tools. Because reindeer corrals in Finland have remained largely unexplored, the first step in our investigation was to use available archaeological databases to gather together the listed historical reindeer corrals into one map. We characterized the current forest structure and understorey vegetation in some of the located sites to understand the legacy of past practises on ecosystems. We also looked at the location and position of corrals across the landscape together with their historical transformations as ways to gain insights into the relationship between people and the natural environment.

## MATERIAL AND METHODS

### *Vegetation and Land-Use History of the Study Area*

Reindeer herding area in Finland extends to a land area of 122,936 km$^2$, which comprises over one-third of the total land area of the country. Most parts of the area are northern boreal forest (see Fig. 2), where Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* L.) H. Karst) together with deciduous trees such as birch (*Betula* sp.) constitute the main tree species. Dwarf shrubs such as bilberry (*Vaccinium myrtillus* L.), lingonberry (*V. vitis-idaea* L.) and crowberry (*Empetrum nigrum* L.) dominate the ground vegetation, underlain by a continuous layer of mosses such as *Pleurozium schreberi* (Willd. ex Brid.) Mitt., *Hylocomium splendens* (Hedw.) Schimp. and lichens such as *Cladonia arbuscula* (Wallr.) Flot. and *C. rangiferina* L.) F.H., Wigg. In Finnish contexts, northern boreal forests are further differentiated into Peräpohjola, Forest Lapland, and Fjeld Lapland (Kalela, 1961; Fig. 2). Compared with Peräpohjola, Forest Lapland is more frequently characterized by Scot pine forests and treeless tundra in mountainous areas and forms a transitional zone towards Fjeld Lapland, which in turn is characterized by subalpine mountain birch forest (*Betula pubescens* ssp. *czerepanovii* (Orlova) Hämet-Ahti) and treeless tundra with an understorey vegetation ranging from lichens and dwarf shrubs to herb-rich communities (Kuuluvainen et al., 2017).

Reindeer are resident in northern Europe, Asia, and America across boreal, subarctic, and Arctic vegetation zones. Reindeer migrate between seasonal ranges depending on forage plant availability; in tundra regions in particular, these migrations may involve very long distances (Oksanen and Virtanen, 1995). Lichens, evergreen dwarf shrubs, and arboreal lichens constitute important food plants during winter, whereas grasses, herbs, mountain birch leaves, and mushrooms are eaten during summer and autumn. Reindeer is the only semi-domesticated animal that naturally belongs to the area and grazes freely. The emergence of large-scale reindeer herding parallels a major genetic shift in reindeer populations during the 16th and 17th centuries, suggesting that non-native animals were introduced to the area during this period—lineages that might have only recently arrived to Fennoscandia from the East (Røed et al., 2018; Heino et al., 2021). Through time, earlier forms of reindeer herding with relatively tame herds have shifted into more free-ranging herds both in Finland (Itkonen, 1948; Näkkäläjärvi and Pennanen, 2003; Helle and Jaakkola, 2008; Lehtola, 2010; Vuojala-Magga et al., 2011) and in other Fennoscandian countries (Turi; 1910; Aronsson, 1991; Kamerling et al., 2017; Norstedt et al., 2017). As a combined result of climatic and environmental conditions and historical developments, reindeer management regimes in Finland differ from other countries. For historical reasons, both Sámi and Finns practice reindeer herding as a livelihood (Kortesalmi, 2008; Lehtola, 2010). Country border agreements have modified reindeer herding by forming barriers to earlier seasonal migration routes (Turi, [1910] 2011). The Finnish-Norwegian border was closed to reindeer herding Sámi in 1852; thereafter, reindeer herders were obliged to live within state borders. As some summer ranges had previously been situated in coastal Norway, Finnish reindeer ranges had to be used year-round from that time on (Pennanen, 2003; Lähteenmäki, 2006; Lehtola, 2010). In 1898, state authorities obligated reindeer owners to establish geographically defined herding districts, which currently encompass 56 reindeer herding co-operatives (*paliskunta* in Finnish) with defined boundaries (Kortesalmi, 2008). During the early 1900s, reindeer numbers in Finland were slightly over 100,000, reaching 140,000 by 1959–60 and a maximum of 250,000 reindeer during the 1980s, after which the number has generally been less than 200,000 reindeer. More than 75% of the reindeer in Finland graze in forests where logging activities are being undertaken, which has created a problematic relationship between reindeer herding and the forestry industry (Turunen et al., 2020). Some Finnish herding co-operatives have seasonal range rotations within the co-operative boundaries (Kumpula et al., 2011; Stark et al., 2021).

Reindeer herding requires a high level of cooperation between individual herders, which is particularly reflected during reindeer separations. The separation processes were characterized by high regional variability until practices became more harmonized in line with the recommendations

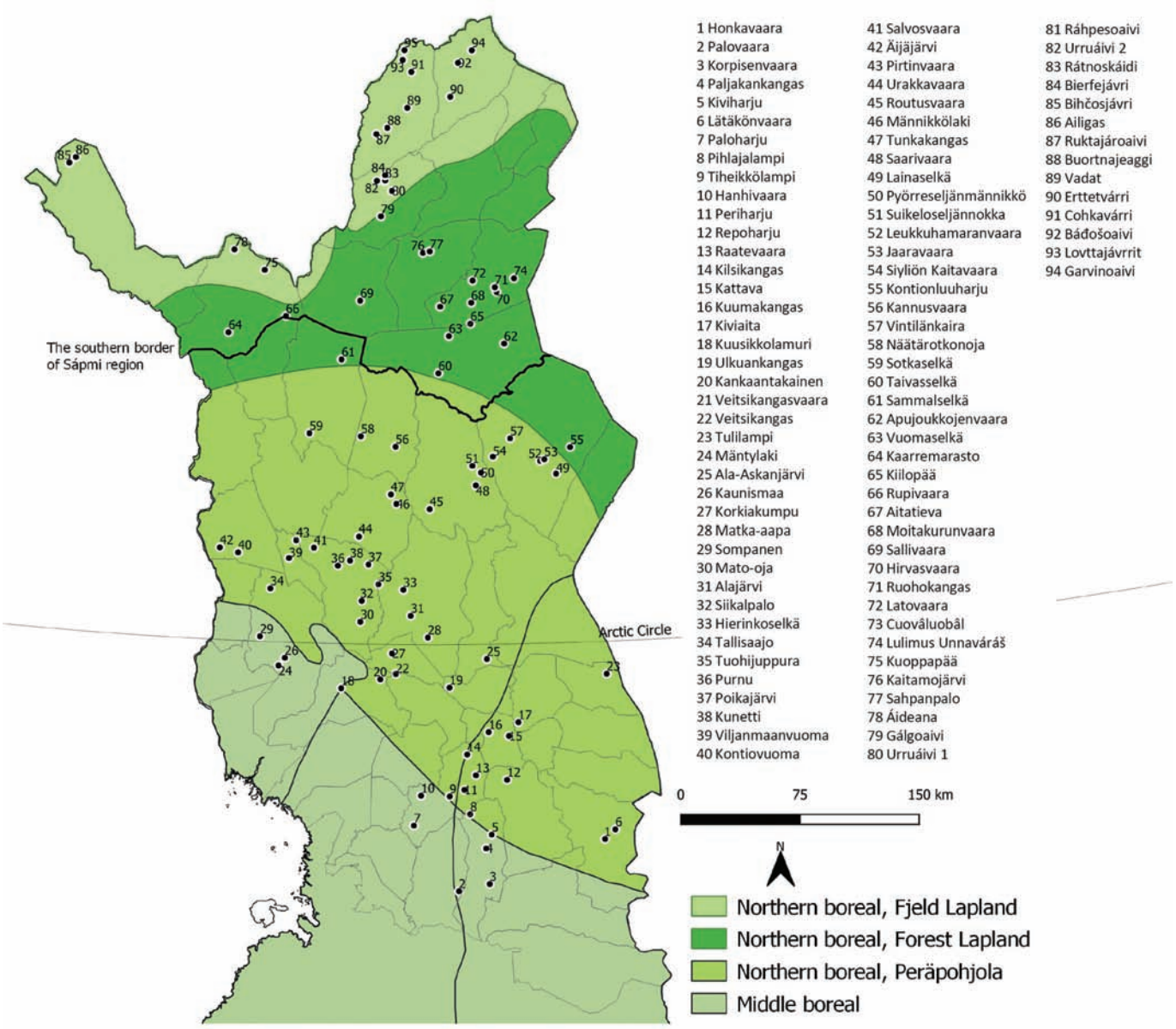


FIG. 2. Map of historical reindeer corrals located from different existing databases. The northern boreal forest zone is further separated into Peräpohjola, Forest Lapland, and Fjeld Lapland based on subgroupings used in Kalela (1961).

of the Reindeer Herders' Association and its predecessor, the Reindeer Breeding Association in the first half of the 1900s (Korhonen, 2008; Lähteenmäki et al., in press). Nowadays it is common for reindeer herders to use assistive technologies, such as motorcycles, snowmobiles, and helicopters in their gathering work. Separations take place twice a year; those for calf-marking usually start around mid-June, since once the air is warm and mosquitoes begin to appear, reindeer gather naturally as herds in open places from where they can be easily directed towards reindeer corrals (Näkkäläjärvi and Pennanen, 2003; Korhonen, 2008). Autumn separations are the time of harvest for reindeer herders, when animals to be slaughtered are separated from the rest of the herd.

*Locating Historical Reindeer Corrals*

To locate currently documented historical reindeer corrals, we utilized the archaeological databases of the National Forest Service (*Metsähallitus* in Finnish) and the Finnish Heritage Agency (*Museovirasto* in Finnish), with the Metsähallitus database forming the primary source. The list of historical reindeer corrals provided by these databases cannot be considered exhaustive, as not all existing reindeer corrals are found or listed. Metsähallitus is a Finnish governmental agency that manages all state-owned land, involving both nature reserves and forests used for forestry. It initiated archaeological site inventories by professional archaeologists during the early 2000s, the results of which were routinely integrated into local

information systems (PAVE). Some archaeological sites that have not been checked by archaeologists are marked in PAVE thanks to information provided by the public. Inventories are conducted according to the instructions and protocols of Finnish archaeological inventories (Museovirasto, 2022). Archaeologists generally begin with background searches of earlier inventories, published historical research of the district, old maps, and other relevant archive material, place names, topography, soil properties, and laser scanning. For historical reindeer corrals in particular, most information is gleaned from old topographic maps, local inhabitants (particularly reindeer herders), place names, and historical research. Interviews are also often conducted. Archaeologists assess and select potential sites for field inventories based on this background search. The site is included into the database provided that clear material evidence dating prior to the 1960s can be found in the field.

The PAVE database was screened for historical reindeer corrals in several steps. All archaeological sites located in the whole of the Finnish reindeer herding area were extracted from the total PAVE database in September 2016, which resulted in over 17,000 records. Initial examination of the descriptions attached to each site revealed that the vocabulary used by different archaeologists in the written descriptions was very diverse, and using a simple word search for picking reindeer corrals out from the database proved to be inefficient. Historical reindeer corrals were therefore hand-picked from the database by reading all 17,000 site descriptions. An initial screening was done using the criterion that the text included indications for any activity related to reindeer herding, which resulted in 218 sites. Descriptions after the initial screening were then examined in further detail, and only sites with a specific word indicating a reindeer roundup fence, separation site, reindeer corral (*erotusalue* or *erotusaitaus* in Finnish), or any typical construction that belongs to a reindeer separation site (e.g., *kirnu*, *johdinaita*, *konttori* in Finnish) were included.

After screening the PAVE database, two separate databases maintained by the Finnish Heritage Agency were checked for any further sites not included in PAVE. The registry of ancient heritage sites (*muinaisjäännösrekisteri* in Finnish) is composed of data collected by archaeologists, local museums, universities, and private consulting companies going back to the 1800s and is publicly available (www.kyppi.fi). In addition, some historical reindeer corrals are also listed in the database for nationally important elements of the built cultural environment (Museovirasto, 2009).

Since the natural landscape and constructed formations were used in combination to control reindeer movement (Korhonen, 2008), we observed the locations of the corrals in the landscape in terms of the vegetation types found adjacent to the corrals. We also looked at how the direction and arrangement of the slopes might have been used to direct reindeer movement. Vicinity to villages and site accessibility also contributed to the decisions on where reindeer corrals were established (Korhonen, 2008), but we focused only on the characteristics of the natural environment surrounding the corrals.

### *Field Measurements for Forest Structure and Understorey Vegetation*

Vegetation analyses were conducted over an area located in central Lapland ranging from about 150 km north and south from the Arctic Circle, focusing on Peräpohjola. Sites in this vegetation zone were screened again to focus where an undisturbed control site and a site with historical reindeer separations could be found side by side, thereby enabling an assessment of the historical legacy on current vegetation. Many sites were heavily damaged by clear-cutting or forest roads with no proper undamaged buffer zone adjacent to the historical reindeer corral, showing that their existence in the database had not fully prevented the use of these sites for logging. We excluded these sites, as well as those that were still presently used for reindeer separations or were located right next to (e.g., Vuomaselkä) or inside a new corral (e.g., Urakkavaara, Poikajärvi). Some sites were excluded from the measurements because they seemed to be abandoned quite recently (e.g., Hanhivaara, Paloharju), as indicated by the structure, decomposition stage, and the epiphytic lichens of the wooden fence constructions.

We analyzed vegetation and tree species composition by first visually determining the centre point of the corral from the remnants of the decayed structures of the wooden fences. Vegetation squares (50 × 50 cm) were located inside the fences half-way between the centre and the fence remnants according to the main compass points (north, east, south and west) and for the corresponding locations outside the fence remnants. The method to include control plots from all compass points was selected to minimize the risk of confounding factors contributing to recorded differences between control and corral plots. The percentage cover of vegetation was estimated visually using a scale from 0% to 100% for field and ground layer separately. Plant species were classified into functional types: deciduous dwarf shrubs, evergreen dwarf shrubs, graminoids, forbs, and cryptogams. We established a circular sampling area (radius 3 m) around each vegetation plot where we counted the number of live and dead seedlings and mature trees. We randomly selected five living individuals of seedlings and trees of each species and recorded their heights.

We calculated mean values for all analyzed parameters for corral and control plots within each site. The normality of not transformed, log- and square root-transformed data was tested with a Shapiro-Wilk test, and Levene's test was applied to check the homogeneity of the variances. The results revealed that the data did not meet the assumptions of parametric tests (i.e., normal distribution, homogeneity of the variances) even after transformations; hence, a non-parametric test was preferred. As corral and control plots


FIG. 3. a) Corral built of stones and boulders in treeless tundra. b) Remnants of a wooden fence constructed of piled-up birch trunks in a subarctic mountain birch forest. c) Corral constructed from large pines using the so-called *perkka* technique (without nails) in a boreal forest. d) Light wooden fence constructed using nails. Building materials are board, felled and trimmed trees. e) Relatively recently built board fence. f) Old corral still in active use, where the remnants of old *perkka* wooden structures are still found at the base of the fence, which was later repaired with a wire mesh (front) and rail board fence (back) and thus represents structures from several different eras in the very same corral. Photos: Outi Manninen (a) and Sari Stark (b–f).

were considered to be dependent on each other within study sites, a related-samples Wilcoxon signed-ranks test was applied.

## RESULTS

### *Historical Reindeer Corrals*

With the criteria we used for screening the archaeological databases, we found a total of 94 reindeer corrals with a geographical distribution ranging from the southernmost parts of the reindeer herding area up to the north (Fig. 2). These corral sites exhibited an immensely wide range of different structures, forms, and materials. In Fjeld Lapland, old fences were built using large stones or mountain birch as material (Fig. 3a, b). In boreal forests, in both Peräpohjola and Forest Lapland, the wooden structures varied from traditional *perkka* fences to boards depending on the age of the corral (Fig. 3c–e). In the corrals with a long history of use reaching up to the present day, different building techniques and materials could be present in the very same fence (Fig. 3f). Old aerial photographs, available for many sites from the late 1950s onward, reveal that the churns were mostly devoid of forest trees except for some individuals (Fig. 4a). The whole structure of the corral is also clearly visible, including the *siula* fences leading towards the corral (Fig. 4a). During the present day, the fences surrounding the churns were well preserved and clearly visible at the sites, whereas *siula* fences have mostly collapsed into the ground and are no longer detectable (Fig. 4b, c).

### *Present-day Forest Structure and Ground Vegetation*

We analyzed ground vegetation and forest structure in 27 corrals (Fig. 5a). The proportion of graminoids and forbs in the ground vegetation was higher and the proportion of deciduous and evergreen dwarf shrubs was lower inside than outside the corrals (Table 1, Fig. 5b). Forest structure inventories revealed that the number of birches was significantly higher inside than outside corrals (Table 1, Fig. 5c); in some corral sites, this meant we found a thick birch grove inside the historical reindeer corral (Fig. 4b–d). There were no statistically significant impacts of historical land use on the number of pine and spruce (Table 1, Fig. 5c). Yet, the average height of pine trees was higher in controls than inside the corrals (Tables 1 and 2). The number of seedlings of all tree species was significantly higher inside the corral than in the control areas (Table 1, Fig. 5d).

## DISCUSSION

So far, little research has been conducted on reindeer corrals and the most important sources are written in Finnish (e.g., Korhonen, 2008 and Kortesalmi, 2008). Our

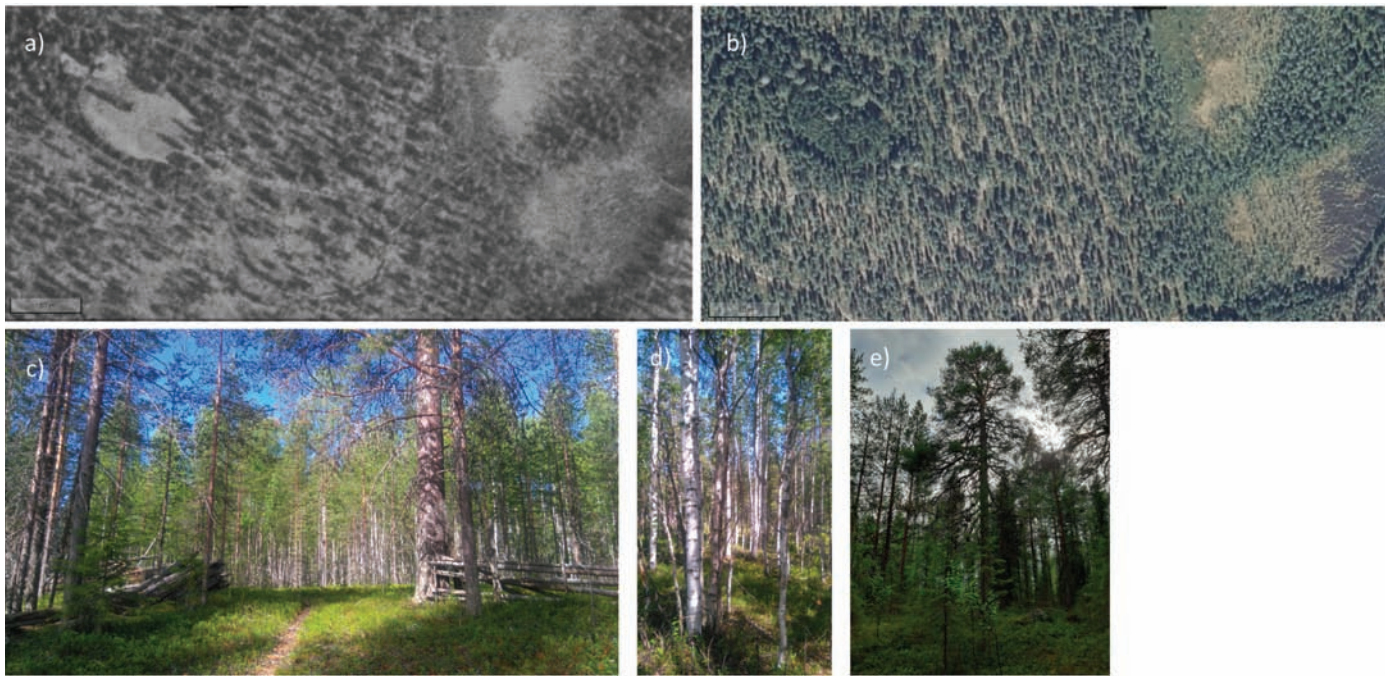


FIG. 4. Historical reindeer corral of Purnu, Rovaniemi. a) Aerial photograph from 1957 showing an older and larger churn and a smaller and younger churn (in the top left corner) next to each other. b) Aerial photograph from 2021 showing a thick birch grove inside both old churns. c) Gate leading to the larger churn photographed in 2018. d) The birch grove inside the large churn photographed from the ground in 2018. e) An old tree left standing in the corral to give reindeer shelter and to direct their movement in the circle.

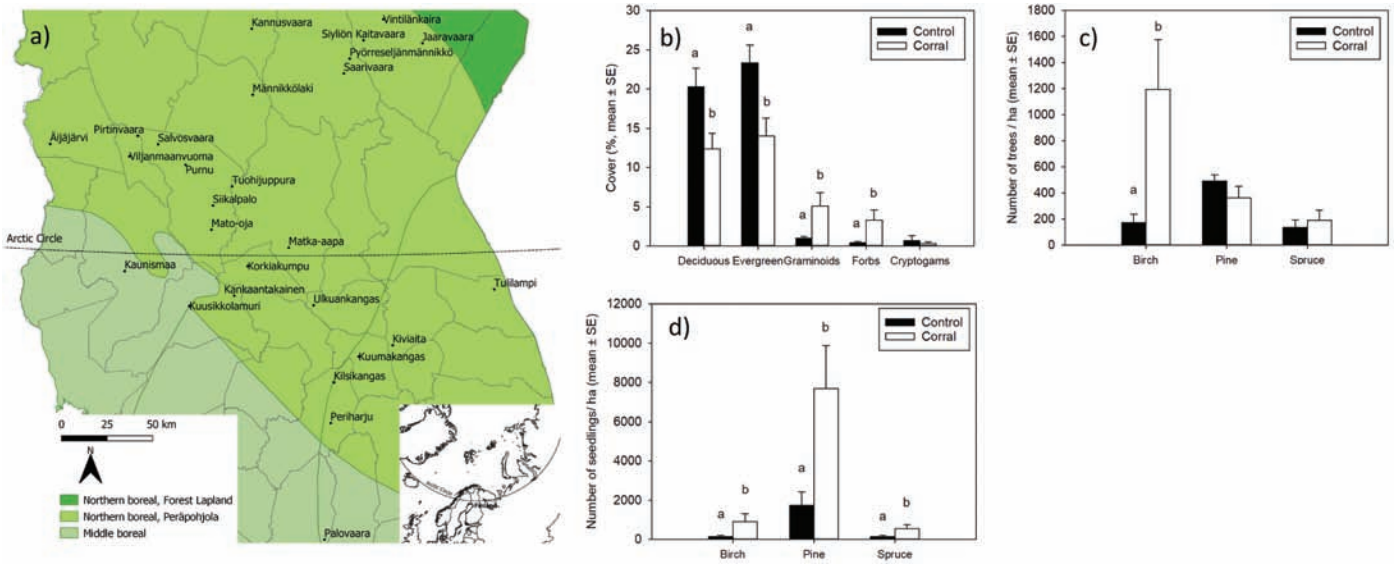


FIG. 5. a) Map of historical reindeer corrals, where forest structure and ground vegetation were analyzed. b) The cover (%) of main plant growth forms in the ground vegetation. c) The number of mature forest trees. d) The number of tree seedlings in controls and corrals. Values are mean + SE, $n = 27$. Small letters above the bars represent a significant difference between the control forests and corrals as revealed by related-samples Wilcoxon signed-ranks test.

study therefore constitutes the first English presentation of historical reindeer corrals in Finland. Earlier publications on reindeer fences in northernmost Sweden have studied long-term enclosures or linear fences, which represent the closest comparison to our study sites (e.g., Josefsson et al., 2010; Kamerling et al., 2017). We were able locate close to 100 historical reindeer corrals in the Finnish reindeer herding area. Through field inventories, we identified the legacies of historical reindeer separations on forest structure and vegetation as a form of cultural biotope with close similarities to earlier documentations of cultural landscapes within the northern boreal forest zone. Through observing the location and characteristics of reindeer corrals in their respective landscapes, we found ways in which the wooden constructions of the reindeer corral and the surrounding natural landscape formed a collective unit that considered the behaviour of the reindeer in its natural surroundings and in the separation events.

TABLE 1. The statistical differences between historical reindeer corrals and control sites on ground vegetation and forest structure in northern Finland. *P*-values are obtained from related-samples Wilcoxon signed-ranks test, $n = 27$.

| | *p*-value |
|---|---|
| Ground vegetation: | |
| Deciduous dwarf shrubs | 0.002 |
| Evergreen dwarf shrubs | 0.001 |
| Graminoids | 0.002 |
| Forbs | 0.011 |
| Cryptogams | 0.345 |
| Trees: | |
| Birch (*Betula pubescens*) | |
| tree number/ha | 0.004 |
| height (m) | 0.953 |
| diameter 1.3 m (cm) | 1.000 |
| Pine (*Pinus sylvestris*) | |
| tree number/ha | 0.166 |
| height (m) | 0.004 |
| diameter 1.3 m (cm) | 0.077 |
| Spruce (*Picea abies*) | |
| tree number/ha | 0.937 |
| height (m) | 0.500 |
| diameter 1.3 m (cm) | 0.500 |
| Tree seedlings: | |
| Birch (*Betula pubescens*) | |
| seedling number/ha | 0.003 |
| height (m) | 0.021 |
| Pine (*Pinus sylvestris*) | |
| seedling number/ha | 0.003 |
| height (m) | 0.332 |
| seedling age | 0.124 |
| Spruce (*Picea abies*) | |
| seedling number/ha | 0.044 |
| height (m) | 0.401 |

TABLE 2. The height (m) of trees and seedlings for downy birch, Scots pine, and Norway spruce in controls and historical reindeer corrals. Values are mean + (SE), $n = 27$.

| | Controls | Corrals |
|---|---|---|
| Tree heights (m): | | |
| Birch (*Betula pubescens*) | 7.9 (1.6) | 7.2 (1.3) |
| Pine (*Pinus sylvestris*) | 14.4 (0.9) | 8.6 (1.5) |
| Spruce (*Picea abies*) | 7.5 (1.9) | 3.7 (1.3) |
| Tree seedlings height (m): | | |
| Birch (*Betula pubescens*) | 0.5 (0.2) | 0.5 (0.2) |
| Pine (*Pinus sylvestris*) | 0.5 (0.2) | 0.5 (0.2) |
| Spruce (*Picea abies*) | 0.6 (0.3) | 0.6 (0.2) |

### *Present-day Vegetation and Forest Structure in Historical Reindeer Corrals*

The vegetation in and around old reindeer corrals in Finland has never been characterized before, and one of our main questions was how they compare with previous historical ecological studies from reindeer herding sites in northern boreal forests. Vegetation inventories showed lower coverages of both deciduous and evergreen dwarf shrubs and higher coverages of graminoids and herbs inside historical reindeer corrals as compared to outside. These results relate well with other studies, as similar ground vegetation changes have commonly been found in connection with human presence and disturbance ecology in boreal and subarctic mountain birch forests and open tundra heaths. For example, palaeoecological analyses in subarctic Sweden showed a vegetation transition from a homogeneous dwarf shrub-dominated tundra to a mosaic of herb- and graminoid-rich and heath- or shrub-dominated tundra following the start of nomadic reindeer herding during the 1300s (Aronsson, 2009). Staland et al. (2010) found an increasing proportion of graminoids and herbs in the vegetation above the treeline in mountain birch forests in northwestern Sweden and associated the change with increasing nutrients due to human presence. Tømmervik et al. (2010) found that abandoned reindeer pens, temporarily fenced areas used in separations or milking, in northern Norway still appeared as oval-shaped areas of lush grass and herb-rich vegetation due to the slow return of dwarf shrubs. Yet, even before the domestication of reindeer, northern hunter-gatherers moving in the forests increased the proportion of graminoids in the vegetation (Hicks, 1993). Similar vegetation changes are also observed with contemporary grazing, as graminoids and herbs both benefit from higher nutrient concentrations (Barthelemy et al., 2015) and can withstand high levels of trampling (Olofsson et al., 2001; Stark and Väisänen, 2014) by recovering effectively from basal meristems (Strauss and Agrawal, 1999). By contrast, deciduous and evergreen dwarf shrubs, which form a major component of undisturbed understorey vegetation, produce a high amount of below-ground biomass and are sensitive to trampling and biomass loss, which disrupts their rhizomatous growth (Bergstedt et al., 2008; Widenfalk and Weslien, 2009).

Studies conducted in the subarctic treeless tundra have indicated that, once taken root, higher graminoid abundances may remain in the vegetation even for a century after grazing has ceased, and could therefore reflect a transition to another alternative ecosystem state (Egelkraut et al., 2018a, b; Stark et al., 2019). In boreal forests, an increase in forbs and graminoids is much more subtle and unlikely to represent a transition to another state. The higher stability of the graminoid-dominated vegetation in tundra zones can be explained by increased soil nutrient availability through the original fertilization effect and the intensity of grazing by other herbivores (Egelkraut et al., 2018a, b). However, studies conducted in boreal forests have indicated that increasing nutrients do not significantly influence vegetation recovery from disturbance (Manninen et al., 2009), which likely explains why the effect of historical high reindeer densities is not as strong in boreal forests as it is in subarctic tundra.

A distinct pattern typical for many reindeer corrals was a formation of a birch grove inside the reindeer corral in the midst of boreal coniferous pine or spruce forest. The birch groves stand out in the landscape and constitute a clearly distinguishable feature of the legacy of reindeer separations in boreal forests. In the boreal forest ecosystem, birch is regarded as a typical pioneer species, which produces extensive amounts of germinable seeds and rapidly colonizes open ground following disturbance

(Hynynen et al., 2010). The birch groves form an interesting comparison to palynological evidence that has also shown human presence to increase the proportion of birches, both in connection with prehistorical hunter gatherers (Hicks, 1993; Hörnberg et al., 2006) and more recent reindeer herding or agricultural practises (Josefsson et al., 2009; Freschet et al., 2014). On the other hand, at the proximity of altitudinal or latitudinal forest treeline, human presence may also be associated with a reduction or even permanent disappearance of birch due to its usage as firewood (Räsänen et al., 2007; Staland et al., 2010; Östlund et al., 2015).

The presence of old, tall individual trees standing out clearly from the rest of the environment and a high abundance of tree seedlings were other common features in the historical reindeer corrals, as witnessed also in reindeer enclosures in Sweden (Östlund et al., 2003). Reindeer herders usually cut most of the trees inside the corrals and used the logs for fence structures but left individual trees to either provide reindeer shade from the sun or to help direct reindeer movement inside the corrals (Korhonen, 2008). The protective status of the corrals has enabled these older trees to be preserved; they are rarely seen in the surrounding area because of forestry and other land uses. We also detected a high number of conifer seedlings inside the corrals, likely promoted by the combination of increased light and favorable microhabitats for seed gemination in exposed ground (Kuuluvainen, 1994; Stuiver et al., 2016). The high density of tree seedlings in combination with the exceptionally old trees likely leaves long-lasting signs in the boreal forest landscape that will be visible long after the wooden structures of the corral are already decomposed (as in Östlund et al., 2003; Josefsson et al., 2010).

*Historical Reindeer Corrals within Their Landscapes*

As expected by the tremendous variety of practical purposes of reindeer corrals and the wide geographical range where they can be found, corrals located from archaeological databases exhibited high versatility in both size and structure. Although it is known that many of the corrals were used in reindeer separations, corrals for other purposes such as calving, milking, or helping reindeer avoid insect harassment (Näkkäläjärvi and Pennanen, 2003; Korhonen, 2008; Kortesalmi, 2008) are also likely, but it is not possible to pinpoint their purpose without oral or written history.

Despite the variety in size and structure, there were still many common characteristics and principles that were true for many old reindeer corrals. As described previously (Korhonen, 2008), the location of the fences in the landscape was designed to aid the reindeer separation process in several different ways. In principle, the wooden constructions of the reindeer corral and the surrounding natural landscape formed a collective unit in which, in terms of their intended purpose, different parts were indistinguishable from each other. As seen in Figure 4a, reindeer movement was guided by fences along open landscapes, such as peatlands, but high hills and valleys could also be used as landscape components that reindeer follow naturally. Another typical feature is that the funnel-shaped siula fences were situated uphill, and that the gate leading into the corral was hidden behind the highest point in the terrain (Korhonen, 2008). These features made the movement of the herds more controllable, because reindeer naturally run upward when scared, and the gates, if unseen by the reindeer, could be easily closed behind the reindeer without frightening them. The strategy to build the corral structures based on natural reindeer behaviour demonstrates how familiar the reindeer herders were with this behaviour, which formed an important part of their traditional knowledge and the cultural heritage of the area (Lähteenmäki et al., in press).

In addition to aiding the separation process itself, the location of the corrals across the landscape was also designed to consider factors affecting reindeer welfare. The corrals used in winter were located near the winter ranges, which are very vulnerable to trampling during the summer months (Korhonen, 2008). During summer, corrals were placed adjacent to peatlands to also provide suitable summer grazing grounds with drinking water. Although the proximity of peatlands was crucial, the corrals themselves were located on dry mineral soils in forests because excessive soil moisture was known to increase the number of infections in reindeer hooves (Korhonen, 2008). The most desirable location was a north-facing slope not reached by the midday sun. As a whole, the locations of reindeer corrals over the centuries were selected by using multifaceted knowledge linked with weather, nature, terrain, and the pasturage cycle of reindeer, which together determined the usefulness of a site for its purpose (Lähteenmäki et al., in press). The information of earlier generations guided herders to build corrals at the best spots in relation to natural reindeer migration routes along with many other factors. Traditional knowledge and cultural historical heritage involving reindeer corrals are increasingly seen as important reasons why reindeer herders find corrals valuable and worthy of protection (Lähteenmäki et al., in press).

During the latter half of the 1900s, several transformations took place in connection with the modernization of reindeer herding, including the introduction of motorized vehicles and of supplementary feeding of reindeer (e.g., Helle and Jaakkola, 2008; Turunen et al., 2016). The reindeer corrals we located in this study also indicated transitions. For example, in central Lapland, during the late 1800s, it was more common to use a few, extremely large main corrals (*valta-aita* in Finnish) where reindeer were gathered from a vast area. The structures of these massive corrals could be built up to 2 m high with the *perkka* technique (i.e., without nails; Fig. 3c) and contain numerous layers of thick pine trunks. The gathering of the reindeer could take as long as a month as the herders with an ever-increasing number of reindeer travelled from the

most remote villages towards the main corral (Lähteenmäki et al., in press). During the 1900s, these main corrals were often replaced by a larger number of smaller corrals, as the separations changed towards handling fewer reindeer in each corral at a time (Helle and Jaakkola, 2008; Turunen et al., 2018; Lähteenmäki et al., in press). In some cases, the use of the old main corral would still continue, but the larger old churn was left unused and a smaller one was built next to the old one, as seen in Figure 4a. During the latter half of the 1900s, accessibility with motorized vehicles to an area became an important criterion for selecting corral locations, and modern technologies and raw materials were introduced into fence construction, leading to lighter and more portable fence structures (Korhonen, 2008). However, some of the old corrals still remain in use and, as demonstrated in Figure 3f, the same corral may show a high diversity of structures from different eras, as the wooden structures were repaired over time using the materials and techniques of its time.

## CONCLUSIONS AND WAYS FORWARD

Reindeer have been present in northernmost Fennoscandia throughout the Holocene, and the effects of reindeer on vegetation as well as ecosystem processes are therefore endemic to the area (Oksanen and Virtanen, 1995). These effects vary tremendously in time and space and depending on both habitat characteristics and the intensity and timing of grazing (e.g., Bernes et al., 2015; Sundqvist et al., 2019). Due to the longevity of these effects over time, earlier studies have argued that in the North, forest characteristics should always be considered in light of their historical context (Josefsson et al., 2010), and that the land history needs to be acknowledged when predicting northern ecosystem responses to global changes (Staland et al., 2010; Väisänen et al., 2014).

Massive events took place in reindeer corrals in the past with sometimes thousands of reindeer circling inside the fence (Lähteenmäki et al., in press). These events created a niche for a specific type of vegetation, which in the boreal forest zone often involved increasing graminoids in the ground vegetation and the formation of a birch grove. These changes are similar to previous findings on human influences on boreal forests (Hicks, 1993; Hörnberg et al., 2006; Josefsson et al., 2009; Freschet et al., 2014). Reindeer corrals have also preserved exceptionally old trees (Östlund et al., 2003). We may identify historical reindeer corrals and their natural surroundings as a cultural biotope formed by the combination of wooden built structures and a specific type of vegetation created by past events. When the wooden structures disappear and decompose after collapsing into the ground, only the different vegetation indicates their past existence.

As vegetation transitions link the historical and cultural processes that induced them (sensu Balée, 2006; Egelkraut et al., 2018a; Rouet-Leduc and von Essen, 2019), at the larger landscape level, reindeer corrals inform us about northern human-nature relationships. The wooden constructions of a reindeer corral and their position in the landscape formed a collective unit, where, in terms of their practicality, the different parts worked in combination and were inseparable from each other. The landscape worked as a tool alongside the man-made structures. As part of a cultural heritage that combines historical, cultural, ecological, and practical choices, corrals are worthy of protection (Lähteenmäki et al., in press). This study gathered information on historical reindeer corrals and will hopefully work as a basis for further, more localized cultural-historical and historical-ecological studies, which would involve systematic analyses of historical records and the documentation of oral histories. Each corral has a unique story behind it, which cannot be understood without knowing its past purpose, seeing the corral itself in its larger landscape, and knowing the prevailing historical situation of its era. Understanding that story provides a means of comprehending how to make a corral in a specific location. Historical reindeer corrals portray the knowledge of reindeer herders of their natural surroundings and reindeer behaviour under a variety of circumstances and therefore expand our understanding of northern ecosystems and their peoples across time.

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