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# Multidisciplinary History of Goats in Finland: A Comparative Approach

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**Abstract:** This article aims to study the history of goats (*Capra hircus*) in Finland using a multisource approach combining zooarchaeological data with evidence from written sources, the Silver Tax Record of 1571, and statistical data from the year 1900. We present an overview of an abundance of goat bones in zooarchaeological sites dating from the Middle Iron Age to the Post-Medieval period. Furthermore, we use Zooarchaeology by Mass Spectrometry (ZooMS) to study the presence of goats in material where it has not been identified by morphological methods. Where the zooarchaeological material and written sources overlap, the results support each other. The meaning of goats in the animal husbandry system in Finland has varied temporally and spatially, and their numbers were in decline by the year 1900. Their diminishing role in 20th-century Finland and their reputation of being the 'poor man's cow' is likely the reason why they have not attracted much research interest. However, according to our data, goats have been an integral part of the animal husbandry system at least from the Late Iron Age onward, even if their proportion among other livestock is never very high.

**Keywords:** goat; *Capra hircus*; zooarchaeology; written sources; ZooMS

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## 1. Introduction

The study of the goat (*Capra hircus*) has frequently been regarded as challenging by zoo archaeologists. This is partly because distinguishing goat bones and teeth morphologically from those of sheep (*Ovis aries*) is difficult. The challenge of the morphological or metrical identification of sheep and goat faunal remains in the archaeological material has created many guidelines [1–4]. Moreover, the role of goats in the economy, especially so in the Northern European context, is often regarded as minor. However, as goats have been present in the Northern Baltic Sea Region for thousands of years, there must have been strong motivation for their breeding. Moreover, their flexible role in the animal husbandry system allows study into the cultural and practical decisions of the farmers, maybe even more so than with the species that were more central to the core subsistence. Perhaps because of their minor role, available data regarding goats are limited. Thus, a study of this species especially merits the multisource approach. Methods of identification such as Zooarchaeology by Mass Spectrometry (ZooMS) and hair identification may reveal the presence of goats from archaeological sites with no osteological evidence or no morphologically identified goat remains [5,6]. In written sources, sheep and goats are usually recorded separately, forming different types of data than zooarchaeological records. In addition, the goat population represented in the zooarchaeological material and written sources are likely to contain ancestors of the modern native goat breed of Finland, the Finngoat. Studies of the native breed's population history may help to protect the cultural history and genetic diversity these animals represent [7].

This article aims to study the history of goats in Finland using a multisource approach that combines zooarchaeological data with evidence from written sources, and to merge these data into visual form as a map. While the Silver Tax Record of 1571 is a widely used source for the study of Finnish animal husbandry, this is the first time the goat data are presented as a map and compared with zooarchaeological data. ZooMS is also utilized as a method of identification. We concentrate on the quantitative data, aiming to study the temporal and spatial abundance of goats in Finland, both in absolute numbers and as a part of livestock.

### *1.1. Goats as a Part of Animal Husbandry System of Northern Europe*

In Northern Europe, goats have been kept for thousands of years, e.g., [6,8], but their role in the animal husbandry system has not yet been systematically studied. The presence of goat remains in zooarchaeological material is regularly noted, but they are usually less abundant than those identified as sheep, e.g., [8–17]. In single site analysis, the number of goat bones is often too small to merit detailed analysis, c.f. [10], and in large-scale synthesis studies, goat data are usually clustered together with sheep ('sheep or goat') and mostly the role of sheep is discussed, e.g., [9,13,18]. While the data at present are too fragmentary for an overview of goat husbandry practices in Northern Europe in the past, goats seem to be a regular but minor component among the domestic fauna. However, in recent years, interest in the history of goats has been increasing, partly due to new methodologies making more secure identification of goats possible [2,5,19].

The Northern Baltic Sea Region follows mainly the same pattern, and it seems that goats were not especially abundant in Finland, Estonia, and Southern and Middle Sweden, compared, for example, to the number of sheep among the livestock, e.g., [10,12,14,15,20]. However, there is variation in their importance. For example, in Medieval Novgorod (Russia), approximately one-third of the sheep and goat bones have been estimated to belong to goats [21]. According to the 16th-century data, the proportion of goats in the livestock was higher in Northern Sweden and Northern Central Sweden than in other parts of the country. This has been interpreted to relate to the high importance of milk production in the area [22].

### *1.2. Animal Husbandry Patterns in Finland*

By the early 19th century, three main agricultural systems were in use in Finland [23]. In the west, where field cultivation prevailed, cattle (*Bos taurus*) were the central source of manure and draught power for the permanent fields, while in the east, where slash-and-burn cultivation was more common, less manure and animal-powered plowing was needed. In Northern Finland, agriculture was based on animal husbandry; due to the harsh climate, little importance was attached to cultivating crops. The long indoor winter-feeding period for farm animals, which could last for up to 34 weeks of the year, was one of the major challenges for Finnish animal husbandry [23]. In the Finnish self-supporting agriculture system, cattle were a central animal and usually the most abundant species identified in faunal samples during the historical period. They were especially needed for milk production and their manure for the fields. Sheep were kept mainly for wool, and pigs (*Sus domesticus*) utilized fodder sources that other farm animals could not. Thus, most farms kept these species during the late prehistoric, medieval, and post-medieval periods [18].

In contrast, goat keeping was one of the non-constant components in the animal husbandry system. It is possible that the goat's role and importance in the agriculture system varied spatially and temporally more than those of other animals. The data on the role of goats in Finland as a part of animal husbandry are fragmentary, and an extensive synthesis study on the subject does not yet exist. However, their utilization seems to be versatile and variable. It has been noted that in the 17th-century Southwestern Finland, the keeping of goats varied greatly between different areas; for example, in the archipelago, goats were quite common (on average over 7 goats per farm), while some mainland areas

had practically no goats [24]. Goats were less common in the most fertile cultivation zone of Southwestern Finland, but more common in rocky or forestry environments. This could relate to the challenges in their keeping in more densely populated areas, as they had a reputation for being difficult to manage and causing damage to the crops by escaping to the fields, see also [25].

Goat's milk was likely to be a major motivation for their keeping [22,23,25,26]. However, goats and their skins have also been sold in town markets, sometimes transported over long distances, summary in [25]. In the town of Turku in the medieval phase, the anatomical distribution of goat bones is likely to reflect select utilization of hides and horncores, while in the post-medieval phase, goats were probably kept in the town as a source of milk for the inhabitants [15]. In the 17th century in Southwestern Finland areas where goat-keeping was common, they were kept especially by wealthier inhabitants; but later, goats were considered especially as affordable options for poor people [24,26,27]. Thus, there has been great variation in the role of goats in the animal husbandry system.

### *1.3. Goats in the Zooarchaeological Material and Written Sources*

Interpretation of the anatomical distribution of archaeological goat remains is challenging. One of the implications of the morphological approach is that many of the bone elements that can be identified with better confidence are from elements relating to crafts, namely horn cores and lower leg bones (metapodials). The consumption of goats, relating to the deposition of ribs, vertebrae, and upper leg bones [28] is more challenging to identify from the zooarchaeological material. Moreover, goat skins or live goats could have been transported long distances to town markets [29]. Thus, the presence of identified goat bones on archaeological sites does not necessarily imply their local breeding.

Tax records are a good source for quantitative studies of the geographic variation of the species. For Finland, the earliest available written record with good geographical coverage is the Silver Tax Records of 1571 (Fi: Hopeaveroluettelo) [30–36]. At that time, Finland was part of Sweden, which had been forced to pay Denmark for the ransom of Älvsborg Castle. As a consequence, people had to pay an equivalent of one-tenth of their metal objects and livestock as an extra tax, except for the nobility. The tax inventories were collected in parishes, house-by-house by the local boards, to which the clergyman, the rural police chief, lay members, and even the bailiff of the jurisdictional district belonged [32,37–39]. This is an exceptionally informative and detailed record of livestock in Finland at that time.

For more recent time periods, other quantitative sources besides tax records are available. In the 19th century, a number of domestic animals were collected by officials as a part of general agricultural statistics. The development of the abundance of domestic animals in Finland can be studied through these figures. At first these figures were partly estimates based on the reports of Governors. Later, as the methods of data collecting improved, reports became more reliable. After the mid-19th century, these data started to be published as a part of The Official Statistic of Finland [23,40,41].

### *1.4. Previous Studies of Goats in Finland*

The earliest evidence of goats in Finland is a hair that has been identified from the Corded Ware burial dating to c. 2900–2000 cal. BC [6]. The osteological material from the Stone Age and early metal periods is small; often, only fragmented burnt bones have survived [42]. The likelihood of an identifiable goat bone surviving is small, and no definite goat bones have been found from this early material [11]. Goats have been identified from the Late Iron Age sites (c. AD 800–1200), where they have been found among food waste but also in ritual deposits [43,44]. Goat bones are also present in the medieval and post-medieval town of Turku [15].

In written sources, goats are mentioned in various tax records and statistics dating from the 16th to the 20th century. While no studies are concentrating especially on goats, they have been studied and included in the research of animal husbandry [24,25,45] or in local histories, e.g., [38,45,46].

### *1.5. Multisource Approach*

Combining zooarchaeological and historical sources is both a fertile and challenging approach [47–49]. Written sources are textual evidence of animals, either quantitative or qualitative. They can, for example, describe live animals, their numbers, the prices of animals, their products, or be poems about them. Zooarchaeological material contains the concrete remains of the animals and can be further utilized for the ancient DNA and isotope studies concentrating on the properties of single individuals.

While the sources describe the same phenomenon—goat husbandry—the resulting data are not directly comparable. For example, historical sources often describe the numbers of live animals while the zooarchaeological material consists of remnants of dead animals. The temporal aspect of the data are also different. The historical sources usually present data from closely defined periods (e.g., the year) while zooarchaeological material has often accumulated over several years, decades, or even centuries. For the periods prior to when the first written sources were available, only zooarchaeological material can be used. Conversely, written sources are available for the 19th and 20th centuries, and archaeological materials available from Finland during that period are only a few [25,47,49].

Collagen peptide mass fingerprinting, i.e., ZooMS, can be used for the identification of goats from fragmented faunal remains or identification of elements without morphological criteria, e.g., ribs [50]. Combined with zooarchaeological data, it could be a valuable tool for studying the different aspects of goat breeding and utilization. For example, mandibular age data that is often presented for sheep and goats combined, could be made species-specific.

## 2. Materials and Methods

### *2.1. Zooarchaeological Data*

The study area is limited to mainland Finland, usually excluding the island of Åland as the cultural connections and development of subsistence diverge from those on the mainland. However, Åland is included in the statistical data of the year 1900 as part of the county of Turku and Pori as it is not given separately. Zooarchaeological goat data were collected from previously analyzed assemblages. In addition, this study includes some new osteological results (Supplementary Table S1). The samples date to the Middle Iron Age (c. AD 375/400–800/825), the Late Iron Age (c. AD 800/825–1200), and the local medieval (c. AD 1200/1300–1520) and post-medieval periods (AD 1520–c. 1900) [51]. The material includes sites in which the Number of Identified Specimens (NISP) of cattle, sheep, goat, pig, and horse remains counted together is larger than 100. For the map, materials from different sites within one town were counted together. Assemblages smaller than NISP 100 with identified goat bones are also included. As the osteological analyses were conducted by several different researchers, criteria for the identification of goat and sheep bones vary. Most often, the criteria given by Boessneck [4] and Prummel and Frisch [1] were used for differentiating sheep and goat bones. For the materials analyzed for this article, criticism given by Zeder and Lapham [3] was also noted.

### *2.2. Written Sources*

For the written sources, the numbers of goats were collected and analyzed using the historical method. It is especially important to be aware of source criticism when interpreting the quantitative data. Thus, we analyzed, for example, the original purpose of the sources and their context. In addition, we analyzed the factors that could have influenced the reliability of the sources or led to errors in the numbers of animals recorded. One general observation in the source criticism was that the numbers only represented the situation in one year, not the years before or after it or the entire century, and thus do not indicate fluctuations in livestock numbers. However, despite these factors, the gathered data provide a usable general overview of the animal stock.

The original manuscripts of the Silver Tax Record of 1571 have been edited into printed books [30–36]. In this tax record, the number of counted animals is likely to represent a minimum number, for example, as people tried to hide part of their stock in order to

avoid paying taxes [31,38]. Even if peasants owned most of the domestic animals in 16th century Finland, goats were also owned by the nobility and thus not included in the Silver Tax Record. At least in some provinces, landed estates had goats and these were not included [26,52]. Even if in Ostrobothnia goats were not recorded in the goat column, few goats were marked in the sheep column in this tax record [33]. Furthermore, goats in towns were not included in this study as this data are not usually available. The summary tables of parish levels presented in the printed editions have been used in this study for goats, except for the province total sum, which has been recalculated when needed. For Finland Proper, the summary was not present, and the sum has been counted from the data. While province-level data are suitable for large-scale comparisons, it is understood that the number of goats varied within provinces. For the number of goats per taxable farm, it should be considered that in some areas, e.g., some parts of Häme, animals from non-taxed farms were included in the counts, c.f. [37]. For Figure 2, previously published summary of Silver Tax Records data [37] was used, except for goats, where the numbers counted come directly from the printed Silver Tax Records.

The other written source selected for the study is The Official Statistic of Finland from the year 1900 [53]. Even if this material was collected for statistical and not taxation purposes and the methods of statistical data collection have developed more reliably, there could still be errors in recording the figures. Compared to the data from the Silver Tax Records, these figures include goats from the towns [23,40].

### *2.3. Cartography*

From the medieval period onwards, crown taxation was based on the taxation of land property. After the Reformation, King Gustav I Vasa (1523–1560) wanted to enhance tax collection and all taxpaying entities were recorded in assessment rolls, i.e., in cadastres. These cadastres for Finland were prepared from 1539 onwards. This earliest taxation data are the basis for the earliest Finnish settlement village register and atlas. The borders of medieval Finnish castle provinces presented here are based on the Atlas of the settlement in Finland in the 1560s [54]. At first, the maps of the Atlas were scanned and georeferenced in ArcGIS, and then borders were digitized and later used in mapping. Province names in Figures 1 and 2 are names of Finnish historical provinces. Older castle provinces were named after province castles, e.g., Raseborg Castle was the capital of Raseborg castle province, etc.

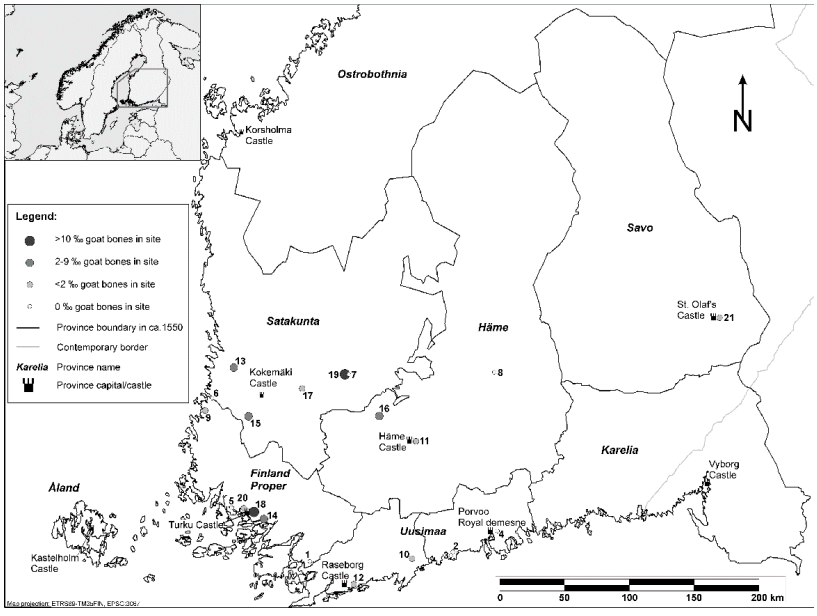


**Figure 1.** Location of the sites and abundance of goat bones for Iron Age and medieval periods. Site names and references in Supplementary Tables S2 and S3. Cartography by Jussi Kinnunen.

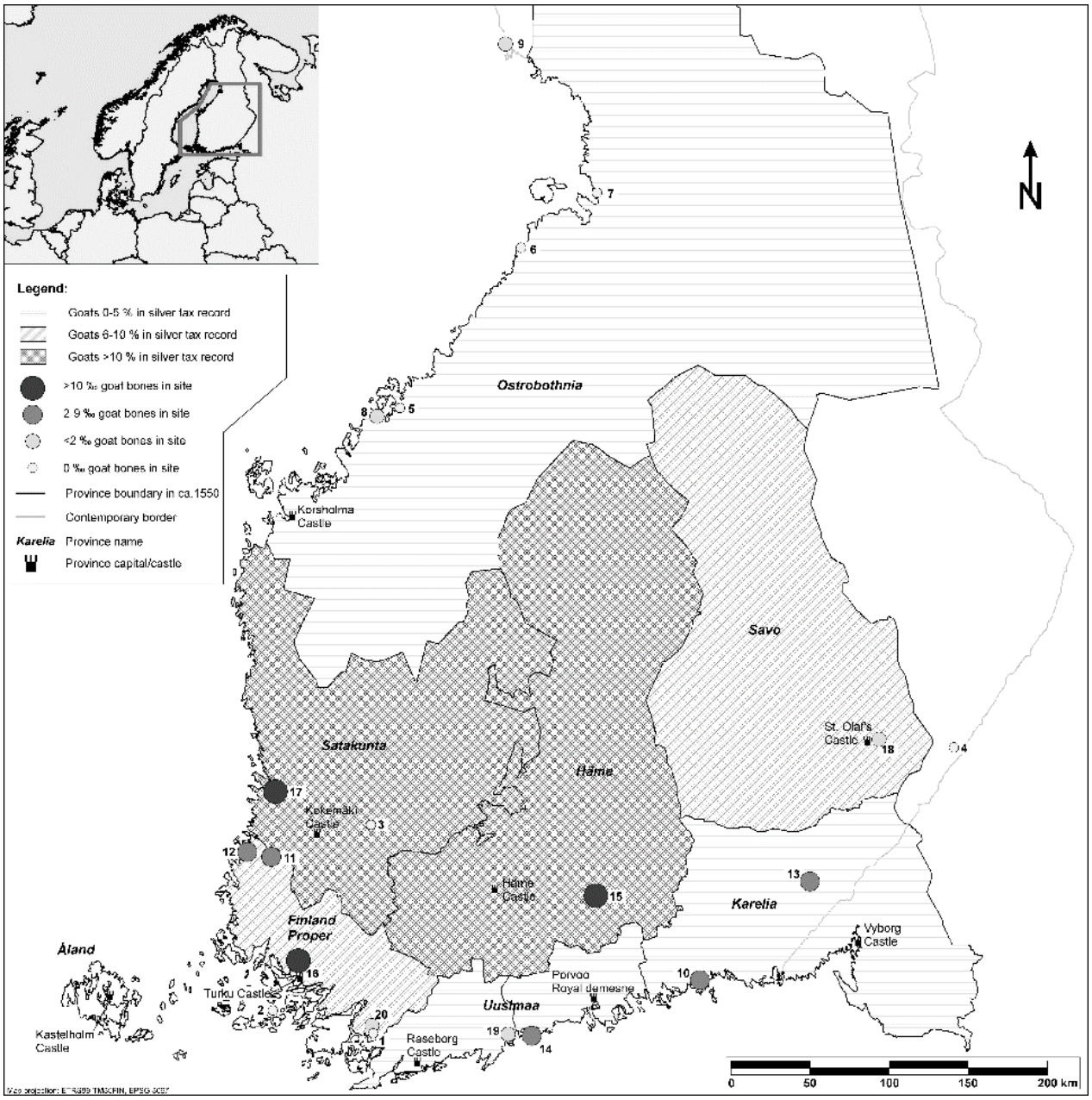


**Figure 2.** Abundance of goats according to the Silver Tax Record of 1571 and abundance of goat bones in the zooarchaeological material (‰ from all domestic animals) in the post-medieval period. Site names and references in Supplementary Tables S2 and S3. Data from Åland are not included. Cartography by Jussi Kinnunen.

### *2.4. Zooarchaeology by Mass Spectrometry*

Eighteen samples from Sastamala Ristimäki, which were originally identified as 'small ungulate' or 'sheep/goat' by their morphology (Supplementary Table S1), were analyzed using ZooMS [55]. This minimally destructive method allows separating different ungulates, among them the goat and sheep. Although the collagen sequences for sheep and goats are very similar, there are peptide differences that can be used to distinguish between the two. The method is described in detail in Appendix A.

## 3. Results

### *3.1. Zooarchaeological Material*

In this study, the earliest goat bone found in Finland was identified by using the ZooMS method. The bone in question, a long bone fragment (TYA 177:1290; Supplementary Tables S1 and S2), derives from the Sastamala Ristimäki site and has been dated to 1444 ± 29 BP, 565 AD–655 cal. AD, i.e., the Middle Iron Age. It was originally identified as a 'small ungulate' (sheep, goat, or pig) bone. The ZooMS spectrum was of good quality: based on the combination of the present peptide markers, we can be certain that the sample is that of a goat.

Goats are present in all Late Iron Age sites with large faunal assemblages and in most of the large assemblages from medieval and post-medieval periods (Figures 1 and 2 and Supplementary Tables S2 and S3). However, in the zooarchaeological material, the number of identified goat remains is always lower than identified sheep remains and they form such a small part of the material they are counted in permille, not in percentage (e.g., in Figures 1 and 2). The proportion of goat bones among the cattle, sheep, pig, and horse bones is over 2% (over 20 ‰) in only three cases: in the Pori Taidemuseo site, Lahti village, and Turku post-medieval town material. There seems to be geographic variation in the abundance of goat remains. The goats are more common in the zooarchaeological material in Southern Finland, especially in Southwestern Finland and Satakunta, than in Northern Finland.

### *3.2. Written Sources*

According to Silver Tax Record of 1571, there was geographical variation in the abundance of goats in Finland. In the Province of Satakunta, goats were most abundant in absolute numbers per taxable farm (Table 1) as well as relative to other domestic animals (Figure 2). They were also common in the Provinces of Häme and Finland Proper (Table 1, Figure 2). While the number of goats and their number per farm was below average in the Province of Savo, the proportion of goats among the livestock was 8%, equal to that of Finland Proper (Table 1, Figure 2).

**Table 1.** Number of taxable farms and goats in Finland in 1571 excluding Åland. Sources: [30–36].

| Provinces | Farms | Goats | Goats Per Taxable Farm |
|---|---|---|---|
| Finland Proper | 7108 | 7803 | 1.1 |
| Satakunta | 4539 | 11,566 | 2.5 |
| Häme | 3973 | 6714 | 1.7 |
| Uusimaa | 4937 | 2118 | 0.4 |
| Karelia | 2311 | 397 | 0.2 |
| Savo | 3849 | 2319 | 0.6 |
| Ostrobothnia | 2332 | | 0 |
| Total | 29,049 | 30,917 | 1.1 |

By 1900, the number of goats in Finland was in decline (Table 2). Even in the old goat-keeping areas of Satakunta, Häme, and Finland Proper (included approximately in the county of Vaasa, Häme, and Turku and Pori in 1900 data), the number of goats was decreasing. In the rest of Finland, the number of goats was almost insignificant. There were only three goats per one thousand inhabitants in Finland in 1900 [53].

**Table 2.** The number of goats in Finland in 1900. The county of Turku and Pori includes Åland. Source: [53].

| Area | Goats |
|---|---|
| The county of Vaasa | 1982 |
| The county of Häme | 1437 |
| The county of Kuopio | 56 |
| The county of Turku and Pori | 3319 |
| The county of Vyborg | 325 |
| The county of Mikkeli | 395 |
| The county of Oulu | 35 |
| The county of Uusimaa | 35 |
| Total | 7584 |

## 4. Discussion

The earliest history of animal husbandry in Finland is based on fragmentary evidence, and the meaning of goats during early prehistory is challenging to study. The evidence for domestic animals dating to the Stone Age consists of finds of goat hair, ruminant milk residues from pottery, and a single bone find from sheep or goat [6,11,56]. All these remains could derive from goats, which would also be a good low-maintenance option for supplementing mainly hunter-fishing-gatherer subsistence. However, at present, the scarce data cannot exclude the presence of other domestic species. It seems as though the animal husbandry indicated to have been practiced by the Stone Age cultures did not succeed in developing into a maintainable subsistence economy, and agriculture gained more importance only later during the Bronze Age and Early Iron Age [56].

While domestic animal bones are regularly found in Bronze Age and Early and Middle Iron Age sites, the fragmentary nature of the material has made the identification of goats unlikely. In our study, the goat bone identified by ZooMS indicates the presence of goats in Finland during the Middle Iron Age. As goat bones are regularly found in Late Iron Age contexts, it is likely that at least during this period goats were an integral part of the animal husbandry system. There is also evidence of goats being used in rituals in settlement sites, possibly in fertility rites of the domestic animals [43].

During the medieval period, the zooarchaeological material reveals a similar pattern, where goats are regularly present but never identified to be as abundant as sheep. However, it should also be noted that the absence of goat bones in a site might not reflect the general goat utilization in the area. For example, the absence of goat bones in the small fortresses of Eurajoki Liinmaan linna, Helsinki Vartiokylä, and the manor site of Salo Vanhakartano could be connected to their different socio-economic status, which made it possible for them to operate outside the framework of self-supporting subsistence. It could be that goat meat was not preferred and therefore not consumed in these sites [18]. Zooarchaeological materials from Eurajoki Liinmaa and the Bridgettine Abbey of Naantali are predominantly food waste [18,57]. While both samples include identified sheep bones, there are no identified goat bones.

During the post-medieval period, comparison between the written sources and zooarchaeological material is possible. Data from the Silver Tax Record of 1571 and post-medieval zooarchaeological material reveal a similar pattern of goat abundance in Finland (Figure 2), where goats were most common in the areas of Satakunta, Häme, and Southwestern Finland. A similar pattern was still present in the statistical data from the year 1900, where these areas had the highest numbers of goats, even if goat keeping in general was already in decline in Finland. The reason for this geographical variation is not yet well understood. In Sweden, goats were abundant in sparsely populated areas with an animal husbandry system oriented to milk production [22]. Yet in Finland, goats kept their importance longest in the western part of the country, where field cultivation was of high agricultural impor-

tance [23]. While in Finland goats were not abundant in the northern parts of the country, in Sweden they were common in the North and mountain area. Thus, harsh climate is an unlikely reason for the geographical variation.

Thus, the meaning of goats in Finland has varied temporally and spatially. While they have never been the central animal in the animal husbandry system, they have been commonly kept in Finland, with the exception of Ostrobothnia and Northern Finland. The decline in goat keeping presented in the statistical data from the year 1900 is likely to be connected with the agricultural reform and the emphasis on cattle dairy production and forestry. As timber became an important product, using forests for grazing ceased in importance as goats were seen as especially destructive for forest renewal. In addition, the specialization of agricultural production diminished the keeping of goats [27,58]. Goats are often presented as the 'poor man's cows' in the literature, as they were often kept by people who could not afford to keep a dairy cow [58,59]. However, in previous centuries this was not the goat's only role, since they were also kept by wealthy people for their milk, skin, meat, and horns [24,25]. The relatively minor role of goats in the agricultural system in the 20th century has possibly led to less research interest in goats and their history.

This study demonstrates that a multidisciplinary approach is useful when studying the history of goats. As their identification from the zooarchaeological material is challenging and often requires large and well-preserved samples, the ZooMS offers a good possibility for examining the presence of goats in periods where morphological data are not available. For Finland, the goat bone identified by the ZooMS method from Ristimäki predates the next identified and dated goat bone from the Late Iron Age by several hundreds of years. Combining zooarchaeological data, written sources, and cartographical data has allowed us to research the presence of goats as a part of the animal husbandry system for several centuries, reaching from the prehistoric period to the year 1900 and covering their long-term history and decline. The zooarchaeological and written sources support each other for the spatial differences in the abundance of goats in the post-medieval period. Thus, even if the identification of goats in zooarchaeological material is hampered by several challenges, the overall pattern seems to follow the same as that presented by the written sources.

The history of goats in Finland is at the same time likely to be the history of Finngoats, the native goat breed of Finland. While the population history of the Finngoat is still poorly understood, the first attempt to study the connection between goats in archaeological samples and modern animals by using ancient DNA has been successful [60]. Many of the genetic properties of the unimproved modern native animal breeds have been shaped by the adaptation to the animal husbandry practices and environmental conditions of the past [25]. Moreover, the decline of the goat population in the late 19th century and the concentration of goat husbandry to limited geographic areas could have created a population bottleneck for Finngoats. Thus, the multisource approach to the history of native animal breeds may help to understand their population history and genetic properties and to help in their protection [7].

This study has created the first overview of data on goat abundance in the zooarchaeological and written sources in Finland. Nevertheless, a more detailed study of the regional differences observed in this paper would be possible in the future, by using qualitative sources and studying the role of goats in the animal husbandry system rather than just their abundance. Further ZooMS samples could be used to study the presence of goats in the Iron Age samples, or to study the species division of bones identified as sheep or goat.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/heritage5030101/s1, Table S1: ZooMS results for Sastamala Ristimäki bone samples; Table S2: Zooarchaeological data from all sites (NISP); S3: References for zooarchaeological data.

**Author Contributions:** Conceptualization, A.B.; methodology, A.B., H.S., J.K. and E.R.; formal analysis, A.B., H.S. and E.R.; writing—original draft preparation, A.B., H.S., J.K. and E.R.; visualization, J.K.; supervision, A.B.; project administration, A.B.; funding acquisition, A.B. All authors have read and agreed to the published version of the manuscript.

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## Appendix A

*Zooarchaeology by Mass Spectrometry (ZooMS)*

Method: ZooMS work was conducted at BioArCh, Department of Archaeology, University of York (United Kingdom) and followed a conventional destructive ZooMS method [61]. Eighteen bone samples, of which it was morphologically not possible to determine the species (small ungulate, sheep/goat), were analyzed (Supplementary Table S1). A small sample of around 13–50 mg was taken from each specimen, demineralized in 0.6 M hydrochloric acid (HCl), washed once in 200 µL 0.1 M sodium hydroxide (NaOH) and three times in 200 µL 50 mM ammonium bicarbonate solution (AmBic) pH 8.0. Samples were gelatinized in 100 µL AmBic for one hour at 65 °C, and 50 µL of each sample was digested with 1 µL trypsin overnight at 37 °C. To terminate trypsin activity, samples were then acidified with 1 µL of 5% trifluoroacetic acid solution (TFA). Peptides were extracted using C18 ZipTip® pipette tips (EMD Millipore), treated with 0.1% TFA washing solution and 50% acetonitrile (AZN)/0.1% TFA conditioning solution. The peptides were eluted with 50 µL of conditioning solution. One microliter of each sample was spotted on a Bruker ground steel target plate in triplicate and mixed with α-cyano-4-hydroxycinnamic acid matrix solution. The plate was operated on a calibrated Bruker Ultraflex III MALDI TOF/TOF mass spectrometer. Three spectra of each sample were averaged and analyzed in mMass v.5.5 [62,63]. Individual peptides were identified according to previously published markers [55,64,65].

Results: Out of 18 samples analyzed, 15 were successfully identified as species, two remained questionable, and one sample failed (Supplementary Table S1). All six samples originally identified as 'sheep/goat' by their morphology turned out to be sheep. Out of the 12 samples originally listed as 'small ungulate', five turned out to be sheep, three cattle, and one a goat; the remaining either did not produce good results or failed entirely.

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