Chapter 7. Mobility in early reindeer herding

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Abstract

In this chapter, we introduce different ways of studying reindeer mobility in Sápmi. Through the application of landscape-level Geographical Information Systems (GIS), geochemical soil, and stable isotope analysis, we aim to present different interdisciplinary methods used in archaeology to trace human-reindeer relationships. To do this, we have exemplified the methods with different case studies, and when no case study is available, we refer to previous or ongoing research. We show that these methods are effective tools for studying reindeer migration.

Abstrákta

Lohkosis ovdanbuktojuvvojit sápmelaš boazobargiid johtima arkeologalaš dutkanvuogit. Ovdanbuktit báikediehtovuogádagaid (Geographical Information Systems, GIS), eananvuođu geokemiijalaš analysaid sihke stabiila-isotohpaanalysaid vejolašvuođaid olbmo ja bohcco gaskavuođa goriid dutkamušas. Dát vejolašvuođat áiccalmahttojuvvojit dáhpáhusdutkamušaid ja juo almmustuhttojuvvon dutkamušaid mielde. Mii čujuhit, ahte visot dát vuogit heivejit bures bohccuid johtima dutkamii.

Tiivistelmä

Luvussa käsitellään saamelaisten poronhoitajien liikkuvuuden arkeologisia tutkimusmenetelmiä. Esittelemme paikkatietojärjestelmien (*Geographical Information Systems*, GIS), maaperän geokemiallisten analyysien sekä stabiili-isotooppianalyysien mahdollisuuksia ihmisen ja poron välisten suhteiden tutkimuksessa. Näitä mahdollisuuksia havainnollistetaan tapaustutkimusten sekä käynnissä olevien ja jo julkaistujen tutkimusten avulla. Osoitamme, että kaikki nämä menetelmät soveltuvat hyvin porojen liikkuvuuden tutkimisen.

Keywords: landscape archaeology, GIS, geochemical soil analysis, stable isotope analysis, mobility

7.1 Introduction

Mobility is an integral part of reindeer-herding societies. Traditional Sámi reindeer pastoralism was based on the annual migration cycles of the reindeer. People followed their animals on their way from one seasonal habitat to another, sheltering the animals from predators, guiding them to fresh lichen pastures, and preserving other pastures for the future. However, there have probably always been large geographical and temporal variations in the timing, direction, and length of the migrations of people and reindeer.

In its natural habitat, reindeer (*Rangifer tarandus*) can move over large areas, depending on the available ecological niches (Andersen 2011). It feeds on more than 250 plants, including shrubs and grasses, as well as lichens and mushrooms (Klein 1990; Mårell 2006: 7; Blind et al. 2015; Morris et al. 2018). However, the reindeer mainly feeds from reindeer (*Cladonia rangiferina*) and tree lichens (*Usnea*, *Bryoria*, *Alectoria*), which represent about 80 per cent of its dietary intake (Heggberget et al. 2002: 15; Inga 2007; Goudeau 2019: 25). For more detailed information on reindeer diet, see Chapter 5 in this volume.

The archaeological and historic movement of Sámi in Sápmi is often related to the natural migration of reindeer, whether reindeer were domesticated or not. While rectangular hearths, hearth row sites, and Stalló foundations, largely dating to the eighth to thirteenth centuries (see Chapter 6), are examples of archaeological remains that testify to early wild reindeer hunting practice, probably with small herds of domesticated reindeer (Halinen 2016; Mulk 1994), the post-fourteenth-century archaeological and historical material from marketplaces, Sámi habitation sites, and Sámi offering sites and tax records all suggest the presence of domesticated reindeer.

Reindeer-herding and mobility practices differ noticeably in different parts of Sápmi. For example, Mountain Sámi reindeer herding in northern Sweden moves seasonally over larger areas, sometimes from one coast to another (from the Baltic to the Atlantic coast), usually staying in the mountains in the summer and in the boreal forests in winter (Manker and Pehrson 1953; Inga 2008: 8). Yet mountain reindeer herding in southern Swedish Sápmi, i.e. in Härjedalen and Jämtland counties, also relies on seasonal mobility, but within considerably more restricted geographical areas. The Mountain Sámi in northern Norway have somewhat different traditions but also rely on the seasonal mobility of herds and the people following them. In Finland, Mountain Sámi reindeer herders previously moved from their winter pastures in the Finnish inland forest landscape to the summer pastures on the northern Norwegian coast, but this practice had to change with the formation and closure of the national borders in the latter half of the nineteenth century (see Heikkinen et al. 2005; Valtonen 2016). In contrast, the Forest Sámi in the more southerly parts of Swedish Sápmi – for example, in Norrbotten and Västerbotten counties – and Finland – for example, in the Sodankylä region – herded their reindeer within smaller areas in the boreal forests all year round (Inga 2008: 8).

In this chapter, we aim to explore the role of mobility in early reindeer-herding practice through GIS and stable isotope analyses. The case studies presented here originate in different regions, so we will discuss the potential to study reindeer mobility through the mentioned methods in various parts of Swedish, Norwegian, and Finnish Sápmi. The discussed approaches have thus far mostly been used separately, in different case studies in different areas, but can be adapted and used together to further explore analogous questions regarding pastoral land use, mobility, and herding practices across Sápmi. By introducing different methods and their use examples, different ways of tracing reindeer mobility are discussed. It goes without saying that the domestication of reindeer, the development of reindeer pastoralism, and the introduction of the domestication of reindeer and human-animal relations overall have taken place at differing rates and in different ways in the different parts of Sápmi over time (Mulk 1994; Hedman 2003; Røed et al. 2008, 2020; Hedman et al. 2015; Halinen 2016; Fjellström et al. 2020, 2021; Seitsonen and Viljanmaa 2021). The mobility studies and landscape-level approaches offer a way to gain a better understanding of the varying regional developments.

7.2 Geographic Information System (GIS) methods for analysing past mobilities

Landscape archaeology and geoarchaeological analyses offer some useful approaches for assessing past mobility. For example, landscape-level Geographical Information System (GIS) analyses allow the examination of latent mobilities across the terrain and their comparison with the spatial distribution patterns of archaeological sites (e.g. Cooper 2010). They also allow the comparison of the clustering or dispersion of traces from past human activity on an inter-site level (e.g. Bonnier et al. 2019; Wright et al. 2020). On a smaller intra-site scale, analyses of the distribution of archaeological features, excavation finds, and geoarchaeological properties of soil offer ways to investigate site use, spatialities, and site-level mobilities related to social factors such as the gendered division of space, for example (see Chapter 6).

Our recent studies in the Lake Gilbbesjávri region highlight how combinations of GIS-based landscape archaeology, documentary evidence, and local transgenerational memories can be used to assess the past transnational land use and mobilities in Sápmi. We describe here some of the practical methods used in the GIS analyses. The listed analyses can all be readily applied to studying the site distributions and potential mobilities of humans and animals in different areas.

The Kernel Density Estimation (KDE) (e.g. Bonnier et al. 2019) and Ripley's K analysis (e.g. Wright et al. 2020) appear to be especially useful approaches for evaluating the site patterning at a landscape level (Seitsonen and Viljanmaa 2021). KDE analysis can be used as a quantitative measure to assess changes in the site clustering and past land-use patterns (see Bonnier et al. 2019 for methodological and algorithmic details). Ripley's K analysis quantitatively assesses the clustering or dispersal of sites by comparing the observed numbers of data points around the localities with the expected numbers based on Markov chain Monte Carlo simulations (Wright et al. 2020, for methodological and algorithmic details).

The application of topography-based cost of movement algorithms instead of Euclidean distances gives more realistic estimates of the proximity and accessibility of various archaeological and landscape features. These can be modelled, for instance, with the R movecost package (Alberti 2019). Latent mobilities can be modelled as cumulative potential pathways and cumulative potential path areas (e.g. Cooper 2010; Seitsonen et al. 2014), based on selected factors such as topography or vegetation, which can highlight the likely least-cost routes through the landscape. Various GIS packages like Circuitscape software (Shah and McRae 2008) allow ready algorithms for such landscape scale analyses of potential mobilities (see Seitsonen and Viljanmaa 2021).

As an example, modelled least-cost paths for the seasonal mobilities of one Sámi *siida* in north-western Sápmi in the early-1900s are shown in Figure 7.1. Least cost path analyses are a well-established set of methods for finding optimal routes between locations (Verhagen et. al. 2019). The analysis consists of two parts: 1) calculating a cost surface quantifying the cost of movement along the surface; and 2) computing the optimal path between the locations of interest using a specific cost-function. We used the leastcostpath package (Lewis 2021a, b) with R (R Core Team 2021) to model the seasonal mobilities between the winter and summer camps known based on the transgenerational memories. The cost surface based on topography was calculated from 25 x 25 metre Digital Elevation Model with a vertical accuracy of two metres (Finnish National Land Survey). To compute the optimal paths, we used Tobler's "hiking function" (1993), which takes into account the effects of slope direction on the potential movements (e.g. Fábrega-Álvarez and Parcero-Oubiña 2007; Herzog 2014). The preliminary example illustrated in the Figure 7.1 shows a close correlation between the modelled routes and the intermittent daily campsites along the seasonal mobility as known from the ethnographic interviews based on the transgenerational memories. This approach is being developed further but suggests already now a high potential for modelling also the past mobilities and land-use in wider scale (Seitsonen & Viljanmaa 2021). In the future, for example multiple factors could be tested for building the cost surfaces in tandem with the topography, for instance soils, such as bogs and boulder fields, and the seasonality of accessibility and latent mobility owing to the lengthy snow and ice cover.

7.3. Landscape archaeological analysis of mobility

In the following section we discuss issues related to the GIS study of landscape-level mobilities, using as an example case our recent work in north-western Sápmi. We have worked several years in the Lake Gilbbesjávri region on the border of Finland, Sweden and Norway, in the Finnish part of the former Ruovdnál *siida* (Fi. Rounala) (Seitsonen 2020–2021; Seitsonen and Eguéz 2022) (Figure 1.7). In these studies, we have assessed the developments related to the reindeer domestication and pastoralism in the Lake Gilbbesjávri region from the ninth to the twentieth centuries using a landscape archaeological perspective (e.g. Seitsonen and Viljanmaa 2021). By combining GIS analyses and newly acquired radiocarbon results based on a set of connected Sámi archaeological remains, these studies contribute to the ongoing discussions of reindeer pastoralism, domestication, and land use (Seitsonen 2021; Seitsonen and Viljanmaa 2021).

Based on historical tax and other records, late-nineteenth and early-twentieth-century ethnographic data, and local folklore in the Gilbbesjávri region, the Mountain Sámi reindeer herders of this region moved annually between their winter pastures in the forests of northern Finnish Sápmi and the summer pastures in coastal northern Norway at least from the late sixteenth century onwards (e.g. Itkonen 1948; Seitsonen 2021). However, a major change in mobility patterns of this area was instigated by the consolidation of the national borders during the late nineteenth century, which caused the disruption of the Ruovdnál *siida* and forced many Sámi families to migrate to other parts of Sápmi when their old herding patterns were disrupted (e.g. Valtonen 2016). The Sámi families who stayed in the region reorganised into new *siida* herding units, whose mobilities became officially demarcated by the national borders. However, many families continued to herd across the borders unofficially until the late twentieth century (Heikkinen et al. 2005).

In this area, and more widely in Sápmi, it appears that major changes in site location and archaeological features were initiated by the fifteenth century, probably connected with the spread of nomadic pastoralism, which continued as the dominant livelihood in this area until the mid-twentieth century (Hedman 2003; Mulk 1994; Halinen 2016; Seitsonen and Viljanmaa 2021). Multiple factors were likely at play behind this major change in the subsistence system and the connected mobilities. These included probably at least the deteriorating climatic conditions caused by the Little Ice Age (c. 1300–1850 CE; Mann et al. 2009), the diminishing wild reindeer herds (Lundmark 1982: 160; Hansen and Olsen 2014: 204), and the increased trade, taxation, and control by nascent states of Sweden, Norway, and Novgorod (Russia), and the associated (forced) Christianisation especially from the seventeenth century onwards (e.g. Carpelan 2003; Halinen 2016).

According to isotopic studies (Fjellström 2011; Dury et al. 2018; Lidén et al. 2019), the individuals buried between the fourteenth and eighteenth centuries at the abandoned Ruovdnál churchyard, the earliest church in this part of Sápmi, about 20 kilometres south of Lake Gilbbesjávri, had a diet containing protein from both the Norwegian Atlantic coast and the Bothnian Sea. This suggests wide-ranging mobilities from one to another, passing through the Lake Gilbbesjávri region. Interestingly, Ruovdnál church was established adjacent to the Dálvas Fjell (literally Winterfell), where according to local transgenerational memories the winter camp of the Ruovdnál *siida* herders used to be situated (Seitsonen 2021; Seitsonen and Viljanmaa 2021). The Ruovdnál church may therefore have acted as a seasonal marketplace like the later church sites in Sápmi, visited by outside traders from various directions (e.g. Halinen 2007; Harlin et al. 2019; Äikäs et al. 2021). The local Sámi probably visited the place in the market period for a short period during their annual migrations. At the other end of their annual migration pattern, the Ivgobahta (Skibotn) marketplace on the Norwegian coast served as a summer market at least from the sixteenth century and may have acted as such already in earlier times (Spangen 2016: 142). Ivgobahta remained an important meeting place for the Sámi, traders, officials, and others into the twentieth century. These two places, Ruovdnál church and Ivgobahta market, may have been significant stopovers and contact points during the annual migrations of the herding families of the Ruovdnál *siida* from at least medieval times onwards.

In contrast with the later historic nomadic pastoralist mobilities, the pre-fourteenth-century Iron Age and medieval movement patterns in the area seem to have been considerably more tethered (Seitsonen and Viljanmaa 2021: 4, 13). Typical archaeological features of the era, including rectangular hearths, hearth row sites, stray finds, and the northernmost known *Stalló* site, are roughly contemporaneous with each other, and date to the eighth–thirteenth centuries CE (Mulk 1994; Sommerseth 2009; Halinen 2016). Based on spatial analyses of their distribution, it appears that hearth row sites may have been central aggregate camps, and the smaller sites with one–three hearths represent places used seasonally by different Sámi families (see Halinen 2016; Olsen 2019) (see Chapter 6).

The *Stalló* site at Devddesvuopmi (Norway) may have been a site with a special purpose, used perhaps for the seasonal hunting of wild reindeer passing through the area (Sommerseth 2009), or alternatively for interaction with the Norse traders from the coast, as a new theory put forward by Kjell-Åke Aronsson (2020) proposes (see Chapter 6). The mobilities of wild reindeer herds can be reconstructed based on the spatialities of trapping pit systems and stray finds that are mostly arrowpoints (Myrvoll et al. 2011; Sommerseth 2015). Although the pitfall traps in the wider area seem to pre-date the Iron Age and medieval period, they can be applied to reconstruct the past seasonal migration routes that would have been strongly directed by the area's local topography (Myrvoll et al. 2011; Seitsonen and Viljanmaa 2021). Furthermore, the stray find arrowpoints are typically found adjacent to or in the modern calving and rutting zones of reindeer in the high fjell region. It therefore seems that the seasonal trips to the fells may have been important for encountering migrating wild reindeer (Sommerseth 2009, 2015).

The tethered mobility pattern seems to mirror the economic basis of the society, a mixed hunter-fisher-herder subsistence pattern with small numbers of domestic reindeer kept mostly as transport animals (e.g. Halinen 2016; Mulk 1994; Olsen 2019). Halinen (2016) has suggested that a similar tethered annual mobility may also have taken place in the southern Eanodat region. The appearance of rectangular hearths and their associated new settlement pattern in the seventh and eighth centuries CE appears to be explained by many factors, but the domestication of reindeer for transport and decoy animals was probably a major driver. At a local scale, the habitation sites shifted from the shores of the lakes and rivers, where they were mostly situated pre-eighth century CE, to new locations that were typically adjacent to small bogs, which would have provided good grazing grounds for the reindeer (see Hedman 2003; Halinen 2016; Seitsonen and Viljanmaa 2021). The climatic deterioration in the wake of the 536 CE atmospheric dust veil event and the subsequent Late Antique Little Ice Age in the migration period (c. 536–660 CE, see Büntgen et al. 2016), and especially the recovery from that disastrous period and the climatic warming during the Medieval Climatic Anomaly

(Mann et al. 2009), may have forced changes in livelihood, mobility, and settlement patterns (Seitsonen and Viljanmaa 2021). There was also a European boom in the request for furs and hides starting in the "long eighth century", which may have acted as an incentive for the Sámi to adjust their mobility patterns in response to this demand (Hansen and Wickham 2000; Pluskowski 2015; Olsen 2019).

If the fur and hide trading was an important driver for the increased hunting of wild reindeer and the use of transport reindeer, there were probably already in the Iron Age and medieval period established points of contact between the Sámi groups and outside traders from various directions. This may have taken place at seasonal sites such as the hearth row sites interpreted as aggregate seasonal campsites (Olsen 2019; Seitsonen and Viljanmaa 2021: 16). It is likely that extensive environmental and socioeconomic factors were also at play in the shift to the fully nomadic pastoral system from the fourteenth century (e.g. Mulk 2009; Sommerseth 2009; Halinen et al. 2013; Hansen and Olsen 2014; Halinen 2016; Larsson and Päiviö Sjaunja 2020). For example, the Europewide disruptions in the trade routes between the twelfth and thirteenth centuries caused by the Mongol expansion (e.g. Kuusela et al. 2020), and the disastrous effect the mid-fourteenth-century Black Death pandemic had, especially in Norway (e.g. Benedictow 2016), may have driven the changes in the subsistence system. These disruptions may have acted alongside other factors such as the intensified taxation by the nascent states (Storli 1996; Carpelan 2003), the deteriorating climate (Halinen 2016, 2019), and the depletion of wild reindeer herds by intensified hunting (Lundmark 1982: 160; Hansen and Olsen 2014: 204). The interplay of these factors may have instigated a change from a more egalitarian hunter-fisher-herder society, in which the sacrifice of valuable objects at sacred sites may have balanced the distribution of wealth, towards a pastoralist society, based on the *siida* and family ownership of reindeer as private property (Hansen and Olsen 2014: 201; Harlin et al. 2019).

7.4. Biochemical identification of reindeer mobility using stable isotope analysis

7.4.1. Sulphur isotopes – additional information on diet and mobility patterns

As noted in Chapter 5 concerning reindeer feeding, knowledge of the reindeer's diet is important for the study of reindeer mobility patterns. Once the reindeer was culturally appropriated, its natural habitat was somehow disrupted, and its feeding patterns may have been altered (see Chapter 5). One way of tracing mobility in archaeology is to use sulphur and strontium stable isotope analysis. The sulphur isotopes present in plants grazed and digested by reindeer are representative of the geological area in which the plant has grown. The application of sulphur isotope analysis to terrestrial and maritime ecosystems is therefore potentially helpful in tracing not only feeding, but also reindeer mobility patterns (Nehlich 2015: 7). Tracing reindeer feeding from different pasture areas is therefore enabled.

Different skeletal elements offer different information about the diet and mobility of the studied individuals. Both bone and dentine collagen can therefore be used to study mobility. However, the turnover of different skeletal elements varies. The turnover for bone collagen can vary by up to 30 years, depending on the skeletal element (Hedges et al. 2007), meaning that the sulphur isotope value in reindeer bones is representative of the reindeer's entire lifetime, especially given that the average age at death of modern reindeer is approximately 20 years. The turnover of dentine collagen in teeth differs somewhat. Dentine collagen does not turn over once the tooth is fully formed; the sulphur isotope value is therefore representative of the age at the tooth crown's final formation. Different teeth are completed at different ages. By combining tooth and bone skeletal material from reindeer, the reindeer's life histories can be studied. By combining sulphur isotope analysis of bone and dentine collagen from one individual, intra-individual changes in mobility patterns can be studied at both general and individual levels. If there are differences between when the reindeer was a calf (teeth) and fully grown (bone), it suggests that the reindeer has been feeding from plants from different geological areas, or even from fodder originating from another area. To study reindeer seasonal migration and mobility, in considering life histories, it is essential to know the how and when of bone and teeth growth. A recent study (van den Berg et al. 2021) of reindeer tooth growth is important for the further understanding and research of archaeological and modern reindeer teeth. Another way to study reindeer mobility has been to compare reindeer teeth growth to other deer species (e.g. Britton et al. 2009; Gigleux et al. 2019).

The collagen analysed for stable isotope on archaeological organic remains, e.g. reindeer skeletal remains, causes different issues, given the diagenetic factors. Archaeological skeletal remains can be affected by physiological, climatic, chemical, biological, and other factors. The collagen in bone and teeth degrades unceasingly and can alter considerably with time. The soil in northern Fennoscandia is often acidic, which does not preserve organic matter very well. This may also alter the isotopic values. Collagen can also be degraded by many environmental factors such as temperature and time (Collins et al. 2002: 385), as well as altitude and humidity (Raich et al. 1997, Craine et al. 2009; Wang et al. 2015, 2019). Furthermore, according to Lidén et al. (1995), the isotopic value analysed for collagen can be altered if there is a strong presence of lipids in the analysed material. For example, if reindeer have been eating or been fed with plants from a marine environment, it can influence the analysed stable isotope values (see Spangen and Fjellström 2018 for a case study on this phenomenon concerning the foddering of sheep in northern Norway). Nevertheless, research has shown that several quality controls can be effectuated to assure that the samples are of sufficient quality to be archaeologically interpreted, such as the percentage of collagen, concentrations of carbon, nitrogen, and sulphur, and ratios of C:N, C:S, and N:S (DeNiro 1985; Ambrose 1990; Van Klinken 1999; Richards et al. 2003; Nehlich 2015).

Reindeer skeletal elements from six different Sámi archaeological sites (i.e. medieval Sámi offering sites, early modern marketplaces and a silver mine, a Late Iron Age/early medieval dwelling site and a modern reindeer-herding district) were analysed for carbon, nitrogen, and sulphur stable isotopes (Fig. 7.2). The results showed that the reindeer had been used in different practices. Not only were some of them foddered; the stable isotope results for reindeer from Sámi offering sites suggested that they were used by single Sámi groups (Fjellström et al. 2020). The study also showed that reindeer were influenced by the Sámi before the transition to mobile pastoralism and the growth of the economic importance of reindeer herding. Stable isotope analysis has been used to study reindeer diet and mobility at Sámi offering sites, dwelling sites, and marketplaces and church locations in Swedish Sápmi (Fjellström et al. 2020). This has proven useful in tracing the historical reindeer diet and mobility. In other words, stable isotope analysis may add to the knowledge of reindeer domestication processes in northern Fennoscandia.

In another interdisciplinary study, researchers from different specialities demonstrated that reindeer mobility could be understood by a combination of the osteometrics and stable isotope analysis of both modern reindeer and reindeer from Sámi offering sites (c. 1200–1700 CE) from Swedish and Finnish Sápmi. Here, the possibility of tracing domestication practices and other characteristics for offering was investigated (see Chapters 5 and 8). The results from the study demonstrated that people had different engagements with different reindeer, and that the Sámi's relationship with reindeer not only suggested that the relationship was either merely wild or merely domesticated, but more complex (Salmi et al. 2020). The sulfur isotope values, together with results of the carbon and nitrogen isotope data, showed that there were three different clusters visible in the stable isotope values displaying different geographical locations. While one the clusters withheld too little isotopic data to draw any further conclusions two other clusters of reindeer sampled from offering sites from the mountain areas of northernmost Sweden and close to the Norwegian border and reindeer samples from inland northern Sweden (Salmi et al. 2020:13). It seems that reindeer from the offering sites studied tend to cluster together and suggest a local use by local communities (Fjellström et al. 2020; Salmi et al. 2020) sulphur values. According to Salmi et al. 2020, the deviating sulfur isotope data from two offering sites (Unna Saiva and Viddjavárri) provides an evidence to human-influenced long-distance relationship (e.g. Salmi et al. 2020). In this study it is demonstrated that reindeer migration and human interaction can be traced using stable isotope analysis, and while stable isotope cannot in itself be used to differentiate between domesticated and wild reindeer, the combination of stable isotope analysis and offerings at *siedis* can provide knowledge about herding communities and families offering practices in the past, whether they were from wide geographical areas or more local.

Even the life histories and osteobiographies of single reindeer have added to the understanding of reindeer diet, mobility, and the entanglement with humans. In a study by Salmi and Fjellström (in press), the life histories of two reindeers' diet and mobility was studied by tracking intra-individual changes. Here, the osteobiography (age, sex, physical activity, health, diet, and mobility) of incomplete reindeer skeletons from the offering site of Paddusas in Gällivare, Swedish Sápmi, enabled an exploration of the entanglements between humans and their reindeer. The age, sex, size, diet, mobility, and many other characteristics of reindeer tells us about their social roles. While their molars' carbon and nitrogen isotopic composition demonstrate the mother-calf relationship and the weaning process that once occurred during the autumn and at some point in their geographical mobility, the simple fact that these reindeer were offered at Paddusas shows that they were entangled in a human-reindeer relationship with cultural implications (Salmi and Fjellström, in press). The comparison between the tooth representing the reindeer young age, being a calf, and the mandible representing the average sulfur isotope values for the reindeers' lifetime exhibits different patterns in sulfur over time, then indicating mobility. Sulfur isotopic values for one of the two reindeer might indicate seasonal migration between winter and summer pastures. The great variation in sulfur isotopic data for the other individual indicate a change of habitat and might be due to a possible human influence (Salmi and Fjellström, in press).

7.4.2. Strontium ($^{87}Sr/^{86}Sr$) isotopes – reindeer mobility and seasonal migration

Strontium isotopes have been used widely in tracing the mobility and migration patterns of both humans and animals (e.g. Ericsson 1985; Montgomery et al. 2007; Britton et al. 2009; Montgomery et al. 2010; Cameron et al. 2012; Glykou et al. 2018; Lahtinen et al. 2020; Fjellström et al. 2021). Without going into any further detail, strontium, in contrast with sulphur, does not undergo any fractionation (Bentley 2006: 141; Britton 2020: 101). For example, the strontium isotope ratio ($^{87}Sr/^{86}Sr$) in any analysed reindeer bone, dentine, or enamel (i.e. bioapatite) is representative of the bioavailable strontium in plants and water ingested at the time of tissue formation. Hence, the strontium isotope ratio reflected in any reindeer skeletal element reflects the strontium taken up by the plant the reindeer has eaten, and therefore the local bedrock where the plant has been growing. If the reindeer has been foddered, the interpretation of reindeer mobility can be more difficult.

Although strontium isotopes undergo scarcely any fractionation between different trophic levels, there can still be diagenetic factors (Hoppe et al. 2003; Trickett et al. 2003; Rasmussen et al. 2019) that alter the "original" strontium present in the bedrock, plants, soil, and eventually the archaeo-osteological skeletal remains. In archaeological studies of human and animal mobility, it is important to establish the local $^{87}Sr/^{86}Sr$ ratio for the studied site. This is also what is often referred to as the biologically available strontium. The best way to do this would be to gather faunal skeletal remains from the same site and time as the studied material. Animals with small home ranges are the most suitable for such an analysis (e.g. small rodents). Modern faunal skeletal elements may be of use; however, imported and more recently immigrated plant species from other geographical areas can affect the strontium ratio in such way that it does not reflect the local ratio. In addition, local soil, plants and water are good additional indicators for the local bioavailable strontium (Price et al. 1992). For further reading on the analytical and archaeological possibilities and problematics of using strontium isotopes in mobility studies, see Bentley 2006.

As previously mentioned, different tissues with a different turnover may represent different stages in life and can therefore be used to trace intra-individual changes and life histories through mobility, whether or not it is anthropogenic (Britton 2020). Here, different methods can be used. While TIMS is used to measure "bulk" strontium isotope ratios of bone or teeth, for example, a mass spectrometer coupled to a laser-ablation (LA-ICP-MS) can be used to study reindeer mobility and seasonality using sequentially targeted sampling. The latter method leaves barely any visible marks on the material, and the results can be obtained for different stages of life in the formation of the tooth (Fig. 7.3.). This method is an effective tool for studying reindeer mobility and seasonality. By combining different methods and stable isotopes (i.e. C, N, S, and O), a larger part of the diet and mobility of one reindeer's lifetime can be studied (Pellegrini et al. 2008; Price et al. 2017; Pederzani and Britton 2019; Britton 2020).

Strontium isotope analysis has been used to trace the mobility and seasonal migration of modern and Palaeolithic caribou/reindeer in northern America (Britton 2018). In addition, strontium isotope analysis in combination with oxygen isotopes in reindeer teeth has proved an effective tool in studying past reindeer mobility (Britton 2020). In a study by Gigleux et al. (2019), strontium and oxygen isotope analysis were effectuated on the tooth enamel of caribou (*Rangifer tarandus* spp.) dated to the Little Ice Age (LIA), between the fifteenth and seventeenth centuries in Nunalleq in Alaska. Sequential data from the strontium and oxygen isotopes results demonstrated a variation in reindeer ranging habits over the period of site occupation, and that there was a difference between modern and ancient caribou herds. The authors also shed light on the climatic conditions. Although they had no access to any information on reindeer tooth formation, the authors used an estimation based on deer teeth (Britton 2009; Gigleux et al. 2019). As previously mentioned, it is important to assess reindeer tooth formation prior to analysis, because this information is necessary for interpreting mobility and seasonal traits in mobility.

Currently, strontium isotope analysis is being used on archaeological reindeer skeletal material from another Sámi archaeological site in the Pite river valley in northern Swedish Sápmi in the counties of Norrbotten and Västerbotten. The study has yet to be published. It aims to investigate wild and domesticated reindeer mobility, as well as diet and climatic variations, from the remains of reindeer skeletons from *Stalló* foundations in Adamvalldá (Liedgren et al. 2007), hearth row sites, and other Sámi archaeological and historical dwelling sites from the Iron Age to the nineteenth century. Stable isotope analysis using carbon, nitrogen, sulphur, strontium, or oxygen has the potential to trace both wild and domesticated reindeer and human landscape use (Britton 2018).

7.5. Conclusions

In this chapter, we have presented various case studies and several possible ways of studying reindeer mobility though landscape-level Geographical Information System (GIS) analyses and biochemical analysis such as stable isotope analyses. With an interdisciplinary approach to archaeology, the past, and especially reindeer domestication and pastoralism in northern Fennoscandia, the combination of different methods for archaeological remains, such as the Kernel Density Estimation (KDE) for GIS or the study of different stable isotopes to understand reindeer mobility, has proved a reasonably effective tool for understanding past and modern reindeer.

Reindeer skeletal material in combination with the known archaeology and history of reindeer domestication, pastoralism, and migration routes, whether or not they are influenced by any human practice, has great potential for understanding past human practices in the reindeer-human relationship. Unfortunately, no new results considering reindeer strontium and oxygen isotope analysis can be presented here, because the research is ongoing. However, they have been shown to be effective in previous studies of reindeer mobility.

The GIS and isotope-based methods can contribute to the understanding of human and domesticated reindeer mobilities, and human-reindeer relations in Sápmi, and elsewhere. Thus far, they have been used separately in case studies in different regions, but when applied together, they can help in achieving more holistic perceptions of past mobilities and land use. This is something to test in the future – for example, in the Pite river region – with ongoing isotopic research.

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Author biographies

Markus Fjellström, PhD in Archaeological Science, is specialised in the study of diet, mobility, and climate changes through stable isotope analysis. He has a special interest in food cultures in Sápmi. In this project, he is studying reindeer domestication processes with regards to the diet and mobility patterns of reindeer, and the possible human impact on reindeer. He is also interested in climate change, and how it has affected both reindeer and human populations in the past. He also has an interest in and is working on glacial archaeology

Oula Seitsonen (PhD 2018, University of Helsinki) is an archaeologist and geographer at the University of Oulu, Finland. His interests cover a wide temporal and thematic range, from the Stone Age of East Africa to the material remains of the 21st century refugee crisis in the Arctic. Besides reindeer pastoralism in Fennoscandia, he is currently also studying the early pastoralist archaeologies in Mongolia.

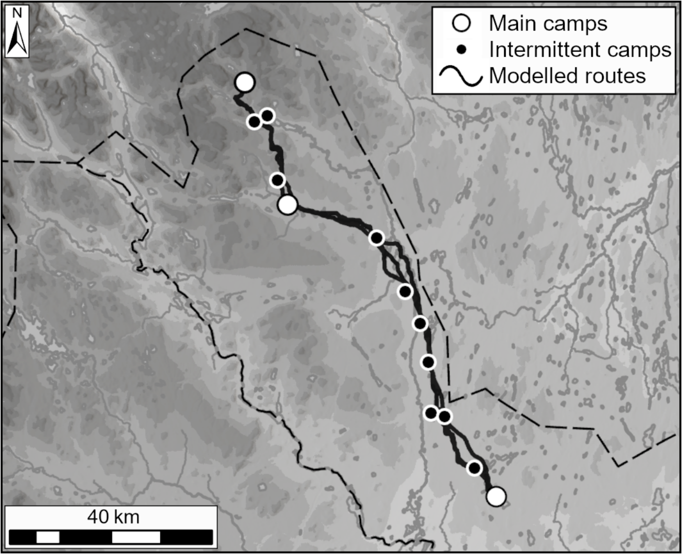
Henri Wallén, Master of Social Sciences, is a doctoral researcher who has been working on environmental issues related to extractive industries and reindeer herding. His research interests also include computational methods in social sciences and applications of complex systems theory.

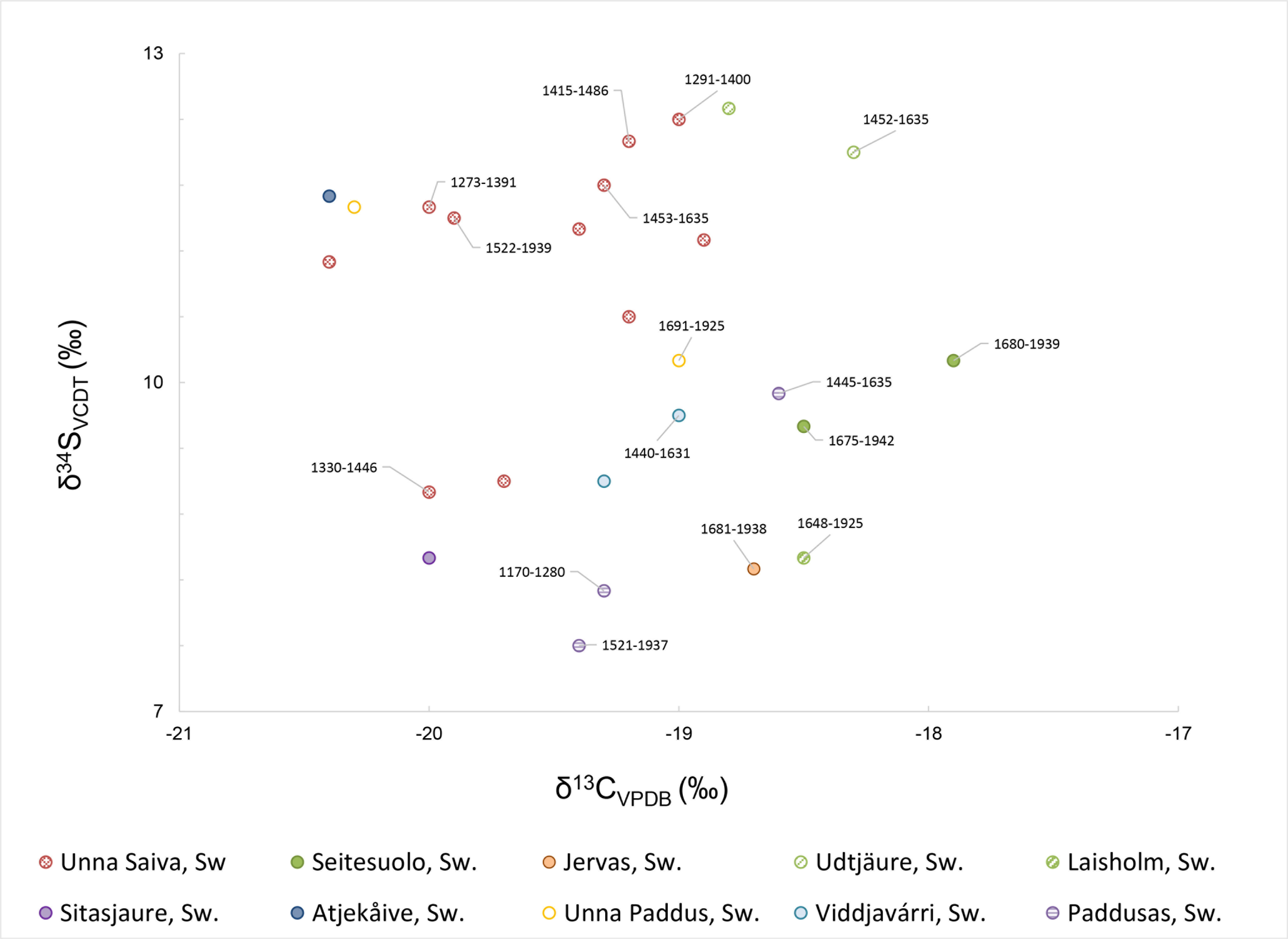
Figure captions

Figure 7.1. Modelled migration pathways from the winter to summer camps of one of the Sámi *siidas* in north-western Sápmi in the early 1900s, based on the cost of movement across the landscape based on topography; parallel routes were calculated using differing variables to test their effect. The main winter and summer campsites (white circles) as known based on the transgenerational memories were used as start and end points for the modelling the spring and autumn migration routes. Marked are also the intermittent camp locations (black circles) along the routes as remembered by the herders, for comparison with the modelled routes. Illustration: Henri Wállen and Oula Seitsonen.

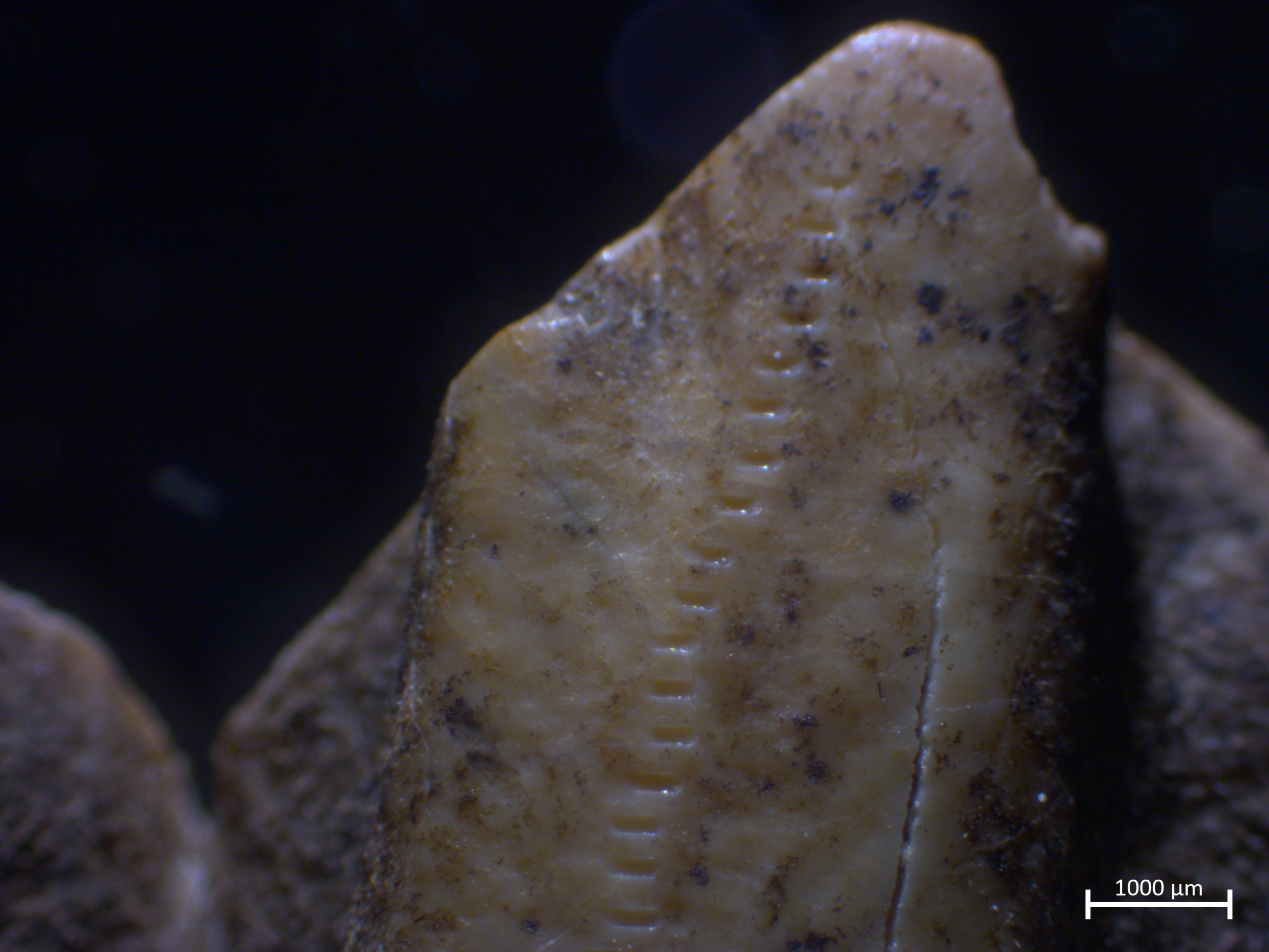
Figure 7.2. Stable carbon ($\delta^{13}C$) and sulphur ($\delta^{34}S$) isotope values of reindeer skeletal remains from Sámi offering sites in Sweden (Salmi et al. 2015, 2020). The radiocarbon dates in the diagram are reported as cal AD (2σ). Illustration: M. Fjellström.

Figure 7.3. A reindeer tooth from Långudden, Arjeplog municipality, Swedish Sápmi, sampled for strontium isotope sequential analysis with a LA-ICP-MS. Photo: M. Fjellström.


N
Main camps
Intermittent camps
Modelled routes
40 km



13
10
7
-21
-20
-19
-18
-17
δ34SVCDT (‰)
δ13CVPDB (‰)
1415-1486
1291-1400
1452-1635
1273-1391
1453-1635
1522-1939
1691-1925
1680-1939
1445-1635
1675-1942
1440-1631
1330-1446
1681-1938
1648-1925
1170-1280
1521-1937
Unna Saiva, Sw
Seitesuolo, Sw.
Jervas, Sw.
Udtjäure, Sw.
Laisholm, Sw.
Sitasjaure, Sw.
Atjekåive, Sw.
Unna Paddus, Sw.
Viddjavárri, Sw.
Paddusas, Sw.


1000 µm