Zooarchaeological and stable isotope evidence of Sámi reindeer offerings

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ABSTRACT

This paper presents new osteometric and stable isotope evidence of Sámi reindeer offerings. Previous archaeological studies have shown that reindeer domestication and intensification of reindeer herding transformed Sámi indigenous religion. However, because of the methodological challenges in the identification of wild and domesticated reindeer in the archaeological record, the exact nature of the relationship between people and offered reindeer has remained elusive. To address this problem, we analyze zooarchaeological and stable isotope data from thirteen Sámi offering sites situated in Finland and Sweden and dating to c. 1200–1700 CE. We employ zooarchaeological analysis of age, sex and size and explore the possibilities of these analyses to identify domestication and other characteristics of reindeer selected for offering. Analyses of stable isotopes of carbon, nitrogen and sulphur are utilized to identify human influence on reindeer feeding patterns and mobility. Our results show that many kinds of reindeer with different engagements with people were offered. The results confirm that people had different motives for giving offerings and that a simple dichotomy of wild/domesticated does not adequately reflect the range of relationships the Sámi had with reindeer.

1. Introduction

Offerings given at sacred sites were an integral part of the religion of the Sámi, the indigenous people of northern Fennoscandia. Sámi offering sites are special landscape features, such as mountains, islands, or lakes. The most common offering sites are stones or boulders called *sieidi* (North Sámi). Offerings were also made to carved wooden poles, sometimes placed on wood platforms or "tables" (Bergman et al., 2008). The offerings were a way to communicate with supernatural forces, make thanks, and ask for a permission to take something from the nature. There were many ways of giving offerings; animal body parts such as antlers or heads were often left as offerings, offering stones could be smeared with blood or grease, or a live animal was left on the site. Sometimes meat was eaten at the sites and it was believed that the sieidi became fed as people were eating. Reindeer were the most common species offered at these sites (Salmi et al., 2018). In addition to animal offerings, metal offerings were also given c. 800–1300 CE (Hedman, 2003; Zachrisson, 1984). Moreover, coins, alcohol, tobacco, and small personal items were and are still left at these sites. As the Sámi offering sites are in most cases unshaped by people, their identification depends on oral tradition, written sources, place names or

archaeological finds attached to certain places (Äikäs, 2015). We have information about hundreds of such sites in Fennoscandia (Qvigstad, 1926; Paulaharju, 1932; Manker, 1957; Äikäs, 2015).

Previous research has shown that reindeer domestication had an effect on the Sámi indigenous religion (Äikäs, 2015; Salmi et al., 2018). The animal offering tradition of the Sámi began around 500–700 CE with wild animal offerings (Mulk, 1994; Hansen and Olsen, 2014: 127–131; Salmi et al., 2018). Depositions of reindeer bones in bone deposits at settlement sites date to around 900–1100 CE (Andersen, 2011) when the transition to reindeer pastoralism was underway in the Scandinavian mountain area (Hedman, 2003; Andersen, 2011; Bergman et al., 2013). Reindeer offerings at offering sites began around 1200 CE (Äikäs, 2015; Salmi et al., 2018). The frequency of reindeer offerings clearly peaks around 1400–1600 CE (Salmi et al., 2018) when reindeer pastoralism spread and became central to economic and social organization (Wallerström, 2000; Mulk, 2009; Sommerseth, 2011; Bjørnstad et al., 2012; Bergman et al., 2013; Bjørklund, 2013; Hansen and Olsen, 2014: 195–206). It is likely that the Sámi shared a way of maintaining relationships with the land and spirits through the practice of animal offering rituals across Fennoscandia, and that the animal offerings proabably were an important factor in shaping both individual identity

Table 1
Archaeological sites in this study and the number of animal bone finds as number of identified specimens (NISP).

Site no.	Country	Site	Municipality/Province	Site ID	Site type	NISP	Date (cal AD)
1	Finland	Sieiddakeädgi	Utsjoki	KM 37,852	Offering stone	107	1165–1659
2	Finland	Näkkälä	Enontekiö	KM 37,851	Offering stone	50	1165-modern
3	Sweden	Seitesuolo	Karesuando	SHM 30,705	Headland/island	435	1296–1942
4	Sweden	Paddusas	Jukkasjärvi	SHM 30,666	Hill	2898	1170-modern
5	Sweden	Jervas vid Karats	Jokkmokk	SHM 30,703		10	1681–1938
6	Sweden	Utdjäure	Jokkmokk	SHM 30,696	Bog headland	39	1452–1635
7	Sweden	Unna Saiva	Gällivare	SHM 31,281	Metal deposit	3547	545–1939
8	Sweden	Laisholm	Tärna	SHM 30,699	Crevice	4	1648-modern
9	Sweden	Sitasjaure	Gällivare	SHM 30,675	Offering stone	15	
10	Sweden	Unna Paddus	Jukkasjärvi	SHM 30,666	Offering stone	370	1691–1925
11	Sweden	Viddjavárri	Jukkasjärvi	SHM 13,886	Beneath a large boulder	1765	1220-modern
12	Sweden	Atjekåive	Gällivare	SHM 30,669	Cave under a boulder	11	
13	Sweden	Meselefors	Vilhemina	SHM 30,693	Offering stone	10	1680–1939

and group integration (Salmi et al., 2018).

However, the nature of the relationship between people and the reindeer they offered has remained elusive. Some researchers maintain that wild reindeer hunt remained an important means of livelihood and a religious concern until the 17th century and later (e.g. Mulk 1994; 2009), whereas others argue for an abrupt change from a hunting economy to a pastoralist one (e.g. Wallerström, 2000; Bjørnstad et al., 2012). This paper presents new osteometric and stable isotope evidence of Sámi reindeer offerings in Fennoscandia. We combine faunal and stable isotope data from thirteen Sámi offering sites situated in present-day Finland and Sweden and dating to c. 1200–1700 CE (Table 1; Fig. 1). During this period, reindeer pastoralism became central to economic and social organisation of the Sámi in many parts of northern Fennoscandia while wild reindeer were still hunted (Mulk, 2009; Bergman et al., 2013). We examine the power of osteometric analysis and age assessment to identify domestication-related morphological and culling pattern change. We also employ the analysis of stable isotopes of carbon, nitrogen and sulphur to assess human impact on reindeer feeding and mobility patterns. If reindeer domestication was a major factor in reindeer offerings, we expect to see human-influenced changes in the mobility, feeding and morphology in majority of the offered reindeer. If wild reindeer continued to be an economic and religious focus despite the transition to reindeer pastoralism, we expect to see variation in the degree of human intervention into the mobility, feeding and reproductive isolation (as reflected in morphological change) of the offered reindeer.

2. Material and methods

2.1. Material

The archaeological material in this article derives from thirteen Sámi offering sites situated in Sweden and Finland. Two sites, Näkkälä (Fig. 2) and Sieiddakeädgi, are situated in Finland and were excavated in 2008. Archaeological research of Sámi sacred sites in Finland was conducted in agreement and with permissions from the National Board of Antiquities and the Sámi parliament. The excavations were conducted as small test pits instead of large areas in order to respect the sacred nature of the sites. The samples were repatriated to the offering sites after analysis.

In Sweden the faunal assemblages from the offering sites are archived at the Historical Museum in Stockholm. Here we selected sites that had yielded a large faunal assemblage. The sites at Seitesuolo, Paddusas, Unna Paddus and Viddjavárri (Rautasjaure) in Jukkasjärvi and Unna Saiva in Gällivare were excavated in the first half of the 20th century (Hallström, 1932; Manker, 1957). We also added samples from a number of small-scale surface sampling investigations of offering sites to cover as much as possible of the Sámi area. Among them were Jervas at Karats in Jokkmokk and Laisholm in Tärna (Manker, 1957), Udtjäure

(Vierronjarka) also excavated at the first half of the 20th century revealing mostly faunal skeletal material (Manker, 1957: 202) and two sites from Gällivare, Sitasjaure and Atjekåive. Atjekåive has been plundered several times (Manker, 1957: 165).

The analysis of the faunal assemblages from these sites is presented in detail in Salmi et al. (2011; 2015; 2018) and Salmi (2016). All the faunal assemblages were dominated by reindeer bones. Other species, such as various fish species, wild forest and aquatic birds, bear and ovicaprids were identified in some of the assemblages. Skeletal frequencies measured indicate that reindeer antlers and crania were the most common skeletal parts. As for vertebrae, the uppermost vertebrae, especially atlas and axis, are clearly most abundant in the assemblages, which suggest that reindeer heads with soft tissue still attaching the vertebrae to the cranium were also offered. Also limb extremities, especially metapodial bones and phalanges were relatively common. Many of the metapodial bones, as well as other long bones, were split for marrow consumption. Osteometric analysis and age assessment was performed on all long bones and mandibles complete enough for analysis.

The samples for stable isotope analysis were selected taking into account the size of the assemblage, the preservation of the bone material, and to avoid sampling the same individual twice. When age determination was possible, we selected adult (e.g. over 4–5 years of age) individuals for sampling. Some assemblages were small and/or poorly preserved and samples deriving from clearly adult individuals was not possible. In those cases, we sampled bones that had fused epiphyses and did not display signs of being from juvenile individuals in terms of size and visual observation of bone porosity. At least one sample from each site was radiocarbon dated (Table 2).

For the purpose of determining the stable carbon and nitrogen values typical reindeer on a human-influenced and natural diets, we sampled six wild forest reindeer, ten free-ranging (not fed) domesticated reindeer, and nine zoo-kept reindeer archived in the collection of the Zoological Museum at the University of Oulu. These animals died between c. 1960–1995 CE. Five free-ranging post-industrial reindeer from Könkämä Sámi village were also included (Fjellström, 2011). The samples were taken from postcranial bones of adult (e.g. fully fused epiphyses, over 4–5 years of age) individuals. (Table 2) The zoo-kept reindeer were fed with reindeer fodder consisting of hay (mainly *Phleum pratense* and *Poa pratensis*), sometimes enriched with barley (*Hordeum vulgare*) and oat (*Avena sativa*) (Nieminen et al., 1998: 103–105). For reference for osteometric measurements, we used reindeer skeletons from the collection of the Zoological Museum at the University of Oulu. The metric data of this collection is presented in detail in Puputti and Niskanen (2008) and Salmi and Fjellström (in press).
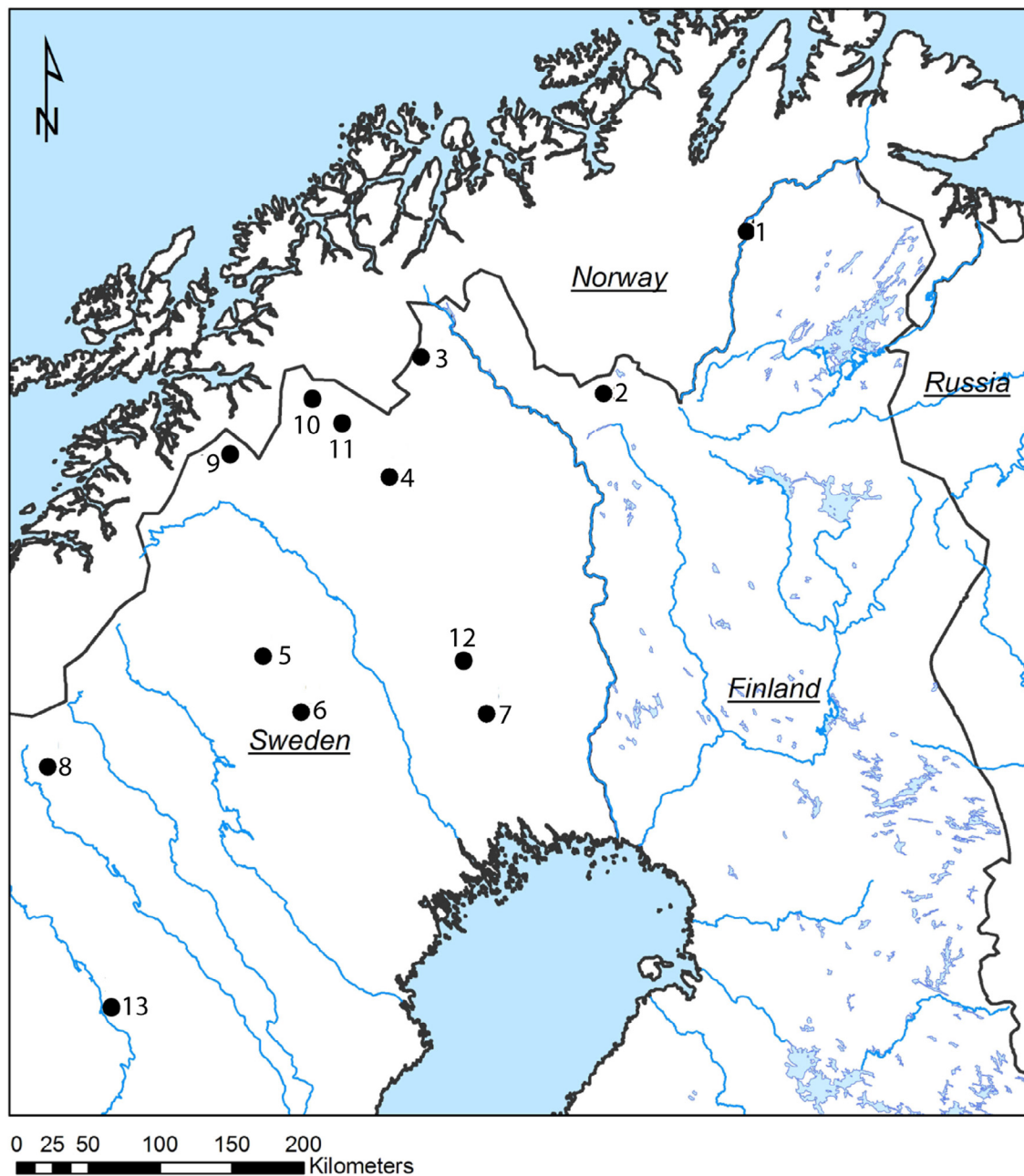
Fig. 1. Map of the offering sites in this study: 1. Sieiddakeädgi, 2. Näkkälä, 3. Seitesuolo, 4. Paddusas, 5. Jervas vid Karats, 6. Udtjäure, 7. Unna Saiva, 8. Laisholm, 9. Sitasjaure, 10. Unna Paddus, 11. Viddjavárri, 12. Atjekåive, 13. Meselefors.

2.2. Age, sex and size assessment

Osteometric measurements were taken according to von den Driesch (1976) and Puputti and Niskanen (2008). We measured all archaeological finds of reindeer mandibles and long bones that were complete enough to measure. List and definitions of measurements taken are presented in Appendix A. There were 157 measurements of archaeological specimens and 185 measurements of modern specimens in total (Table 3). In the analysis of the osteometric measurements, we used the log ratio method that enables the combination of measurements of different scales to one dataset to increase sample size (Albarella, 2002; Thomas, 2005). The log ratios were calculated as $\log_{meas} - \log_{stand}$. As a standard, we used the mean of measurements of individuals from the collection of the Zoological Museum at the University of Oulu (metric data presented in detail in Puputti & Niskanen, 2008).

Reindeer age was estimated based on tooth eruption and wear (Miller, 1974; Nieminen et al., 1981) for mandibles, and epiphyseal fusion for long bones (Takken Beijersbergen and Hufthammer, 2012). Reindeer is a sexually dimorphic species in which the males are, on average, 1.6 times heavier than females (Nieminen and Petersson, 1990). Therefore, midsex means of osteometric measurements were used in sex assessment. Midsex mean is the mean of male and female means. All specimens above the midsex mean were assessed as males and all specimens below as females (Krogman and İşcan, 1986). The midsex means of osteometric measurements of modern reindeer in the collection of the zoological museum of Oulu (metric data presented in detail in Puputti & Niskanen, 2008) were used in sex assessment of reindeer in this study. In humans, the rate of correct sex assessment based on this method is about 85% (Krogman and İşcan, 1986). Because

Fig. 2. The sieidi stone in Näkkälä, Enontekiö, Finland (Photo: T. Äikäs).

reindeer is more sexually dimorphic than human, this approach should provide considerably more accurate sex assessments for reindeer (Puputti & Niskanen 2008). It has to be noted, though, that the possible presence of forest reindeer, slightly larger in size, in the sample, presents a source or error in the sex assessments.

2.3. Methods in stable isotope analysis

Carbon, nitrogen and sulphur isotope analysis was conducted to detect any human influence on reindeer diet and mobility.

The carbon isotope value ($\delta^{13}C$) distinguishes between terrestrial C_3 and freshwater resources on the one hand, and marine resources on the other hand (Schoeninger and DeNiro, 1984). The nitrogen isotope value ($\delta^{15}N$) increases with the level in the food web (Minagava and Wada,

Table 2

Results from the stable carbon, nitrogen and sulphur isotope analysis of reindeer bone and antler from Sámi offering sites and modern reindeer. The initial $\delta^{13}C$ isotope values of the modern reindeer were corrected for a fossil fuel effect according to Long et al. (2005). Correction factor *1.2‰, **0.8‰, ***0.44‰.

Lab sample #	Species	Site	Element	Age (years)	Sex	Collagen (%)	Initial $\delta^{13}C$ (‰)	Corrected $\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	% C	% N	% S	C/N	C/S	N/S	^{14}C-dates (BP, and year of colection)	Lab ID #	Calibrated dates (AD, 95,4%)	Isotope lab
USA 1	R. tarandus	Unna Saiva	Mandibula dx	6–7	–	7.2	−19.0	–	5.1	12.4	43.1	15.1	0.25	3.3	460	161	622 ± 30	–	1291–1400	SIL
USA 2	R. tarandus	Unna Saiva	Mandibula dx	6–7	–	3.3	−19.2	–	3.5	10.6	40.9	14.4	0.25	3.3	437	154	–	–	–	SIL
USA 3	R. tarandus	Unna Saiva	Mandibula dx	6–7	–	6.2	−20.0	–	4.6	11.6	43.2	15.3	0.27	3.3	427	151	672 ± 30	–	1273–1391	SIL
USA 4	R. tarandus	Unna Saiva	Mandibula dx	6–7	–	4.4	−18.9	–	4.4	11.3	44.1	15.5	0.26	3.6	453	159	–	–	–	SIL
USA 5	R. tarandus	Unna Saiva	Mandibula dx	6–7	–	5.3	−19.2	–	5.4	12.2	43.8	15.5	0.24	3.3	487	178	446 ± 30	–	1415–1486	SIL
USA 6	R. tarandus	Unna Saiva	Mandibula dx	6–7	–	4.1	−19.3	–	5.0	11.8	43.7	15.7	0.25	3.2	467	168	356 ± 30	–	1453–1635	SIL
~~USA 10~~	~~R. tarandus~~	~~Unna Saiva~~	~~Mandibula~~	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
~~USA 11~~	~~R. tarandus~~	~~Unna Saiva~~	~~Mandibula~~	–	–	~~10.1~~	~~−21.4~~	–	~~2.3~~	~~11.8~~	~~41.5~~	~~10.8~~	~~0.16~~	~~4.5~~	~~691~~	~~180~~	–	–	–	SIL
~~USA 13~~	~~R. tarandus~~	~~Unna Saiva~~	~~Mandibula dx~~	6–8	–	~~3.3~~	~~−23.1~~	–	4.4	–	~~38.7~~	~~7.9~~	–	~~5.7~~	–	–	–	–	–	SIL
~~USA 14~~	~~R. tarandus~~	~~Unna Saiva~~	~~Mandibula dx~~	8–10	–	~~2.6~~	~~−23.4~~	–	4.4	–	~~38.9~~	~~7.5~~	–	~~6.1~~	–	–	–	–	–	SIL
USA 15	R. tarandus	Unna Saiva	Mandibula dx	8–10	–	3.6	−20.0	–	5.5	9.0	39.6	13.9	0.20	3.3	529	185	508 ± 29	–	1330–1446	SIL/Iso Analytic
USA 16	R. tarandus	Unna Saiva	Mandibula sin	5–6	–	4.5	−19.7	–	4.0	9.1	40.5	14.1	0.18	3.3	600	209	–	–	–	SIL/Iso Analytic
USA 17	R. tarandus	Unna Saiva	Mandibula sin	5–6	–	1.0	−20.4	–	3.4	–	31.9	10.4	–	3.6	–	–	–	–	–	SIL/Iso Analytic
USA 18	R. tarandus	Unna Saiva	Mandibula sin	5–6	–	2.7	−19.9	–	4.4	11.1	36.7	12.9	0.19	3.3	516	181	258 ± 29	–	1522–1939	SIL/Iso Analytic
USA 19	R. tarandus	Unna Saiva	Mandibula sin	6–8	–	2.4	−19.4	–	5.4	11.5	36.7	13.0	0.19	3.3	516	182	–	–	–	SIL/Iso Analytic
USA 20	R. tarandus	Unna Saiva	Mandibula sin	> 6	–	5.2	−20.0	–	4.1	11.4	40.7	14.3	0.18	3.3	603	211	–	–	–	SIL/Iso Analytic
~~USA 21~~	~~R. tarandus~~	~~Unna Saiva~~	~~Mandibula sin~~	~~8–10~~	–	~~6.5~~	~~−22.3~~	–	4.6	–	~~40.6~~	~~10.4~~	–	~~4.6~~	–	–	–	–	–	SIL
SEI 1	R. tarandus	Seitesuolo	Humerus dx	5–16 months	Female	6.9	−18.5	–	2.3	9.6	41.5	14.7	0.23	3.3	482	170	109 ± 32	Ua-50875	1680–1939	SIL
SEI 2	R. tarandus	Seitesuolo	Antler	–	–	7.3	−17.9	–	2.5	10.2	42.9	15.3	0.22	3.3	520	186	127 ± 34	Ua-50876	1675–1942	SIL
JER 1	R. tarandus	Jervas vid Karats	Mandibula sin	Juvenile	–	5.3	−18.7	–	2.3	8.3	39.2	14.0	0.19	3.3	550	196	105 ± 33	Ua-50874	1681–1938	SIL
JUD 1	R. tarandus	Udtjäure	Humerus dx	> 6–15 months	Female	5.3	−18.3	–	4.3	12.1	34.9	12.1	0.21	3.4	444	153	358 ± 28	Ua-53301	1452–1635	SIL
JUD 2	R. tarandus	Udtjäure	Mandibula	3–4	Male	1.3	−18.8	–	5.8	12.5	30.2	10.0	0.19	3.5	424	141	–	–	–	SIL
~~VIM 1~~	~~R. tarandus~~	~~Meselefors~~	~~Mandibula~~	–	~~Male~~	~~0.4~~	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Archaeological Samples

Table 2 (*continued*)

Lab sample #	Species	Site	Element	Age (years)	Sex	Collagen (%)	Initial $\delta^{13}C$ (‰)	Corrected $\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	% C	% N	% S	C/N	C/S	N/S	^{14}C-dates (BP), and year of colelction	Lab ID #	Calibrated dates (AD, 95,4%)	Isotope lab
TÅL 1	R. tarandus	Laisholm	Mandibula	8–9	Male	5.9	−18.5	–	2.5	8.4	33.8	11.9	0.21	3.3	429	151	196 ± 29	Ua-53302	1648–1925	SIL
SGÄ 1	R. tarandus	Sitasjaure	Antler	–	–	4.8	−20.0	–	1.2	8.4	36.6	13.1	0.29	3.3	337	120	–	–	–	SIL
ATG 1	R. tarandus	Atjekäive	Antler	–	–	4.0	−20.4	–	4.4	11.7	32.5	11.4	0.22	3.3	394	139	–	–	–	SIL
UNN 1	R. tarandus	Unna Paddus	Antler	–	–	9.1	−19.0	–	1.4	10.2	39.1	13.9	0.19	3.3	549	196	83 ± 27	Ua-53303	1691–1925	SIL
UNN 2	R. tarandus	Unna Paddus	Mandibula	6–7	Male	1.4	−20.3	–	1.9	11.6	25.3	8.3	0.35	3.5	193	64	–	–	–	SIL
RAU 8	R. tarandus	Viddjavárri	Bone	–	–	2.3	−19.3	–	1.7	9.1	36.6	13.1	0.26	3.2	375	135	–	–	–	SIL
RAU 9	R. tarandus	Viddjavárri	Bone	–	–	0.9	−19.0	–	3.0	10.0	36.9	13.1	0.13	3.3	757	270	391 ± 33	Ua-48933	1440–1631	SIL
RAU 10	R. tarandus	Viddjavárri	Bone	–	–	1.1	−21.8	–	4.1	–	32.8	11.9	–	3.2	–	–	–	–	–	SIL
RAU 11	R. tarandus	Viddjavárri	Bone	–	–	7.1	−18.7	–	1.6	9.7	42.4	15.6	0.21	3.2	538	199	416 ± 33	Ua-48935	1425–1626	SIL
RAU 12	R. tarandus	Viddjavárri	Bone	–	–	7.7	−17.8	–	2.9	10.8	42.7	15.6	0.20	3.2	570	209	487 ± 34	Ua-48936	1333–1456	SIL
RAU 13	R. tarandus	Viddjavárri	Phalanx	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RAU 14	R. tarandus	Viddjavárri	Bone	–	–	5.6	−18.5	–	3.5	11.7	41.8	15.1	0.20	3.2	558	201	–	–	–	SIL
RAU 15	R. tarandus	Viddjavárri	Bone	–	–	2.4	−21.2	–	2.1	9.9	42.7	11.4	0.15	4.4	759	204	401 ± 32	Ua-48934	1435–1630	SIL
RAU 16	R. tarandus	Viddjavárri	Bone	–	–	8.4	−18.8	–	2.0	–	42.2	15.3	–	3.2	–	–	–	–	–	SIL
RAU 17	R. tarandus	Viddjavárri	Mandibula	–	Male	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RAU 18	R. tarandus	Viddjavárri	Mandibula sin	–	Male	8.4	−18.2	–	3.0	9.8	42.0	15.2	0.21	3.2	534	193	–	–	–	SIL
PAD 1	R. tarandus	Paddusas	Mandibula	3–4	–	1.3	−18.6	–	1.6	9.9	42.1	14.8	0.19	3.3	591	208	373 ± 35	Ua-50877	1445–1635	SIL
PAD 5	R. tarandus	Paddusas	Antler	–	–	5.0	−19.4	–	2.6	7.6	42.9	15.3	0.21	3.3	545	194	248 ± 33	Ua-50878	1521–1937	SIL
PAD 6	R. tarandus	Paddusas	Mandibula	> 10	–	5.6	−19.3	–	2.1	8.1	43.1	15.2	0.22	3.3	523	184	790 ± 36	Ua-50879	1170–1280	SIL
FLA 6	R. tarandus	Näkkälä	Antler	–	–	8.7	−19.0	–	3.3	–	45.1	16.0	–	3.3	–	–	795 ± 25	Hela-1882	1206–1276	SIL
FLA 1	R. tarandus	Sieiddakeädgi	Antler	–	–	6.3	−20.4	–	1.1	–	45.1	16.0	–	3.3	–	–	740 ± 25	Hela-1892	1225–1290	SIL
FLA 12	R. tarandus	Sieiddakeädgi	Antler	–	–	8.1	−18.5	–	2.0	–	45.3	16.3	–	3.2	–	–	425 ± 25	Hela-1894	1428–1610	SIL
FLA 14	R. tarandus	Sieiddakeädgi	Antler	–	–	5.4	−19.1	–	2.1	–	45.4	16.0	–	3.3	–	–	800 ± 25	Hela-1890	1191–1274	SIL
FLA 16	R. tarandus	Sieiddakeädgi	Antler	–	–	2.5	−19.4	–	1.0	–	40.0	14.1	–	3.3	–	–	575 ± 25	Hela-1891	1306–1418	SIL
FLA 4	R. tarandus	Sieiddakeädgi	Frontal	–	–	9.9	−19.9	–	2.2	–	45.8	16.4	–	3.3	–	–	295 ± 25	Hela-1897	1496–1655	SIL

Table 2 (*continued*)

Lab sample #	Species	Site	Element	Age (years)	Sex	Collagen (%)	Initial δ^{13}C (‰)	Corrected δ^{13}C (‰)	δ^{15}N (‰)	δ^{34}S (‰)	% C	% N	% S	C/N	C/S	N/S	^{14}C-dates (BP), and year of colelction	Lab ID #	Calibrated dates (AD, 95,4%)	Isotope lab
FLA 3	R. tarandus	Sieiddakeädgi	Atlas	–	–	6.1	−19.0	–	3.3	–	45.2	16.1	–	3.3	–	–	325 ± 25	Hela-1893	1496–1644	SIL
Modern Samples																				
AKS-41*	R.t. fennicus (zoo)	Linnanmaa Zoo	Sacrum	Adult	–	–	−22.1	−20.5	5.2	–	44.3	15.0	–	3.5	–	–	1995	–	–	Beta Analytic
AKS-42*	R.t. tarandus (zoo)	Linnanmaa Zoo	Sacrum	Adult	–	–	−22.4	−20.8	3.5	–	43.6	15.1	–	3.4	–	–	1995	–	–	Beta Analytic
AKS-43*	R.t. tarandus (zoo)	Linnanmaa Zoo	Ulna	Adult	–	–	−22.5	−20.9	5.1	–	44.7	14.7	–	3.5	–	–	1995	–	–	Beta Analytic
AKS-44*	R.t. tarandus x fennicus (zoo)	Linnanmaa Zoo	Tarsal	Adult	–	–	−22.1	−20.5	4.7	–	43.7	15.0	–	3.4	–	–	1995	–	–	Beta Analytic
AKS-45*	R.t. tarandus (zoo)	Linnanmaa Zoo	Tarsal	4 years, 3 months	–	–	−22.0	−20.4	4.0	–	43.9	15.3	–	3.4	–	–	1995	–	–	Beta Analytic
AKS-46*	R.t. tarandus (zoo)	Linnanmaa Zoo	Humerus	Adult	–	–	−21.7	−20.1	1.7	–	44.7	15.1	–	3.5	–	–	1995	–	–	Beta Analytic
AKS-47*	R.t. tarandus (zoo)	Linnanmaa Zoo	Atlas	Adult	–	–	−21.7	−20.1	4.6	–	44.3	15.8	–	3.3	–	–	1995	–	–	Beta Analytic
AKS-48*	R.t. fennicus (zoo)	Linnanmaa Zoo	Tarsal	Adult	–	–	−20.9	−19.3	2.0	–	43.4	15.7	–	3.2	–	–	1995	–	–	Beta Analytic
AKS-50**	R.t. fennicus (zoo)	Ähtäri Zoo	Rib	Adult	–	–	−21.3	−20.3	3.7	–	44.0	16.6	–	3.1	–	–	1980	–	–	Beta Analytic
AKS-49**	R.t. fennicus	Kuhmo	Atlas	Adult	–	–	−21.4	−20.4	1.4	–	43.2	15.0	–	3.4	–	–	1980	–	–	Beta Analytic
AKS-51**	R.t. fennicus	Kuhmo	Tarsal	Adult	–	–	−22.0	−21.0	2.9	–	44.2	14.9	–	3.5	–	–	1980	–	–	Beta Analytic
AKS-52**	R.t. fennicus	Kuhmo	Tarsal	Adult	–	–	−20.1	−19.1	2.2	–	43.7	15.2	–	3.4	–	–	1980	–	–	Beta Analytic
AKS-55**	R.t. fennicus	Kuhmo	Atlas	Adult	–	–	−20.8	−19.8	2.3	–	43.7	15.3	–	3.3	–	–	1980	–	–	Beta Analytic
AKS-56**	R.t. fennicus	Kuhmo	Lumb.vert.	3	–	–	−21.4	−20.4	2.8	–	44.1	14.9	–	3.5	–	–	1980	–	–	Beta Analytic
AKS-57**	R.t. fennicus	Kuhmo	Tarsal	Adult	–	–	−20.8	−19.8	3.1	–	44.3	15.1	–	3.4	–	–	1980	–	–	Beta Analytic
AKS-58***	R. t. tarandus	Enontekiö	Med. phalanx	6	–	–	−19.0	−18.4	1.9	–	44.0	15.4	–	3.3	–	–	1960	–	–	Beta Analytic
AKS-59***	R. t. tarandus	Enontekiö	Med. phalanx	7	–	–	−18.9	−18.3	3.1	–	44.2	15.0	–	3.4	–	–	1960	–	–	Beta Analytic
AKS-60***	R. t. tarandus	Enontekiö	Med. phalanx	6	–	–	−20.2	−19.6	2.2	–	45.3	14.4	–	3.7	–	–	1960	–	–	Beta Analytic

Table 2 (*continued*)

Lab sample #	Species	Site	Element	Age (years)	Sex	Collagen (%)	Initial δ^{13}C (‰)	Corrected δ^{13}C (‰)	δ^{15}N (‰)	δ^{34}S (‰)	% C	% N	% S	C/N	C/S	N/S	^{14}C-dates (BP), and year of colelction	Lab ID #	Calibrated dates (AD, 95,4%)	Isotope lab
AKS-61***	R. t. tarandus	Enontekiö	Med. phalanx	4	-	-	-20.0	-19.4	1.9	-	46.3	13.9	-	3.9	-	-	1960	-	-	Beta Analytic
AKS-62***	R. t. tarandus	Enontekiö	Med. phalanx	5	-	-	-18.9	-18.3	1.3	-	44.1	14.9	-	3.5	-	-	1960	-	-	Beta Analytic
AKS-63***	R. t. tarandus	Enontekiö	Med. phalanx	10	-	-	-20.3	-19.7	1.6	-	44.9	14.7	-	3.6	-	-	1960	-	-	Beta Analytic
AKS-64***	R. t. tarandus	Enontekiö	Med. phalanx	6	-	-	-19.5	-18.9	1.9	-	43.2	15.0	-	3.4	-	-	1960	-	-	Beta Analytic
AKS-65***	R. t. tarandus	Enontekiö	Med. phalanx	4	-	-	-19.2	-18.6	2.7	-	44.5	14.7	-	3.5	-	-	1960	-	-	Beta Analytic
AKS-66***	R. t. tarandus	Enontekiö	Med. phalanx	3	-	-	-20.8	-20.2	1.4	-	44.2	14.3	-	3.6	-	-	1960	-	-	Beta Analytic
AKS-67***	R. t. tarandus	Enontekiö	Med. phalanx	5	-	-	-19.2	-18.6	1.8	-	45.4	14.6	-	3.6	-	-	1960	-	-	Beta Analytic
KÖN 1***	R. t. tarandus	Könkämä	Mandibula	Adult	-	8.6	-19.5	-18.9	2.2	10.7	44.9	16.5	0.27	3.2	444	163	1960	-	-	SIL
KÖN 2***	R. t. tarandus	Könkämä	Mandibula	Adult	-	9.1	-19.8	-19.3	2.1	9.3	43.4	15.0	0.30	3.4	386	133	1960	-	-	SIL
KÖN 3***	R. t. tarandus	Könkämä	Mandibula	Adult	-	10.5	-20.4	-19.8	3.4	10.4	47.0	15.6	0.27	3.5	464	154	1960	-	-	SIL
KÖN 4***	R. t. tarandus	Könkämä	Mandibula	Adult	-	12.2	-19.9	-19.3	3.0	11.5	45.6	16.0	0.25	3.3	487	170	1960	-	-	SIL
KÖN 5***	R. t. tarandus	Könkämä	Mandibula	Adult	-	9.8	-19.7	-19.1	2.4	10.1	44.9	15.7	0.28	3.3	428	150	1960	-	-	SIL
					Mean Value	Archaeological		-19.3	3.2	10.4										
					S.d.			0.8	1.4	1.5										
					Mean Value	Modern		-19.9	2.8	10.8										
					S.d.			0.9	1.1	1.0										

8

Table 3

Comparison of log ratio measurements of archaeological samples and modern domesticated reindeer with *t*-test. Statistically significant differences are marked in bold.

Measurement set		Modern	Archaeological	t	p
All	Mean	−0.0008	0.0160		
	Std. Dev.	0.0258	0.0276	−5.813	**0.000**
	N	185	157		
Length	Mean	−0.0006	0.0176		
	Std. Dev.	0.0206	0.0367	−1.796	0.080
	N	39	6		
Articular	Mean	−0.0008	0.0174		
	Std. Dev.	0.0278	0.0310	−3.602	**0.000**
	N	106	47		
Cranial	Mean	−0.0009	0.0153		
	Std. Dev.	0.0254	0.0257	−3.401	**0.001**
	N	40	104		

1984), and the sulphur isotope value (δ^{34}S) reflects the local geology of the consumed resources (Peterson and Fry, 1987), (for a more detailed review of stable isotope analysis within the field of archaeology, see e.g. Makiarewicz & Sealy 2015 for carbon and nitrogen; Nehlich, 2015 for sulphur).

Collagen was extracted from bone and antlers following the procedures of the modified Longin method (Brown et al., 1988). Samples were dated and analyzed for stable isotopes in different locations, presented in Table 2. Forty-five archaeological samples for carbon and nitrogen analysis were analysed at Stable Isotope Laboratory (SIL) at the Department of Geological Science, Stockholm University (Table 2). Here samples were analyzed using a Finnigan Delta Plus advantage connected to a CarloErba NC2500 elemental analyzer through a ConfloIV with a precision of 0.15‰ for both carbon and nitrogen. Twenty-five modern reindeer samples were sent and analysed for carbon and nitrogen at Beta Analytic. Here, samples were analysed using a Costech ECS connected to a Thermo Finnigan Electron Delta V Advantage IRMS via a Conflo IV (EA-IRMS) with a precision of 0.3‰ for δ^{13}C and 0.5‰ for δ^{15}N. In this case, samples were gently crushed after being washed with deionized water and scraped free of the outermost layer. A cold HCl acid is then applied several times until the bone apatite is eliminated. Before isotope measurement, the samples were pretreated with sodium hydroxide (NaOH) in order to remove any secondary organic acids. Twenty-six samples for sulphur were analyzed using a Finnigan Delta Plus connected to a CarloErba NC2500 elemental analyzer through a ConfloII with a precision of 0.2‰ at SIL (Table 2). Five intern

standards at SIL (CDT, MSS-3, SSS-2, SSS-3 and NBS-127) are calibrated against IAEA-S-1, IAEA-S-2 and IAEA-S-3. Finally, five samples from Unna Saiva were sent to ISO-analytical in the United Kingdom (Table 2) for sulphur isotope analysis. The samples were analyzed with a Sercon CNS-EA elemental analyser auto-sampler linked with a Europa Scientific 20–20 isotope ratio mass spectrometer and heated at 1080 °C, then combusted in the presence of oxygen at a precision of 0.3‰. An in-house standard IA-R068 and IA-R069 were used and calibrated against and traceable to NBS-127 and IAEA-SO-5. Results from the different laboratories are reported with δ (‰) and measured relative to Pee Dee Belemnite (PDB) for δ^{13}C, to atmospheric N_2 (AIR) for δ^{15}N and relative to Vienna Canyon Diablo Troilite (VCDT) for δ^{34}S. Forty-five (out of 74) samples yielded enough collagen (around > 1%) for further analysis (Table 2). The collagen yield for samples analysed at the Beta Analytic was not provided, 29 samples. Twenty-five of these are within the criteria for well-preserved collagen, with a carbon concentration of 15.3–47.0% and a nitrogen concentration of 5.5–17.3% as well as a C/N ratio of 2.9–3.6. Seven samples, analysed for carbon and nitrogen isotopes, did not apply to these criteria's and were excluded (Ambrose, 1990; DeNiro, 1985; van Klinken, 1999). Thirty-two samples were sent for sulphur isotope analysis, of which three did not comply to the criteria for sulphur (sulphur concentrations 0.15–0.60%; C/S ratio 300–900; N/S ratio 100–300) (Nehlich and Richards, 2009).

Although we are aware of that lipids may alter the carbon isotope values, particularly in modern bones, we did not extract lipids from the modern reindeer bones prior to isotope analysis. However, in a set of nine reindeer samples from another study from the Swedish mountains we analysed for an effect of lipids on carbon isotope values. Here, one part of each sample were subjected to lipid removal with chloroform and methanol (2:1) whereas the other part was not. We found no significant effect on carbon isotope values between the lipid extracted and non-lipid extracted samples.

3. Results

3.1. Age, sex and size assessment

The offered reindeer were mainly adults between four and ten years of age based on mandibular tooth eruption and wear (Fig. 3; Appendix B). Sub-adult and animals older than ten years were also present. Epiphyseal fusion of the bones also indicate that the majority of the offered individuals were adults. The age profile may suggest an emphasis on domesticated reindeer, because mainly adult individuals were
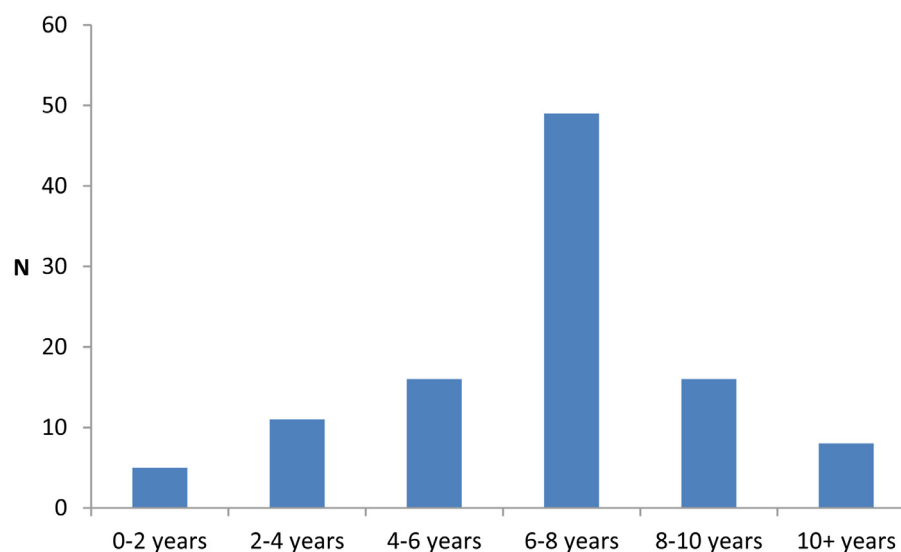

Fig. 3. Age distribution based on mandibular tooth wear and eruption. Site-wise distributions of age assessments are presented in Appendix B.
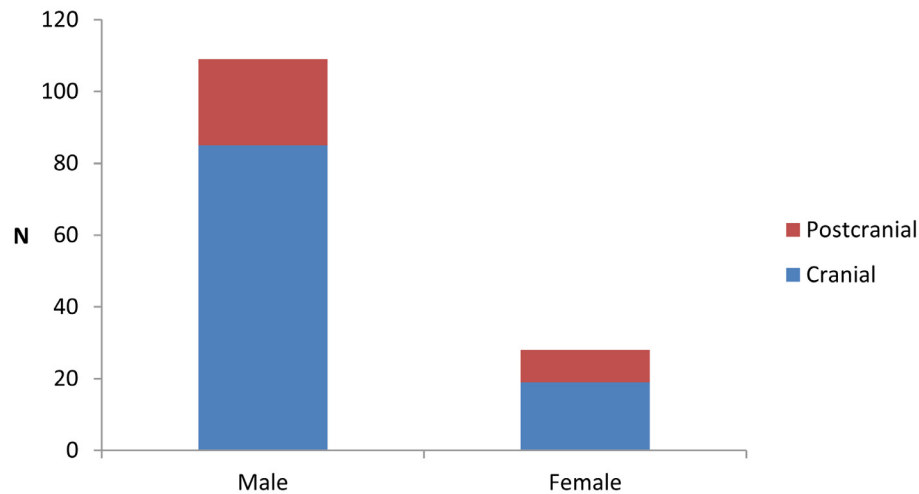
Fig. 4. Sex assessments based on midsex means of osteometric measurements. Site-wise distributions of sex assessments are presented in Appendix B.

slaughtered in traditional reindeer pastoralism (Hambleton and Rowley-Conwy, 1997; Jomppanen and Näkkäläjärvi, 2000; Lahti, 2006; Korhonen, 2008:137). When a whole herd of reindeer is hunted, a catastrophic mortality profile with all age classes present would be more likely. On the other hand, prime-age adults would probably have been the preferred target for a hunter preying individual reindeer.

Sex assessments suggest that the majority of the animals were males, but females were also present (Fig. 4; Appendix B). However, the possible presence of wild forest reindeer, which are larger in size than domesticated reindeer, has to be taken into account (Nieminen and Helle, 1980), cannot be excluded as a source of error in the sex estimations.

Comparison of log ratios of osteometric measurements of the archaeological reindeer bone finds with the adult modern domesticated reindeer from the skeleton collection of the Zoological Museum at the University of Oulu (Fig. 5; Appendix C) shows that individuals of all sizes were selected for offering, although the size distribution leans towards larger individuals than in the modern reindeer sample. The range of log ratios in the archaeological sample is similar to, or slightly larger, than the modern samples. The difference between the means of archaeological and modern samples is statistically significant (Table 3). Breaking down the size difference, the difference between length measurements of long bones was not statistically significant, whereas the differences between articular measurements and cranial measurements was statistically significant between archaeological samples and modern domesticated reindeer.

Body size reduction and changes in skull size and shape are often the main domestication-related characteristics observed on animal bones (Clutton-Brock, 1992; Zeder, 2006: 171–172). There are reports and oral tradition of body size reduction in reindeer herds under domestication, presumably due to the selection of smaller males that are more docile and easier to handle (Helle, 1980: 29; 1982: 74). However, the interpretation of the size difference observed between modern and archaeological specimens is complicated. First, there were two reindeer subspecies of different but overlapping sizes present in northern Fennoscandia. Second, the sexual dimorphism in reindeer means that the sizes of male mountain reindeer and female forest reindeer may overlap considerably (Puputti and Niskanen, 2008). Third, historical and ethnographic sources suggest that there may have been regional size differences between different populations of domesticated reindeer (Nieminen and Helle, 1980; Nieminen and Pietilä, 1999: 11). Fourth, environmental factors can cause size reduction in reindeer (Helle, 1982: 74–80). And finally, the reindeer bones from offering sites are a product of human selection of particular individuals, and large size may have been an important factor in the selection of reindeer individuals for

offering (Paulaharju, 1932; Itkonen, 1948: 318; Salmi et al., 2015). It is unclear if any or several of these factors contribute to the observed size difference between archaeological and modern samples or if it is due to domestication.

The comparison of different types of measurements also produced inconclusive results. The lack of statistically significant size difference in long bone length measurements may suggest that wild forest reindeer, with relatively longer limbs (Nieminen and Helle, 1980) were absent in the archaeological sample. Mountain reindeer skulls are relatively wider and shorter in comparison with wild forest reindeer (Siivonen, 1975), but wild and domesticated mountain reindeer do not differ in skull length and width (Nieminen, 1980). The difference between the molar row lengths of modern and archaeological reindeer bone samples may therefore be an indication of presence of forest reindeer, but again, it can relate to the selection of overall large individuals for offering. A further complication in the interpretation of the size patterns is that the sample size of archaeological long bone length measurements was very small (N = 6).

3.2. Stable isotope analysis: Nitrogen and reindeer feeding patterns

The $\delta^{13}C$ values for all modern reindeer were corrected for the fossil fuel effect. Corrections were applied in relation to the year of the death of the reindeer where we used the model by Long et al. (2005) based on Francey et al.'s (1999) records of atmospheric CO_2. We calculated the CO_2 for the death year of the modern reindeer and added the offset for the fossil fuel effect for each reindeer. The value, added to the initial $\delta^{13}C$ values for the years 1960 (−7.04‰), 1980 (−7.40‰) and 1995 −7.80‰), were 0.44‰, 0.8‰ and 1.2‰ (Table 2). The corrected $\delta^{13}C$ values of modern wild forest reindeer varies between −21.2‰ and −19.3‰ with a mean and standard deviation of −20.3 ± 0.7‰. The carbon values of free-ranging domesticated reindeer ranges from −20.4‰ to −18.5‰, with a mean value and standard deviation of −19.2 ± 0.6‰, and the zoo reindeer ranges from −21.3‰ to −19.7‰, with a mean value and standard deviation of −20.7 ± 0.5‰. All modern reindeer (i.e. free-ranging domesticate, wild forest, zoo-kept) have a mean value and standard deviation of −19.9 ± 0.9‰. The archaeological samples have $\delta^{13}C$ values between −21.8‰ and −17.8‰ with a mean value of −19.3‰ and a standard deviation of 0.8‰. The very low carbon isotope value (-21.8‰) is from a non-dated sample and considering the re-use of sieidis this sample could be a modern reindeer, also considering its rather high nitrogen value.

The analysis of $\delta^{15}N$ values of modern free-ranging reindeer shows that the nitrogen values of bone of adult wild and free-ranging reindeer
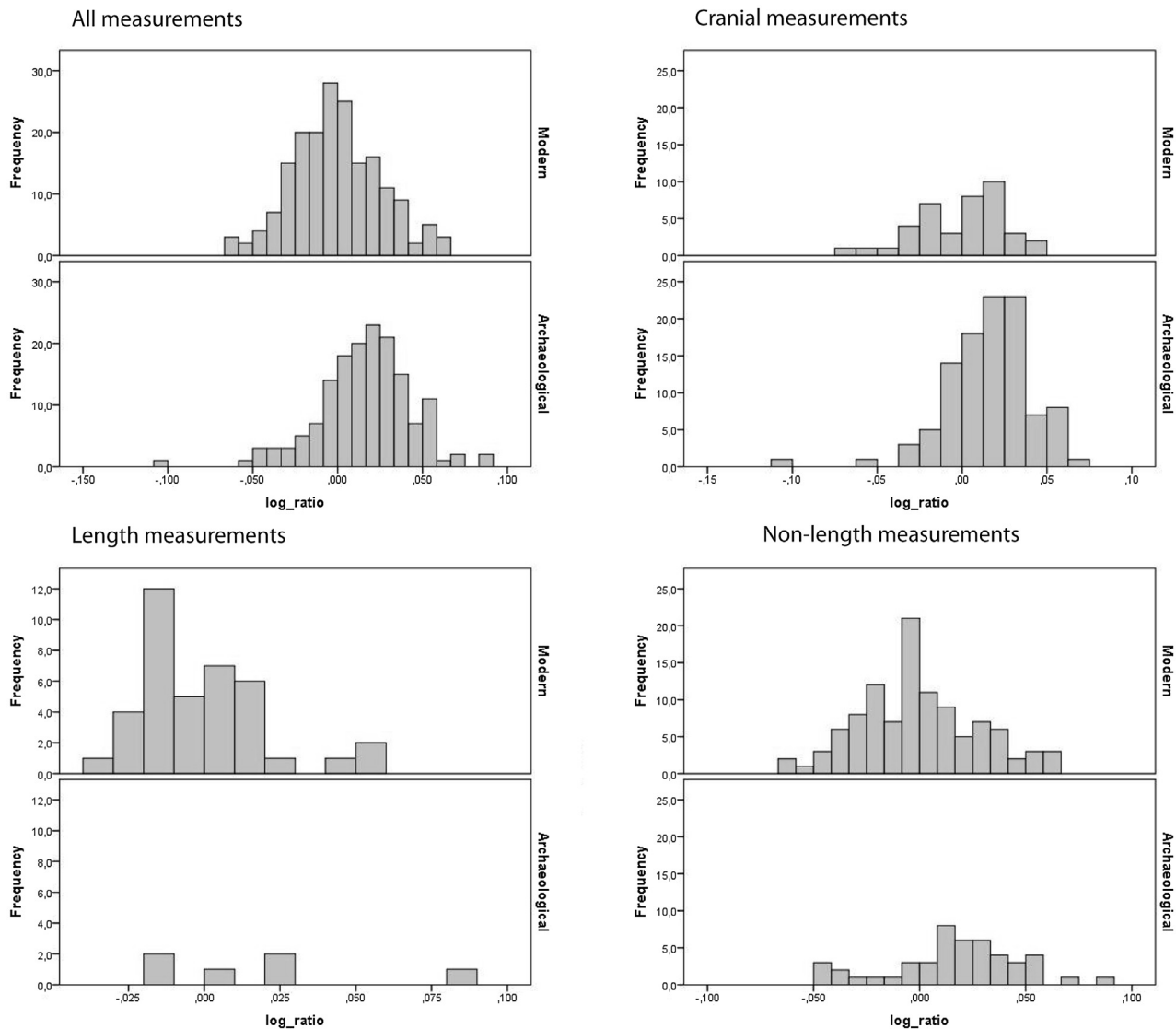
Fig. 5. Comparison of log ratios of modern reindeer bones with those found from the archaeological sites in this study. Site-wise distributions of log ratios are presented in Appendix C.

ranges from 1.3‰ to 3.4‰ with little variation with a mean and standard deviation of 2.2 ± 0.6‰ (Fig. 6). Further, there is a total overlap in values of the different ecotypes/subspecies. On the contrary, the bone samples from adult zoo reindeer show consistently δ^{15}N values higher than 3.5‰, except for two individuals (1.7‰ and 2.0‰). Modern zoo reindeer nitrogen values ranges from 1.7‰ to 5.2‰ and with the most elevated mean value 3.8‰ and the highest standard deviation of 1.3‰. The δ^{15}N values of the archaeological samples varied between 1.0‰ and 5.8‰ (Fig. 6), with a mean of 3.2‰ and standard deviation of 1.4‰.

The interpretation of reindeer bone δ^{15}N values is complex. Environmental changes such as change of temperature, lower or higher soil activity due to climate changes and differences in altitude would affect the isotopic signatures of plants and animals. For example, a decreased contribution of lichen to reindeer diet could cause a decrease in δ^{13}C values, while higher altitudes would reflect a decrease in δ^{15}N values and an increase in δ^{13}C values (Drucker et al., 2003, 2012). In general, though, lichens, a central part of reindeer diet, exhibit enriched δ^{13}C values and low nitrogen isotope values in comparison with vascular plants (Fizet et al., 1995; Michelsen et al., 1998; Beck and Mayr, 2012; Gustine et al., 2012; Skrzypek et al., 2015; Liu et al., 2018; Shin et al., 2018). Although the δ^{15}N content of lichens varies greatly

according to, for instance substrate and metabolism, they tend to exhibit lower δ^{15}N values than vascular plants in the corresponding environment (Fizet et al., 1995; Michelsen et al., 1998; Beck and Mayr, 2012; Gustine et al., 2012; Biazrov, 2014; Skrzypek et al., 2015; Liu et al., 2018; Shin et al., 2018). This has also been demonstrated in arctic and subarctic environments (Michelsen et al., 1998; Skrzypek et al., 2015; Liu et al., 2018). Especially grasses and sedges in arctic and subarctic environments tend to exhibit higher δ^{15}N values than lichens (Michelsen et al., 1998; Skrzypek et al., 2015; Liu et al., 2018).

The relationship between dietary and body δ^{15}N in the reindeer is complicated by many factors. Nitrogen values are elevated in young reindeer due to lactation up to the age of 6–7 months (Itkonen, 1948: 79, 85; Nieminen and Pietilä, 1999: 116; Parker et al., 2005; Barboza and Parker, 2006; Eriksson, 2013). There are also differences in δ^{15}N accumulation between tissue types. For instance, reindeer antlers are shed yearly, but the shedding schedule varies according to sex, age, fertility, castration, and nutritional status, among other things (Nieminen, 1994: 31–32). Therefore, the stable isotope values of reindeer antlers probably vary according to the season they are shed in, which in turn varies according to sex, age, and nutritional status (but see Stevens & O'Connell, 2015; Osborne, 2017). Bone δ^{15}N, on the other hand, reflects an average over several years due to the slow turnover in
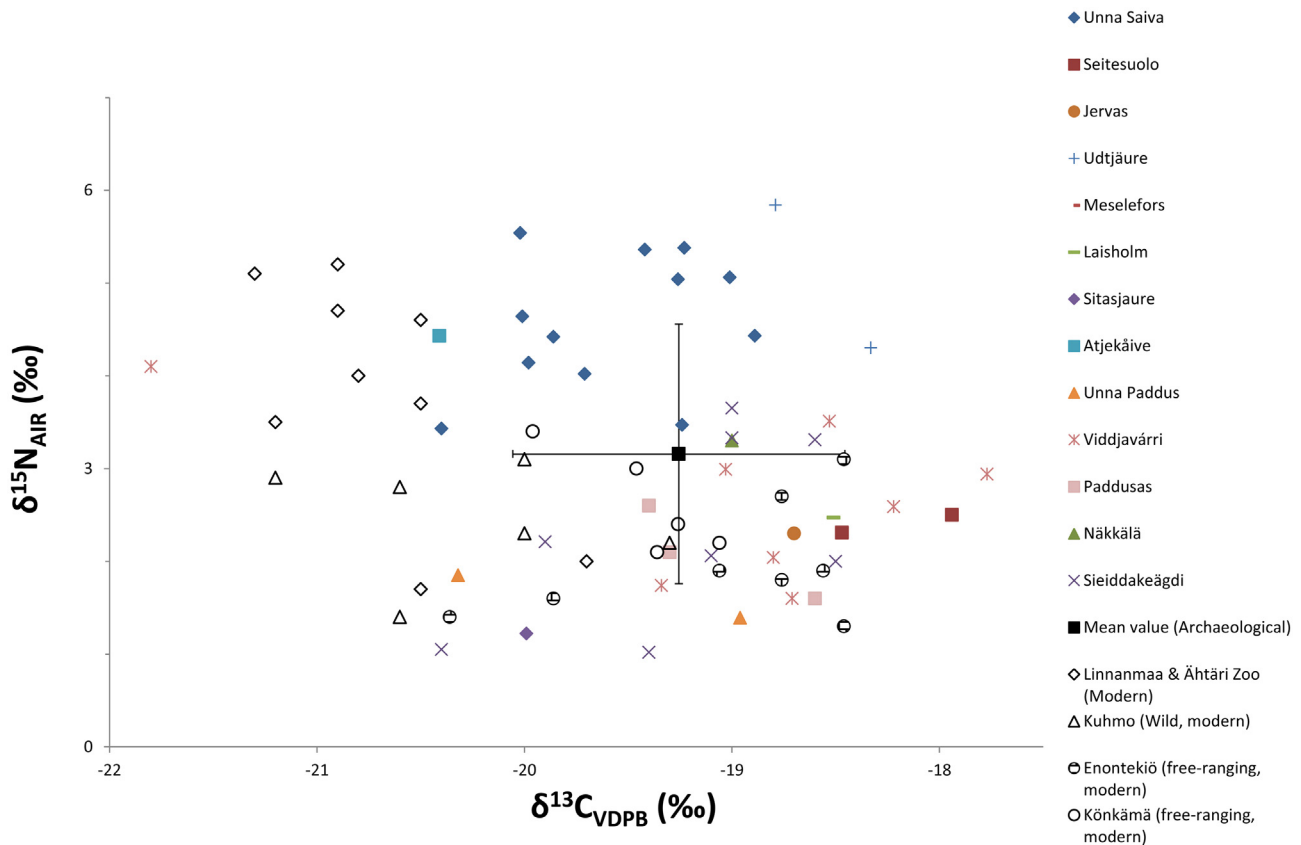
Fig. 6. Scatterplot of isotope results for carbon and nitrogen (modern reference and archaeological samples).

bone (Eriksson, 2013). The reindeer also store protein in blood serum during the summer and autumn, to be re-used during the winter when intake of dietary N nitrogen is low (Nieminen, 1994; Parker et al., 2005). Use of endogenous protein increases the proportion of heavy ^{15}N isotope in body tissues (Parker et al., 2005; Barboza and Parker, 2006). Also starvation, leading to the re-use of muscle protein (Nieminen, 1994), and recycling of urea may play a small role in enrichment of ^{15}N in reindeer tissues (Parker et al., 2005; Barboza and Parker, 2006). Probably due to the combination of these reasons, there is inter- and intra-annual variation in reindeer body δ^{15}N values (Gustine et al., 2012). However, it is currently unclear how these intra- and inter-annual variation in body δ^{15}N values (measured from blood, muscle and urine) are reflected in the bone δ^{15}N values, because the bone δ^{15}N values represent the environment and diet over several years (Eriksson, 2013).

Because of the difference in the δ^{15}N values between arctic and subarctic lichens and vascular plants, and the fact that bone δ^{15}N values reflect an average accumulation of several years (Michelsen et al., 1998; Beck and Mayr, 2012; Gustine et al., 2012; Skrzypek et al., 2015; Liu et al., 2018; Eriksson, 2013), we claim that the most plausible explanation for the elevated δ^{15}N values in relation to those of wild and free-ranging reindeer in adult reindeer bone samples is long-term dietary change. More specifically, we argue that the δ^{15}N values are elevated in the modern zoo-kept reindeer probably because they were fed fodder consisting mainly of hay (Nieminen and Heiskari, 1989; Nieminen et al., 1998: 98–108). Organic fertilizer increase the δ^{15}N values of plants (Eriksson, 2013) and may therefore contribute to the observed δ^{15}N values in modern fodder-fed reindeer. Grasses also tend to exhibit higher δ^{15}N values than other components of the reindeer diet (Michelsen et al., 1998) which may elevate δ^{15}N values in hay-fed reindeer. Moreover, industrial reindeer fodder is richer in protein than plants in natural reindeer diets (Nieminen and Heiskari, 1989; Nieminen, 1994: 94–97).

The δ^{15}N values of some of the archaeological samples are clearly out of the range of adult wild or free-ranging reindeer. The individuals with the elevated δ^{15}N values (≥ 3.8‰) were from the Unna Saiva (N = 10), Udtjäure (N = 2) and Atjekåive (N = 1). The samples with elevated δ^{15}N values date both to the early phase of the offering site use (c. 1200 CE) and to the peak phase (c. 1400–1700 CE) (Table 3). Young age cannot be ruled out as an explanation for the elevated δ^{15}N value of sample (JUD 1), estimated to be older than 6–15 months. Further, one of the samples with an elevated δ^{15}N value (ATG 1) was a piece of an antler. The remaining samples with elevated δ^{15}N values were bone samples from adult individuals. Again, judging by the current knowledge of reindeer biology and ecology (Nieminen, 1994; Parker et al., 2005; Barboza and Parker, 2006; Gustine et al., 2012), variation of δ^{15}N in arctic and subarctic plant ecosystems (Michelsen et al., 1998; Beck and Mayr, 2012; Gustine et al., 2012; Skrzypek et al., 2015; Liu et al., 2018) and current understanding of bone δ^{15}N metabolism (Eriksson, 2013), we hypothesize that the elevated δ^{15}N values in archaeological samples of adult reindeer bone reflect dietary change over several years.

In traditional reindeer pastoralism, the animals were supplementary fed only during especially difficult winters and then with fodder consisting of hay, dried tree branches, and lichens (Itkonen, 1948: 83–84; Korhonen, 2008:42; Olaus Magnus [1555], 2010: 803; Vorren and Manker, 1976: 32; Fjellström et al., submitted). Reindeer winter diet consists mainly of lichens and summer diet of a variety of grasses and shrubs. In the autumn, reindeer also consume mushrooms (Nieminen and Heiskari, 1989; Nieminen, 1994: 94–97; Mårell, 2006: 7; Inga, 2007). Based on this, we propose that the elevated δ^{15}N values in the archaeological samples may reflect a shift from a low-δ^{15}N lichen-based winter diet towards higher-δ^{15}N vascular plants, especially grasses and sedges. If people gave their reindeer supplementary winter fodder consisting mostly of high δ^{15}N plants such as grasses, sedges, and dried willow branches (Gustine et al., 2012), it is possible that this feeding

raised the δ^{15}N values in comparison with reindeer eating a lichen-based winter diet.

The adult reindeer individuals with elevated δ^{15}N values were offered at Unna Saiva, Udtjäure, Viddjavárri and possibly Sieiddakeädgi offering sites and date from c. 1273 CE to modern. Therefore, reindeer with probable human influence in their diet were offered almost as early as the time when reindeer offerings at these sites started (Salmi et al., 2018). The individuals with elevated δ^{15}N values were both male and female according to osteometric sex assessments (Table 2). At some sites, for instance at Paddusas, Unna Paddus, and Seitesuolo, only individuals with low δ^{15}N values were offered (Table 2). On the other hand, at some sites, for instance Unna Saiva, Viddjavárri, and possibly Sieiddakeädgi (Table 2), individuals with both low and elevated δ^{15}N values were offered.

In sum, we propose that the δ^{15}N values of some of the archaeological samples are elevated in comparison with wild and free-ranging reindeer. We propose that the most likely reason for the elevated values is supplementary winter feeding of the reindeer with grasses, sedges and dried tree branches. The oldest samples with elevated δ^{15}N values date to the 13th century, suggesting that supplementary reindeer feeding may have been a part of the reindeer herder's practices at that time. Moreover, samples with elevated and non-elevated δ^{15}N values were sometimes discovered from the same site, suggesting that animals with different diets were offered. It is important to bear in mind, though that although we were able to rule out some factors affecting reindeer bone δ^{15}N, such as young age and antler metabolic patterns, a number of unclear issues in the interpretation of reindeer bone δ^{15}N values in relation to diet and feeding patterns remain. Some contributing factors, such as long-term nutritional stress, could not be excluded. Reindeer are also known to occasionally eat rodents and bird eggs in periods of stress during spring (Fellman, 1910 III:270, IV:42). However, the amount of animal protein from these sources is likely to be so small that it does not affect the overall nitrogen isotope values. In principle, it is also possible that a shift towards a diet poorer in lichens was not due to feeding by humans, but an environmental or climatic change affecting lichen availability. However, the contemporaneous samples with non-elevated and elevated δ^{15}N values suggests that there was not a major climatic shift affecting lichen availability. Importantly, the complex and multiple factors affecting δ^{15}N in plant communities need to studied further to understand the variation of isotopic values in animal tissues.

3.3. Stable isotope analysis: Sulphur and mobility patterns

The δ^{34}S values for modern reindeer from Könkämä Sámi village were used as references, ranging from 9.3‰ to 11.5‰ with a mean and standard deviation of 10.8 ± 1.0‰ (Table 2; Fig. 7; Fig. 8; Fjellström, 2011). The archaeological samples have δ^{34}S values ranging from 7.6‰ to 12.5‰ with a mean and standard deviation of 10.6 ± 1.5‰. The modern reindeer from Könkämä display nitrogen isotope values typical to free-ranging reindeer and their sulphur isotope values are probably representative for the region. The archaeological reindeer with a δ^{34}S value, higher than 10‰ (n = 17), do not differ in δ^{13}C values from those with δ^{34}S values lower than 10‰. Long-distance migrations of reindeer (with or without human influence) and fodder collected from distant areas can result in very large variation in δ^{34}S values.

Three geographical clusters are visible if we combine the values from the three analysed stable isotopes. 1) Samples from the mountain area of northernmost Sweden close to the Norwegian border (Unna Paddus, Seitesuolo, Viddjavárri, Sitasjaure, Paddusas, Könkämä) have the highest δ^{13}C values (probably from a strong lichen based diet), the most widespread δ^{34}S values (9.6 ± 1.8‰) and low δ^{15}N values (probably due to a higher altitude (Drucker et al., 2012)). 2) Samples from sites in inland northern Sweden (Unna Saiva, Udtjäure, Atjekåive) show high δ^{34}S values (11.3 ± 1.1‰), the most widespread δ^{13}C values and the highest δ^{15}N values, which are different from the previous and that would represent areas of high soil activity (Drucker et al.,

2012). And finally 3) The sites in the south-western inland of Sweden (Laisholm and Jervas), show elevated δ^{13}C values, low δ^{15}N and low δ^{34}S values. The interpretation of this pattern is complicated by the small number of samples (N = 2) in the last group.

The variation in sulphur values compared to carbon and nitrogen suggests variation in geographic origins of the reindeer. Samples within an offering site tend to cluster together, suggesting that most sites were mainly used by local communities. There are only two exceptions to this pattern: Unna Saiva and Viddjavárri. It is likely that the variation in δ^{34}S values at these two sites reflect the variability of the home regions and reindeer herding traditions of the Sámi families and communities using them. Both of these offering sites were large and well-known with rich archaeological finds indicating a widely cast contact network (Hallström, 1932; Serning, 1956: 87, 119–133; Manker, 1957: 45–52, 167–168). The reindeer offered at Unna Saiva and Viddjavárri were therefore probably domesticated reindeer accompanying people from different areas on their yearly migrations between seasonal habitations.

4. Discussion

The stable isotope evidence presented in this paper suggest that some of the reindeer offered at Sámi offering sites between c. 1200–1700 CE probably were domesticated. Based on the overall low variation of δ^{34}S values, the deviating δ^{34}S values at Unna Saiva and Viddjavárri provides possible evidence of human-influenced long-distance migrations of reindeer offered. Because these sites were well-known and visited by people from near and far (Hallström, 1932; Serning, 1956: 87, 119–133; Manker, 1957: 45–52, 167–168), it is likely that the deviating δ^{34}S values there indicates that the reindeer offered were domesticated reindeer accompanying people from different areas on their yearly migrations. We also argue that the elevated δ^{15}N values of adult reindeer are most likely caused by supplementary winter feeding, where lichens have been replaced by plants with higher δ^{15}N values, such as grasses, sedges and tree branches. There is later ethnographic data suggesting that the Sámi practiced supplementary reindeer feeding with such fodder, especially when the winter weather conditions made it difficult for reindeer to dig for lichen from under the snow (e.g. Itkonen, 1948: 83–84; Korhonen, 2008:42). It is notable that reindeer with elevated δ^{15}N values were offered from the beginning of the reindeer offering tradition, c. 1200 CE onwards. This supports our earlier hypothesis that there was a connection between the beginnings of reindeer pastoralism and emerging reindeer offerings at sacred sites (Salmi et al., 2018). Due to the many uncertainties in interpreting reindeer bone δ^{15}N values, the feeding hypothesis should be ideally confirmed in the future with further research on δ^{15}N variation arctic and subarctic ecosystems.

The results of the osteometric analysis did not indicate whether the offered reindeer were wild or domesticated. The low resolution of the osteometric analysis probably a result of multiple confounding factors, including sexual dimorphism, the presence of two subspecies of different sizes, possible environmentally induced and regional variation in the body size of the reindeer, and human selection. It is also likely that the commonly used domestication markers are not likely to reflect domestication in the reindeer as clearly as in many other species. This is due to the limited and varying human influence on the reindeer's life cycle in past reindeer pastoralism. However, the osteometric analysis reveals that that people often selected large (probably male) animals for offering. Previous results show that especially their crania and antlers were offered (e.g. Salmi et al., 2011; 2018). Offerings of male reindeer were possibly related to offerings given to certain deities such as the thunder god Horagalles (Kildal and Reuterskiöld [1740], 1910; Mebius, 1968:50–51). The selection of mainly adult individuals may be due to their large antlers, as reindeer antlers are shed yearly and grow larger each successive year (Nieminen, 1994: 29). Reindeer antlers have also been symbols of regeneration of the reindeer species for the Sámi (Olofsson, 2010). Age of the offered reindeer may also reflect the
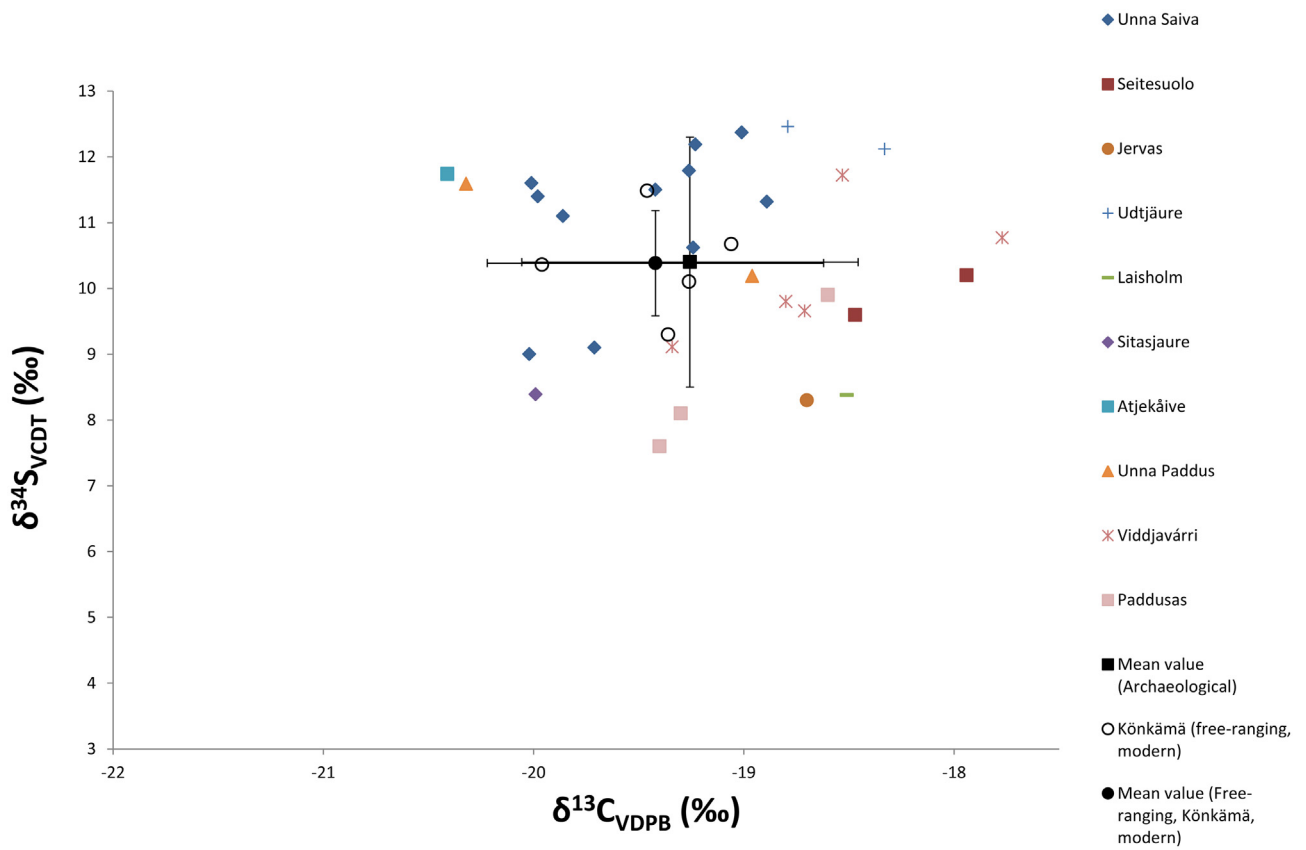
Fig. 7. Scatterplot of isotope results for carbon and sulphur (modern reference and archaeological samples).
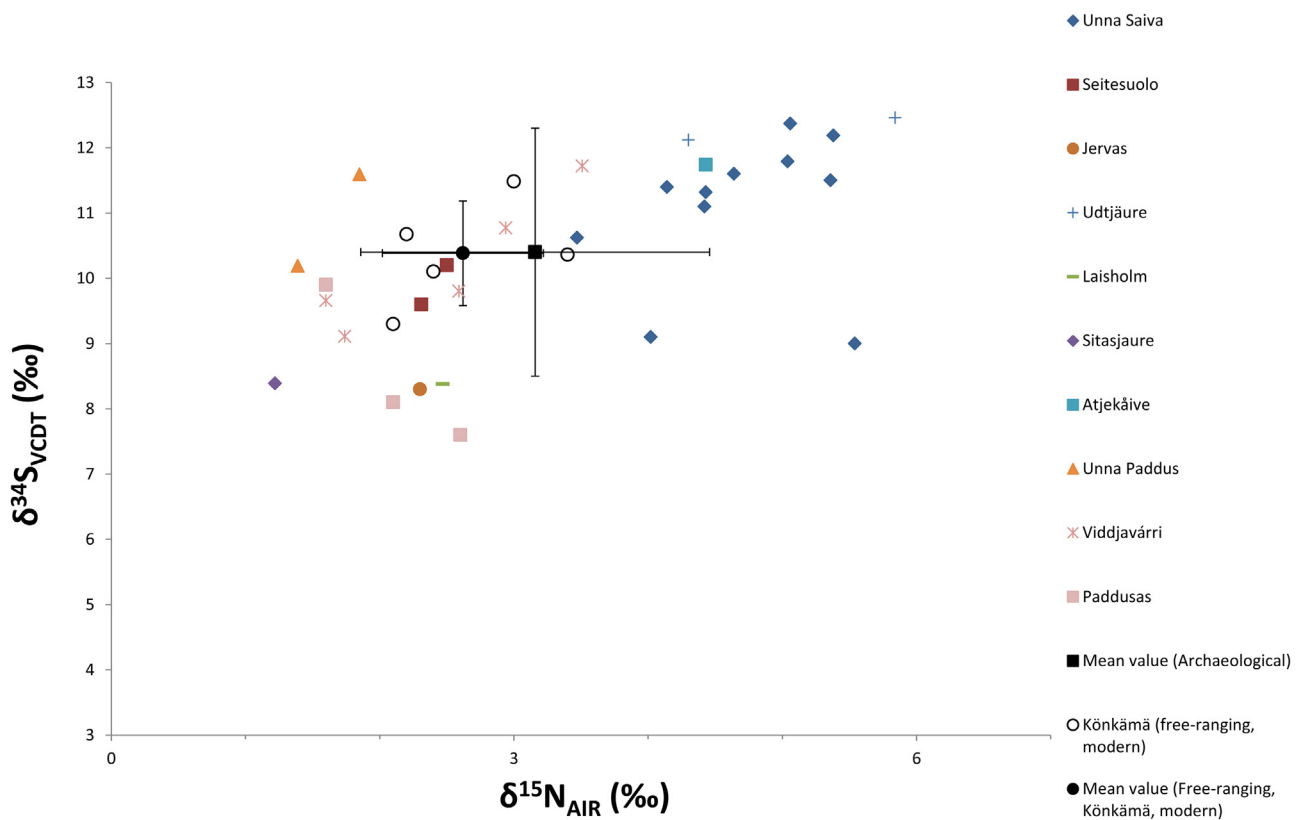

Fig. 8. Scatterplot of isotope results for nitrogen and sulphur (modern reference and archaeological samples).

special bonds that had formed between reindeer and humans in the course of several years. Adult reindeer which, for instance, had grown a large pair of antlers, or had developed a special relationship with a human person over the years, may have been preferred (e.g. Paulaharju, 1932).

Our results also clearly show that different kinds of reindeer were offered at all sites. Osteometric measurements indicate that large, probably male individuals were offered along with smaller individuals of both sexes (Fig. 5; Appendix B; see also Salmi et al., 2015). The fact that the range of the log ratios of the archaeological samples was similar to or even larger than that of modern reindeer also suggests that reindeer of all sizes were offered at these sites. Large size, although an important selection criterion in many instances, was not the only determining factor for the selection of animals for offering. Animals of different ages were also offered: although prime-age adults were the largest group among the offered animals, there were also sub-adult and old individuals present. Analysis of $\delta^{15}N$ also shows that reindeer with both low and elevated $\delta^{15}N$ values were sometimes offered at the same site (e.g. Unna Saiva, Viddjavárri, possibly Sieiddakeädgi), possibly suggesting that some of the offered reindeer received supplementary winter feeding and others not.

It seems likely that the variation in the kinds of reindeer selected for offering partly relates to differences in reindeer herding strategies of the Sámi which have varied in time and space, for instance in terms of size of the reindeer herds, intensity of the human interference with the lives of the reindeer, and extent of seasonal migrations (e.g. Tegengren, 1952; Helle and Jaakkola, 2008; Kortesalmi, 2008: 22–28; Bjørklund, 2013). Wild reindeer hunt and reindeer pastoralism also coexisted in many areas until the 17th century or even later (Mulk, 2009; Andersen, 2011; Bjørklund, 2013). Another important source of variation in the kinds of offerings made were choices made by local communities and individuals according to their specific religious needs. The Sámi made offerings for various purposes, such as success in hunting and reindeer herding and personal and family matters (Äimä, 1903; Paulaharju, 1932; Itkonen, 1948: 311–318; Rydving, 1993: 104–106). Different animals may have served different purposes in the communication between people and supernatural powers, as demonstrated by the example of male reindeer being offered to the thunder god Horagalles (Kildal and Reuterskiöld [1740], 1910; Mebius, 1968:50–51). Also personal relationships between people and certain animal individuals may have played a part in the selection of the offering (e.g. Paulaharju, 1932).

Ultimately, the Sámi had engagements with many kinds of animals (wild, domesticated, different ages, sexes, social roles in their herds and human communities) at the same time. The various engagements people had with the reindeer resulted in different religious significance of these animals in different occasions. Identification of many kinds of reindeer with different relationships and interactions with people in the archaeological material from Sámi offering sites shows how people had different motives and concerns when making offerings. Moreover, we argue that a simple binary categorization such as wild vs domesticated is not likely to reflect the range of relationships the Sámi had with reindeer. Instead, archaeological data can be used to examine the varying human-animals interactions and cultural practices concerning animals. A combination of different methods such as stable isotope analysis and zooarchaeological analysis is likely to yield a more nuanced understanding of human-reindeer relationships among the Sámi and the role reindeer played in the Sámi religion.

5. Conclusion

In this paper, we used a combination of faunal analysis and stable isotope analysis to disentangle the engagements the reindeer, offered at Sámi offering sites, had with people. Faunal analysis reveals that specific kinds of reindeer, especially large males, probably with impressive antlers, were preferred as offerings. However, also females, different sizes and other ages were also offered but to a lesser extent. Stable isotope analysis also shows a variety of relationships between people and the offered reindeer. Some of the individuals probably belonged to domesticated herds and had received supplementary winter fodder. However, reindeer with a "natural" diet were also offered, sometimes on the same site. Analysis of mobility patterns in combination with other offerings at the siedis show that some sites were used by reindeer herding communities and families from wide geographic areas, probably stopping by during their seasonal migrations whereas other sites were mainly used by local communities. It is obvious that there were many kinds of reindeer offered, with varying relationships to people, for instance wild reindeer, draught reindeer, household reindeer, and individuals of different colors, sizes, personalities and reproductive successes. Identification of many kinds of reindeer and their interactions with people in the archaeological material from Sámi offering sites shows how people had different motives and concerns when making offerings, and that a simple binary categorization such as wild and domesticated is not likely to reflect the range of relationships the Sámi had with reindeer.

CRediT authorship contribution statement

Anna-Kaisa Salmi: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Visualization, Funding acquisition. **Markus Fjellström:** Methodology, Formal analysis, Investigation, Writing - original draft, Visualization, Funding acquisition. **Tiina Äikäs:** Writing - original draft, Investigation, Visualization, Funding acquisition. **Marte Spangen:** Writing - review & editing. **Milton Núñez:** Writing - review & editing, Supervision, Funding acquisition. **Kerstin Lidén:** Methodology, Formal analysis, Writing - review & editing, Supervision.

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Appendix A. . Definitions of osteometric measurements used in this study.

Measurement	Reference
Length of the molar row	von den Driesch (1976)
Humerus trochlear height	Puputti & Niskanen (2008)
Radius greatest length	von den Driesch (1976)
Radius proximal anterior-posterior	Puputti & Niskanen (2008)
Radius proximal breadth	von den Driesch (1976)
Tibia distal breadth	von den Driesch (1976)
Metatarsal greatest length	von den Driesch (1976)
Metatarsal proximal breadth	von den Driesch (1976)
Metatarsal distal depth	von den Driesch (1976)
Metatarsal proximal depth	von den Driesch (1976)

Metacarpal greatest length		von den Driesch (1976)
Metacarpal proximal depth		von den Driesch (1976)

Appendix B. . Age and sex distributions based on mandibular tooth wear and eruption per site.

Age Group	Laisholm	Jervas vid Karats	Udtjäure	Näkkälä	Seitesuolo	Paddusas	Saivarova	Unna Saiva	Nitsijärvi	Ukonsaari
0–2 years		1				1		2		1
2–4 years			1			2		5	3	
4–6 years				1	3	3	1	7	1	
6–8 years					13	12		19	5	
8–10 years	1			1	3	6		5		
10 + years					1	4		3		
Sex estimations (M/F)	0 M, 1F		2 M, 0F	1 M, 0F	9 M, 5F	18 M, 3F	1 M, 1F	71 M, 15F	5 M, 1F	

Appendix C. . Sample sizes, means, ranges and standard deviations of log ratios of osteometric measurements per site.

	Laisholm	Udtjäure	Näkkälä	Seitesuolo	Paddusas	Unna Saiva	Udtjäure	Meselefors
N	1	3	1	14	35	97	3	3
Mean	− 0.0560	− 0.0127	0.0250	0.0085	0.0224	0.0172	0.0127	− 0.0114
St.dev.		0.0159		0.0044	0.0034	0.0028	0.0159	0.0178

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