"Innovative Subsistence Strategies"

Neolithic Hunting and Husbandry at Lake Bienne on the basis of the Archaeozoological Data of the Lakeshore Sites of Sutz-Lattrigen (Switzerland)

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Manar Kerdy

Abstract

Swiss Neolithic wetland sites offer an incomparable source of information for prehistoric pile dwellings. The exceptional preservation of organic materials, such as animal bones, antler and plant remains, allow extraordinary insights into the Neolithic life. The preserved wooden posts of the houses make an exact dating of the sites as well as the reconstruction of the settlement patterns possible. The lake-dwellings of Sutz-Lattrigen (Lake Bienne, Switzerland), which are situated at the southern shore of Lake Bienne, provide a rich Neolithic sequence. The economic and environmental data presented here are based on identifications of more than 20,000 animal bones from three Neolithic lake shore settlements dated between 3800-3100 BC (Cortaillod and Horgen cultures).

With the aim of reconstructing subsistence practices and environmental conditions, animal bone identification results were compared with other settlements at the Lake of Bienne. The results have proven that chronological and geographical variation of economy and ecology of hunters and herders of the 4th Millennium BC can be reconstructed. The species spectrum indicates a broad exploitation of domestic and wild species. Multiple factors, such as topography, climatic, weather conditions or cultural influences have played a role in the socio-economic society and the clever change in the herd management during the Horgen period is based ultimately on economic imperatives.

Additionally, this thesis investigates in the bone and antler tools that have been excavated in the above-mentioned settlements. Ca. 1100 pieces show a great variety of raw material usage and in the final form of artefacts produced. Semi-finished objects and production debris have been studied, which helped in reconstructing the modes of production. Tool production consists not only of manufacturing activity aimed at particular tasks, but also comprises traditions of manufacturing know-how in production techniques for exploiting the available fauna resources. Bone tools have been selected from the species based firstly on their physical properties. Antler tools have developed locally at the settlements influenced by people culture and their way of implementing the tools in daily wooden work. The use-wear traces observed on the tools have shown broad techniques of hafting. The tools were hafted in a variety of ways using different materials, such as sinew and tar. Most of the bone tools are either points or chisels related to hunting activities and domestic works. While bone tools were employed in domestic and hunting equipment, most of the antler tools were used in agricultural activities, such as clearing land, construction of houses, wooden work etc.

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1. Introduction

1.1 Framework of the dissertation

Due to the agreement between Prof. Dr. Jörg Schibler and the author from the University of Basel, IPAS institute and the archaeological service of the canton of Berne ADB and the excavation leader Prof. Dr. Albert Hafner, the animal bone assemblages and bone and antler tools from 3 settlements of Sutz-Lattrigen bay have been transported to Basel to be analysed by the author as a Ph.D. thesis.

This synthesis text summarizing all results of the PhD research is divided into eight chapters: Chapter one will be a general introduction to the pile dwellings in the alpine region, the history of Sutz-Lattrigen discoveries and the development of the settlement. Chapter two will describe the faunal assemblages and the methods used in the osteological determination of the materials. Chapter three will present the peer-reviewed published papers presenting the most important results of the thesis and in Chapter 4, other results of species identification, ageing and skeletal representations as well as the bone-and-antler tools assemblages are provided. Chapter five will be the final syntheses presenting the subsistence strategies of Sutz-Lattrigen people during the 4th millennium and some themes using the keywords in the title of this thesis are expanded. The last chapters will contain the conclusion, bibliography, figures and tables.

1.2 Aims of the archaeozoological analysis

In the northern Alpine Foreland, many waterlogged sites have been archaeozoologically analysed. The exceptional preservation of organic materials such as animal bone, antler, wood and botanical remains, which mainly occur in uncarbonised form allow exceptional insights into the Neolithic life. The preserved wooden posts of the houses make an exact dating of the sites, as well as the reconstruction of the settlement evolution possible.

In this respect, the studied materials show a great potential for the knowledge of Neolithic lifestyle and food system. The organic remain recovered from Sutz-Lattrigen bay are plentiful and very diverse, which enables many different research questions to be answered and offer the possibility to dig deeper into understanding the subsistence strategies of the Neolithic population.

The studied sites in this work are dated as follow; Sutz-Lattrigen Hafen lower layer US 3834-3820 BC, Sutz-Lattrigen Hafen upper layer OS 3641-3631 BC, and Sutz-Lattrigen Aussen 3201-3047 BC. A big part of the original settlement of Sutz-Lattrigen Aussen is already eroded. Thus, only extensive fields of ancient support-piles remain. In contrast to the intact layers of the sites, the information potential of the eroded areas is naturally limited (Hafner 2012; Hafner *et al.* 2016). Despite this, the absence of the flotation operation led to lacking small faunal remains, such as fish, reptile and small bird bones.

Even though, and despite all recent studies, there are still many questions about what people in Neolithic Switzerland have eaten. What foodstuffs were eaten dictated how people farmed, managed their animals and lived their daily lives.

Therefore, by studying animal bones from Neolithic periods, I aim to reconstruct the environment and the behaviour of the Sutz-Lattrigen people through the excavated faunal assemblages. These faunal assemblages consist of bone, antler and teeth. These shreds of evidence, modified by taphonomic circumstances and excavation strategies, allowed me to examine aspects of animal-human interactions and subsistence strategies such as husbandry, farming and hunting. With this dissertation, I shall combine a series of data sets; faunal analysis, archaeological data and information on the environment, vegetation and animal distribution in the region of Lake Bienne, western Switzerland, and in all of Neolithic waterlogged sites in Switzerland, especially that is dated in the 4th Millennium to try to reconstruct the food system and diet habits of the Neolithic people and their subsistence strategies.

My research aims, therefore, to explore the role and the importance of different animal species in Sutz-Lattrigen sites through an analysis of taxonomical, osteological data and toolkit production. By focusing on material derived from cultural layers without ignoring finds coming from offshore and mixed layers, I aim to understand the world in which the "Lattriger" lived in and to investigate if the environment, climate, weather and new cultures have affected their life in a way or other.

In order to do so, I needed to investigate in several questions:

- Which kind of species have they eaten/ utilised regularly?
- Did the inhabitants of Sutz-Lattrigen have a diverse subsistence strategy and wild animal exploitation or did they heavily rely on livestock management? How did the animal economy change over time?
- How did the people habitation affect animal management decisions compared to their neighbourhood? Did they manage cattle, sheep, goats and pigs differently?
- Can the similarities or differences be explained by the climate, vegetation, and/or topographical conditions?
- How did they hunt, slaughter or butcher? How they made their tools and what influenced their toolkit production?
- Why they produced specific tools, what did influence the choice of raw materials?

By answering these questions in the dissertation, new information will be revealed on the human-animal relationship and on the complexity of the depositional patterns in the Cortaillod and Horgen periods. Yet, this complexity represents the importance of animals in the past for the Pile dwelling society.

1.3 State of research

1.3.1 The importance of the animal bone assemblages within the archaeological research of the pile dwellings in the alpine region

Verified version of applied SNF project in 2013 (Nr. 100011_150228)

Lakes and bogs around the Alps conserve more than 1000 settlements from the Neolithic and the Bronze Age covering the time period 4300–800 BC. These sites are famous for their excellent conservation for organic material, especially wood. Research goes back to the early 19th century and from 1854 on regular publications are on the record. Because of their outstanding universal value in 2011 UNESCO declared a choice of 111 representative sites as World Heritage ("Prehistoric pile-dwellings around the Alps").

During the course of the 4th and the beginning of the 3erd Millennium time span (Pfyn, Cortaillod, Horgen and Lüscherz cultures) a large number of sites in Switzerland and Southern Germany offer perfectly dated material complexes from cultural layers. The wide use of dendrochronology allows placing artefact series into a precise and fixed chronological frame that is perhaps unique in prehistoric-archaeological science. The same period is marked by fundamental changes in the material culture. It is common sense among researchers that these changes in styles mark a major cultural change whereas the reasons behind are still under discussion: adaptation to influences from outside, migration or continuous evolution. Major changes occur in Central Switzerland Lake Zurich region (from western influenced Cortaillod to eastern Pfyn style) and in Western Switzerland (Three-Lakes-Region) where obviously ceramics from Burgundy shows up in Cortaillod complexes.

Many Cortaillod and Horgen culture lake-dwelling settlements of Western Switzerland show foreign impacts originating from neighbouring cultures (Stöckli 1995, Burri 2007). In the material culture, these are well remarkable in pottery and in raw materials of stone artefacts. Over the last thirty years' cultural influences from North-Eastern Switzerland and Eastern France have been discovered in many sites of the research area however the background of these social networks was never studied in detail (Stöckli 1981, Schifferdecker 1982, Burri 2007, Stöckli 2009).

Furthermore, most of the archaeozoological results (economy, environment, morphological and osteometric) in Neolithic lakeshore settlements are known from sites at Swiss lakes. In 2012 archaeozoological results from certain layers from the site Concise at the lake of Neuchâtel were published (Chiquet 2012). The published archaeozoological data from this site are mostly from layers that are dated to the first half of the 4th millennium BC. Nevertheless, comparing the two lake regions; the East Swiss plateau (with the larger lakes of Constance, Zurich and Zug) and the West Swiss plateau (larger lakes of Bienne, Neuchâtel and Geneva) we have much more archaeozoological results from sites of the eastern part. If we include the newest published and not yet published (on-going research at IPAS) archaeozoological results for sites dated to the 4th millennium BC, the current archaeozoological knowledge is based on around 60 sites from the eastern part and only 32 sites from the western plateau (Schibler 2006). This clear difference means that we have a much denser insight of the Neolithic faunal evolution at the eastern part of Switzerland.

Archaeozoological information from Neolithic lakeshore sites from adjacent areas is known from southern Germany, Austria and northeast France. Most of the results from Germany come from sites of Lake of Constance region and are integrated into the overview of the results from Swiss lakes (Schibler 2006). Only a few archaeozoological results from Austrian Neolithic sites of the 4th millennium is known and were published in an overview by (Ruttkay *et al.* 2004). The only archaeozoologically relevant lake dwelling site which is dated to the 39th / 38th century BC is the Mondsee site (Pucher and Engel 1997).

In the last 25 years, the determination of animal bones from most of the Swiss lakeshore dwellings were done by the archaeozoological research group of the Institute for Prehistory and Archaeological Science (IPAS) at Basel University. Especially sites from the Zurich region (Schibler *et al.* 1997) (Schibler and Schäfer 2017, Schibler 2017) but also sites from the Lake of Constance like "Arbon Bleiche 3" (Deschler-Erb and Marti-Grädel 2004) and other sites (Hosch and Jacomet 2001) were thoroughly analysed. Together with the detailed determination of the animal bones from single sites several archaeozoological overviews for the whole Alpine lakeshore dwelling region were done and economical and ecological results and synthesis were pointed out (Schibler and Chaix 1995; Schibler and Hüster-Plogmann 1995; Schibler *et al.* 1997; Schibler and Steppan 1999; Schibler 2004; Schibler 2006). Comparisons between the archaeozoological results between Neolithic wetland and dryland sites were also done (Schibler and Jacomet 2005). Most important fields of research and results for wetland sites were:

- Economic Importance of husbandry (Schibler 2004, 2006, Marti-Grädel and Stopp 1999)
- Economic importance of the different domestic animal species (Schibler 2004, 2006, Arbogast 2008)
- Economic importance of wild animals resp. hunting (Arbogast *et al.* 2006, Arbogast 1997, Arbogast *et al.* 2000, Jacomet and Schibler 1999, Schibler and Jacomet 2010)
- Human impact on the environment (fauna and vegetation) (Schibler/Hüster Plogmann 1995, Schibler and Steppan 1999)
- Socio-economic significance of animal bone assemblages (Doppler *et al.* 2011 and 2012).
- Bone and antler artefacts (Schibler 1981, Suter 1981, Kissling 2010, Wojtczak and Kerdy 2018).

1.3.2 History of research at Lake Bienne

Lake Bienne or (Lake Biel) is situated in the alpine foothills in western Switzerland, south-east of the Jura mountains and belongs to the canton of Bern. Lake Bienne, together with Lake Morat and Lake Neuchâtel are one of the three large lakes in the Jura region of Switzerland (Fig. 1). The Lake is of a glacial origin and was covered during the upper Würmian by the advance of the Rhone glacier. The lake has two different topographical characteristics. The north shore of the lake has steep banks which are part of the Jura mountains climbing up to 1600 m asl. (Brombacher 1997). The southern bank is open to the Swiss plateau (flat, lowlands) and has relatively flat banks.

Many lakeshore sites have been discovered at both shore of the Lake, five of them are listed on the UNESCO world cultural heritage sites (Fig. 2). Most of the sites are well preserved and some are invisible because they are either underwater or buried under large thick of sediment.

In the 1853/54, due to the extremely low level of the lake water level, numerous prehistoric sites appeared on the surface including the one of Sutz-Lattrigen bay. This record low water level was because of an extraordinary drought time and long persistent cold period. In Lake Zurich for example, the water level undercuts the minimum of 1674 by about 30cm. Shortly afterward, Ferdinand Keller has discovered the lakeshore site of Feldmeilen and has interpreted it as a settlement built in the lake (Keller 1854).

On Lake Bienne, the antiquities collector Friedrich Schwab exploited several lakeshore sites and had filled his private museum by the find he has found (Stadelmann 2016). The numerous artefacts lying on the surface have been collected by a special machine designed for this purpose, later on, rods and dredges have been used to dig into the bottom of the lake to assemble as many artefacts as possible. An antiquities market has been slowly developed into a lucrative business.

1.3.3 Jura water correction

The project was conducted between 1868-1878 and aimed to lower the water level to limit the risk of flooding. The project was carried out in the region of the three lakes: Lake Morat connected to Lake Neuchatel by the Broye Canal, the latter connected to Lake Bienne by the Thielle Canal, an area called the "Seeland" (Vischer 2003). The water level of Lake Bienne was artificially lowered by two meters. This correction has allowed parts of the ancient sites to become, beginning of 1870, exposed and easily accessible (Hafner 2012). (Fig. 3). This change of the topographic situation revealed different sites in the area. While no project has been executed in Sutz-Lattrigen, some private collectors found traces of undocumented interventions.

The ancient finds were at such time so much sought-after, that immediately after the dry period and the visible settlements (Fig. 4), a regular rubbery by the local inhabitants and fisherman's started collecting every possible artefact (Fellenberg 1874). This massive exploitation in the years of 1871-1872 was so large so the state had to intervene and announced in the year 1873 barring all kind of collecting and excavating any shore site or to dig in the lakes. This prohibition was a great decision allowing scientific researchers such as Edmund von Fellenberg to start a systematic work to document the settlements. However, as early as 1875, the exploitation of the pile dwellings was released again by the state on the grounds that further investigations would only provide repetitions of the same foundations without promoting much new facts. In any case, it was thought that most stations were already totally exploited (Heierli and Keller 1888). However, by the second Jura correction 1962-1973, the lake level was slightly raised and the settlements were covered again with water.

1.3.4 Systematic investigation from the 1980th

Between 1984 and 1987 a team of the Archaeological service of Berne made a new inventory of the sites on the southern shore of Lake Bienne respectively core drilling and some diving soundings (Hafner 1994). Remarkably, the southern shore of Lake Bienne compared to the north-western shore provides a better possibility to relocate archaeological settlement due to the uneven surface and the big number of inlets. However, the two water correction projects have caused serious erosion problems to the prehistoric lakeside settlements of the three interconnected lakes of Biel, Neuchâtel and Morat (Hafner *et al.* 2011)

Systematic underwater excavations at the inlet of Sutz-Lattrigen have been executed between 1988 and 2002 encompassing two goals; an inventory of the erosion threatening prehistoric settlements of the area and the protection of the surfaces that are still flawless. A total of over 40,000 m2 of the lake bottom was systematically documented and dendrochronological studies were conducted from ring-width measurements taken from over 23,000 wooden pilings (Hafner 2005). In the period between 1988-2003 as inventory success, an extensive probing and archaeological excavation were carried out at Sutz-Lattrigen stations (Fig. 5), including "Kleine station" (Lattrigen VIII), The Riedstation (Lattrigen VI) and the Hauptstation 4 (Lattrigen VII).

The oldest settlement in the bay of Sutz-Lattrigen is dated to 3827 BC, indicating a village of the Cortaillod complex. Within the structures of this settlement from the inner Hauptstation, other dendrochronologically dated piles reveal a distant village of some 200 years younger. Later on, building phases occurred around 3637, 3607, and 3696 BC and continued to around 3400 and 3150 BC (Fig. 7). The youngest settlements, at present, which have been discovered in the area of Sutz-Lattrigen, are those of two Early Bronze Age villages from the site Buchtstation. The first is dated between 1763 and 1746 BC and shows the presence of intensive fortifications. A second village dates between 1662 BC and 1659 BC, but little is known about its structure (Hafner 2012).

All of the Sutz-Lattrigen settlements were originally situated on the shore of a large, shallow bay. The rescue excavation carried out at the settlements delivered very well preserved organic remains, such as animal bones, botanic macro-remains, ceramics and wood. These finds are characteristic of pile-dwelling settlements in a high state of preservation. Their excellent condition resulted from the fact that the greater part of the settlements, having remained below the groundwater table after the settlements, were abandoned (Hafner 2012; Hafner 2010).

1.4 Sutz-Lattrigen Hafen

The lakeside settlements of Sutz-Lattrigen are situated on the southern shore of Lake Biel. The site of Sutz-Lattrigen Hafen was excavated in 1991 and is located precisely to the east of Sutz-Lattrigen VII Innen and to the south-east of the Sutz-Lattrigen Aussen (Fig. 6). The section is 80m long and 10m wide and was dug out after Square meter plan from northeast to southwest (from the lake toward land direction). The individual squares are from east to west numbered with the letters A-K and from north to south numbered with running meters 1-80. The finds were recovered separately by layer and square. Almost all woods were labelled with a Dendronumber (Dnr.) and sampled (Stapfer *et al.* 2014)

The composited profiles show that, indeed, one cultural layer can be recognised. This layer is laying over the lake marl and is covered with chalk, sand and organic materials. However, in a someplace, double cultural layer are visibly separated by lake marl layer. The wooden piles are to find either stuck in the Lake marl layer or laying over the cultural layer. The date of the piles gave two different dates; the 39th century and the second half of the 37th century BC (Fig. 8).

The finds come partly from the two cultural layers, in heavily eroded areas of the surface of the Lake Marl. Even the spatial displacement of the two layers has affected the surface but still possible to assign the finds and mainly the animal bones into the dated cultural layers (Stapfer, oral comm). In the middle of the section and based on the wooden pile, it's possible to reconstruct a row of wooden houses oriented parallel to the shallow part of the lake. Two houses are completely located in the excavation area and potentially allow the southwest corner of a third household (Fig. 8).

1.4.1 The settlement development in the 39th and 37th Century BC.

The two full constructed houses were built between 3827-3825/3823 BC. It consists of tow-aisled rectangular buildings with six bays, a length of 8.1-9.5m and a width of a 3.3-4.5m with a total base size of 28-40 m^2. Due to the construction and the dimensions, it can be assumed that they were living houses. The main piles are from oak (Stapfer *et al.* 2014) (Fig. 8, violet coloured).

Both houses have been reconstructed in the walls as well as the roof, which were made between 3824-3817 BC, just several years after its first construction. Since no subsequent repairs have been done later, it's to assume that the houses were abandoned in the last two decades. It's unknown if the whole settlement has been abandoned in this period. However, this field was then almost 200 years no longer built and the remains of the settlements have been covered by the Lake Marl, which indicates a rise in the lake level (Stapfer *et al.* 2014).

Almost after 200 years, the Sutz-Lattrigen Hafen has been alive again. Four houses have been reconstructed and dated to the thirties of the 37th Century BC.

The houses were built as their prior in the 39th Century parallel to the shallow side of the Lake and oriented to NW-SO. House number 1 and 3 lies entirely in the excavation area, but from house 2 and 4, the western walls are missing and from the two potentially houses number 5 and 6, only the northern part has been detected.

The houses were arranged in three lines at a distance of one to two meters next to each other. All houses were made of long rectangular, two-aisled buildings with 6-7 bays and interpreted as living houses. They mass 9.3-10 m in length and 3.5-4.2m in width, which indicated a total size of about 35-40 m^2, making them similar to the houses of the 39th century BC.

The houses 1 and 3-6 were built between 3638/3637 BC. House number 2 probably a couple of years later around 3633 BC. All the houses were built from fresh wood, which came mostly from the same years or a maximum of three preceding years. Olden wood was not used.

Only a few years after its construction in the years 3635 and 3634 BC, the walls and the roof were repaired. No more repairs were later witnessed, so it's assumed that the settlement was shortly afterwards abandoned (Stapfer *et al.* 2014).

1.5 Sutz-Lattrigen Aussen

From 1988 until spring 1991 and based on prior results from "sampling" in Sutz-Lattrigen Hauptstation settlement several cultural layers have been identified in the area of Sutz-Lattrigen Aussen. The excavation aim was to clarify tow points; the preservation of the cultural layers and the expansion of the piles in the settlement. In order to check the conservation of the cultural layers and the ability to retrieve the discovered materials, a quadratic surface of about 100 m^2 (Section 1) in the middle of Sutz-Lattrigen Aussen has been investigated. Further "Sondages" in size of 2m width have been examined (Section 2-5) (Fig. 6; 9).

However, the pile's fields indicated that originally, a much larger area was overbuilt and large parts of the former cultural layers have been massively damaged by the erosion. Nevertheless, due to the observed pile fields in the recent years, the various late Neolithic village facilities of the 32^{nd} and 31^{st} century BC should extend over an area of over 10,000 m^2.

A similar large surface size has been described by Ischer (1928). This comparison confirms the assumption that the settlement remains of Sutz-Lattrigen Aussen consist of several successively built villages above each other, whose position in the course of time has clearly shifted and eroded.

Due to the 19th century excavations, the upper layers in section-1 are almost everywhere damaged. Only in a few places, the sequence of the layers is preserved to the surface. These sites with intact layer preservation had probably been left undisturbed by accident. The date of the wooden piles in section-1 has given several dates;

The first houses were built in the year of 3202, and are in the middle of section-1. In the following years, the houses have been repaired and mostly in the year of 3182 BC. Two piles are dated, then to the 3174 and 3173 BC, which indicates a concise settling period.

Then, in year 3172, a new rebuilding of the whole settlement is seen, 75 piles have been dated to this year, which refers to a new building over the old settlement. Some of the piles that were used in restoration are dated to 3158 BC. The village in the year was in 3157 BC greatly enlarged and some at the beginning of the 3150 BC (Hafner, 2010). However, because of cultural layers' erosion, the only 2m wide "Sondage" that have been carried out at the settlement, and after discussion with the excavators, the decision was to consider the animal bones that are coming only from the certainly dated area of the settlement (Section-1), which is dated between 3202-3147 BC. The bone materials coming from sections 2-5 have been "speed-screened" in order to check any difference in animal taxa or material preservation.

2. Material and methods

2.1 The faunal assemblages

The faunal remains analysed are coming from the settlement of Sutz-Lattrigen Hafen lower layer US, upper layer OS and from Sutz-Lattrigen Aussen. The faunal analysis (Tab. 1-3) was carried out on 14474 remains. 8631 specimens (44.3%) have been identified to the level of species or genus that are coming from cultural layers. Though only remains from cultural layers are listed here, mixed- and off-layers finds have been analysed by using the quick "screening" technique. This method makes sure that the identification of special and seldom species; e.g. human bones, wild horses or Alpine species (e.g. ibex, marmots, etc.) is not overlooked. The "screening" identification has been carried out on 4803 remains coming from 4 sections of the settlement Sutz-Lattrigen Aussen S2-4 (Tab. 4). No exotic or new specimens that differ it from the other settlement have been registered.

The representation of small animals such as fish, reptile and small bird bones in the cultural layers is relatively low, owing to unsystematic sieving of the samples. All the animal bones that could be identified were registered individually. The exact location of the bone (field-section and QM), its osteological identification (species, skeletal element, the individual's age, fragmentation, and measurement), and its weight and state of preservation (surface preservation, presence and state of broken edges, traces of burning, etc.) have been all registered and studied.

2.2 Taphonomy

Taphonomy comprises both; natural and cultural process by which bones, teeth or antler of once living species become part of the bone assemblages excavated from an archaeological site (Backer *et al.* 1997).

Several cultural processes can influence bone, such as cutting, chopping, cooking and burning by humans during food acquisition and preparation or tool making (Nelson 2008). The non-cultural bone modification could be caused by several factors e.g., carnivore and rodents gnawing, weathering, plant roots, animal burrowing etc. All these factors that lead to such significant change of the bone can help archaeozoologist to draw conclusions about the disposal of the bone after procurement and to construct accurately past animal utilisation patterns. In addition to weathering, gnawing marks, and butchering marks, special attention has been paid to the pathological lesions on the faunal material, such as osteoexostosis, osteoporosis or arthritis (Plug 1988; Nelson 2008). One must have kept but in mind that not all bones contain the same nutritious marrow. Not all bone, therefore, endure the same processing and discard process. Skeletal parts with high grease content, such as humerus or femur shafts, are likely to undergo more intensive processing than other parts that are in less interest to external species, such as the ribs (Backer *et al.* 1997; Nelson 2008).

2.3 Quantification methods

Archaeozoological quantification of animal bone remains can be based on numbers of bone fragments, bone weight, a minimal number of individuals or concentrations of bones in archaeological layers (bone densities). Unfortunately, the only method available for the comparative quantification of the different animal species in all lakeshore settlements is the number of bone fragments (NISP) as the other methods have been applied unevenly.

The comparison between assemblages in this dissertation is based on NISP, i.e. the number of the identified specimens (bones). NISP, has some disadvantages for comprising quantities of bones especially when the assemblages are large. NISP is dependent on the degree to which bones are fragmented. Therefore, NISP can lead to an overestimation of the number of individuals at the site. Among the problems that have been noted with NISP is that it varies not only with taxonomic abundance, but also with the degree to which bones have been fragmented: breaking bones into more pieces means more pieces that can potentially be identified and hence potentially higher NISP values (Cannon 2012).

The weight (gram) of the identified and the unidentified fragments has also been recorded. The identified remains were numbered as well. Each element was weighed, measured when possible and described with all relevant details. This information was entered into OSSOBOOK. All data approaches were inserted using OSSOBOOK, a program developed by the Institute for Prehistory and Archaeological Science in Basel at the beginning of the 1990s (Schibler 1998). The aim is to band the coding systems used by archaeozoologists to enter data and contribute correspondingly to basic unprepared data easily. For each fragment, the following was recorded: Context number, layer, quadrate meter, field/section, species, skeletal part and to a skeletal element and the section of this skeletal element, age, sex, preservation (gnaw marks, root etching, patina, surface preservation, fragmentation, calcification) weight, anthropological modification (cut marks, chop marks, burn marks) and any pathological traces.

2.4 Age at death

Age at death or age at killing offer relevant information about the husbandry and hunting strategies of past populations. An age distribution that is different from the 'natural' mortality pattern of a species shows the selective nature of hunters and farmers and thus links to the human decision-making processes (Frosdick 2014). There are several techniques for assessing the age at death of an animal e.g., dental eruption and wear, epiphyseal fusion animal. Both of these dental eruptions and wear, as well as the epiphyseal fusion data, are used often in archaeozoological research because other methods, such as the cementum increment analysis can be time and money consumer, which lack in most of the projects.

Dental development and eruption, in mammals, as with humans arise at practically expectable ages. All that needs to be known to be able to use the state of the eruption of the deciduous or permanent tooth is a typical age at which the tooth erupts in the studied species (Frosdick 2014). Research has produced data for dental development and eruption in many of the domestic and wild species that are of economic importance to modern and past human. However, only when the permanent dentition has fully erupted, the eruption of the deciduous and permanent dentition is then used up to a certain point. In most of the cases, the dentin of the teeth has fully erupted longer before the animal has reached its maximum age. Age at death after a full eruption can be assessed due to the fact that these teeth are in constant wear. Two ways can assist the measurement of the attrition: The crown heights of teeth or by the examination of the patterns left by dentine exposure on the occlusal surface (Habemehl 1975; Lowe 1967; Payne 1973; Grant 1982).

Not only with the dental eruption, but also the skeletal elements of the body develop in a reasonably predictable manner. In young animals, the ends (epiphyses) of long bones are attached to their shafts by cartilage that converts into bone over a known period of time (Nelson 2008). Fusion of the articulation ends with the shafts being complete when the bone stops growing (ossification), which take place at different stages in different joints from after birth to adulthood.

This is to say that the unfused epiphyses of a young animal fuse to the diaphysis at a predictable age. All that is needed is the data as to the timing of the closure of the epiphyseal plate (Frosdick 2014). Several authors have tabulated forms of the epiphyseal fusion times of many species (Silver 1969; Amorosi 1989).

In this thesis, the ageing of the bones was done by assessment of the state of epiphyseal fusion. This was coded for each bone on the OSSOBOOK program. For the postcranial remains, several age categories have been created (fetal-neonant) (infantile) (juvenile) (sub-adult) (young-adult) (adult) (alt-adult) (senil). Ageing of the teeth was done on the stage of eruption and wear of the crown and also entered in the database. Both mandibular and isolated teeth have been evaluated. For the mandibles, the eruption of the molar M3 was taken as representative for the animal age of death. The ageing determination was oriented based on the literature of mainly (Habermehl 1975; 1985).

2.5 Skeletal representation

The data presented here are from identified anatomical elements of Sutz-Lattrigen faunal remains. Both, the number of bone and their percentages and also the weight of the bone haven registered and compared. The material is therefore combined as grouped elements with respect to the position within the animal body;

The Skull group, includes the mandible, horncores, loose teeth and hyoid. The Stylopodium group contains humerus, scapule, pelvis and femur. The Trunk group contains all vertebrae (atlas, axis, cervical, thoracic, lumbar, sacral and caudal) as well as the rib fragments. The Zygopodium group consists of radius, ulna, tibia and fibula. The Autopodium group includes all the foot bones including the carpals and tarsals (i.e. carpals, tarsals, metapodials, and phalanges I, II and III).

It should be expected that through the taphonomic forces certain fragments or parts of elements are likely to be missing from the faunal remains. The reasons are mainly due to the relative structural density of different parts of the skeleton. Therefore, it is likely that vertebrae and ribs will be lost in relation to the proportion of the whole skeleton as these are thin, relatively less dense than other elements. Small bones such as phalanges of small mammals, as well as smaller tarsals and carpals are likely to be destroyed by taphonomic forces or not recovered from the excavation due to the hand collected nature of the material. Other elements have different properties within the whole element and thus the survival of more or less of the less dense material can affect the proportions that are different from the skeleton as a whole (Frosdick 2014).

2.6 Biometry

Biometrical data can be used widely in archaeozoology. Various measurements can be used to distinguish between domestic and wild species. Skeletally similar species such as sheep and goat can be separated based on the metric analysis of skeletal elements e.g. the distal of the metacarpus (Payne 1969). The change in animal body size through time is an important evidence that can be caused by several reasons e.g. domestication, overhunting, castration or breed strategies differences. However, to be able to compare biometrical data put by different authors to a different assemblages belong to different periods and it must be agreed to use similar measurement methods. The published series of measurement of (von den Driesch 1976) illustrates one of the widely used literature. The data are available on the website of the IPAS Institute under the following link:
https://duw.unibas.ch/de/forschungsgruppen/integrative-biologie/ipnaintegrativepraehistorisch-naturwissenschaftlichearchaeologie/forschung/archaeobiologie/archaeozoologie/tabellen-abbildungen/.

2.7 Sex determination

The determination of sex ratios is an important factor in archaeozoology as it provides information on husbandry, hunting strategies and other cultural practices. Many techniques and methods could be applied for identifying the gender of an animal which is dependent on two factors: the studied species and the skeletal elements.

Only several bones have a morphological characterisation that can give a clue about animal gender. (Boessneck *et al.* 1964; Leppenau 1964; Bosold 1966; Fock 1966).

Usually, the pelvis and the especially the pubis are one of the significant parts to identify the sex of animal. Additionally, metric analysis of the metapodials, horn cores and castration can be important elements for gender identification (Armitage and Clutton-Brock 1976; Davis 2000). Canine teeth of pig and the antler of the red deer can assist significantly to determine the gender.

The minor identifiable data doesn't allow appropriate statistics about the determination of sex, however, determination data are listed in (Tab. 17).

3. Research Papers

3.1 Wojtczak, D., Kerdy, M. 2018: They left traces, Preliminary analysis of micro-wear traces on bone and antler tools from Sutz-Lattrigen Aussen, Lake Bienne, Switzerland. Journal of Archaeological science: Reports 17 (2018), p. 798-808.

3.2 Kerdy, M., Chiquet, P., Schibler, J. 2018: Hunting, Husbandry, and Human-Environment Interactions in the Neolithic Lakeshore Sites of Western Switzerland. Journal of archaeological science. 2018, p. 1-19.

3.3 Kerdy, M., Schibler, J. 2018: Skilled Management. Exploitation of bone and antler raw materials in Neolithic pile dwellings of Sutz-Lattrigen, Switzerland. In process, submission to the proceedings of the PZAF 7th conference, Palermo, Italy. Publication with BAR international series, Cambridge, UK.

Journal of Archaeological Science: Reports 17 (2018) 798–808

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They left traces. Preliminary analyses of micro-wear traces on bone and antler tools from Sutz-Lattrigen Aussen, Lake Bienne, Switzerland

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ABSTRACT

The site of Sutz-Lattrigen Aussen has yielded a high quality series of tools made from bone, antler and teeth. Thus this remarkable assemblage led us to consider the importance of carrying out functional studies. The recorded 601 worked pieces have been analysed typologically and technologically in a separate report. In this paper we explore the potential for use-wear analysis on the artefacts. They are well conserved and therefore seem to be perfectly suited for such examinations. Preliminary results show that they were used in a variety of activities including processing wood, bark, hide and pottery. This short investigation demonstrates how significant the use of the micro-wear analysis might be, together with technological and experimental studies to elucidate the principal economic and technological activities of Neolithic populations.

1. Introduction

As a consequence of questions that arose whilst studying the Sutz-Lattrigen bone and antler tool industry (Kerdy et al., in preparation), we set ourselves the task of analysing its function and use-wear patterns. Until a few years ago, the bone and antler tools industry of the lake dwelling sites had been studied in morphological, metrical and stylistic terms. However, these kinds of studies did not answer our questions, so we decided to dig deeper and try to find out how these tools were used, from the manufacturing process to the identification of the use-wear patterns and the purpose of the tool production. These observations are complemented by experimental work.

Sutz-Lattrigen Aussen is a lakeside settlement located in the west of Switzerland, on the southern shore of Lake Bienne, 4 km southwest of the lake outflow (Figs.1 and 2). The site dates back to the end of the 4th Millennium (3201–3047 BCE-Horgen Culture; Hafner and Suter, 2000). Several small communities of hunter-farmers occupied the site with the meat portion of the diet consisting mostly of domestic animals especially pig (*Sus domesticus*). The exceptional preservation of the organic and non-organic material due to anaerobic conditions allow not only the identification of the remains but also offers the potential for analysing use-wear patterns on many bone, antler and stone tools.

The assemblage of worked teeth, bone and antler contains 601 exceptionally well preserved artefacts. Therefore, the site of Sutz-Lattrigen Aussen provides outstanding archaeological documentation about tool manufacturing and past activities.

2. Functional analysis

All examined bone and antler tools come from the single assemblage at Sutz-Lattrigen Aussen (LA) and have been selected on the condition of their preservation. The goal of this study was to check the potential for use-wear analysis on the bone and antler tools from this lake dwelling site, therefore a wide range of tool types have been sampled. However, this made it impossible to report anything about the functional uniformity of the tool types. In the future the sample will be expanded to include more specimens of different tool types. Results presented here should be seen as preliminary and as a part of a larger, forthcoming project. Sutz-Lattrigen Aussen yielded 601 antler, bone and teeth artefacts, out of which 18 specimens were analysed for use-wear traces (Table 1). Currently it is commonly accepted that antler and bone tools can be investigated in similar way to stone specimens and such studies are gaining increasing attention (i.e. Semenov, 1964; Peltier and Plisson, 1986; LeMoine, 1997; Christidiou, 1999; Korobkova, 1999; Griffitts, 2001; Maigrot, 2003, 2005; Alvarez et al., 2014; Evora, 2015; Sidéra and Legrand, 2006; Maigrot, 2011).

To begin, all artefacts including the experimental tools were observed through stereomicroscope Leica MZ 125 at $\times 8$ to $\times 100$ magnifications, to examine manufacturing traces and locate residues. Next, use-wear analysis was conducted with Leica metallurgical microscope, equipped with optics ranging from 50 to $500\times$ magnification. No chemicals, alcohol or acetone were involved in cleaning, the investigated implements were only rinsed in water before analysis.

Since functional analysis and experiments are time consuming and

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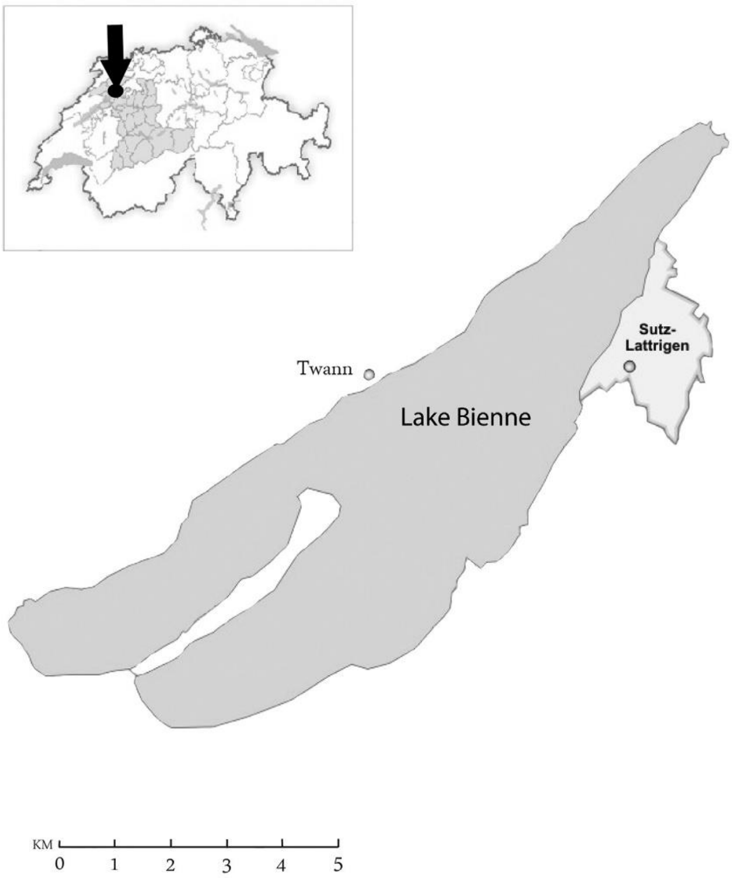

Fig. 1. The location of lake Bienne, Sutz-Lattrigen and Twann around the lake.

logistically complicated activities, at present we have only been able to undertake over a dozen experiments but fortunately alongside this there are many macro and micro observations of different kinds of use-wear signatures that can be drawn from the literature (Mansur et al., 2014; Buc and Loponte, 2007; Gates St-Pierre, 2007; Legrand and Sidéra, 2007; Van Gijn, 2007).

3. Experiments

Numerous experiments have documented the development of interpretable use-wear traces on bone and antler tools. Although, the wear trace analyses can become complicated either by the presence of manufacturing traces or by effects of various taphonomic processes (LeMoine, 1994; Christidou and Legrand-Pineau, 2004; Vercoutère et al., 2007). Therefore, a series of natural examples of antler and unworked bones as references have also been examined. For comparative reasons unpolished bones have been used in processing skin and dry clay and it appeared that micropolish developed on natural bone surfaces are diagnostic.

The first experiments were intended at reproducing the manufacturing traces perceived on archaeological specimens. The experimental work is ongoing and currently includes 16 tools and 13 experiments in which tools have been used in processing a variety of materials (Table 2). Firstly, chisels made from red deer metapodial and points made from cattle, sheep and pig ribs were manufactured using flint specimens and pebbles, shaping followed with coarse and fine sandstone and water as lubricant (Fig. 3). Next, the manufacturing traces were evaluated microscopically and then compared with traces visible on archaeological implements. In this way it was possible to distinguish between manufacturing and use-wear traces. It seems that during the manufacturing processes, especially polishing, the polish develops gradually on bone surface. Initially deep, rather wide and regular striations form on the bone surface. It is often following by progressive smoothing of bone tool edges meanwhile striations and micro-topography of the bone surface become brighter and more even (Fig. 4A–B). It was also perceived that in the case of polished bone surface, distinguishing use-wear from technological pattern is not as easy as with unpolished bone surfaces. Regardless of these obstacles, indicative characters of motion and operated material could be identified in all analysed artefacts.

Afterward these tools (Fig. 5) were used in processing fresh skin, lightly humidified leather, bone, dry clay and bark (Fig. 6). Three chisels made from red deer metapodials have been used in degreasing fresh skin, splitting bones and working dry clay (Figs. 3C–D; 6C–F; 7C).

Special attention has been paid to rib points. Dry ribs are fragile and break easily therefore we have chosen to work with fresh and water saturated ribs. Cattle and sheep ribs have been used in fresh and soaked states and pig ribs have been softened for 10 days in water. Flesh and sinew were cleaned from all items with the help of flint flakes. The bone supports were attained through grooving and splitting and also by fracturing the lateral edges of ribs.

In the case of sheep and pig the edge of the rib has been placed on a

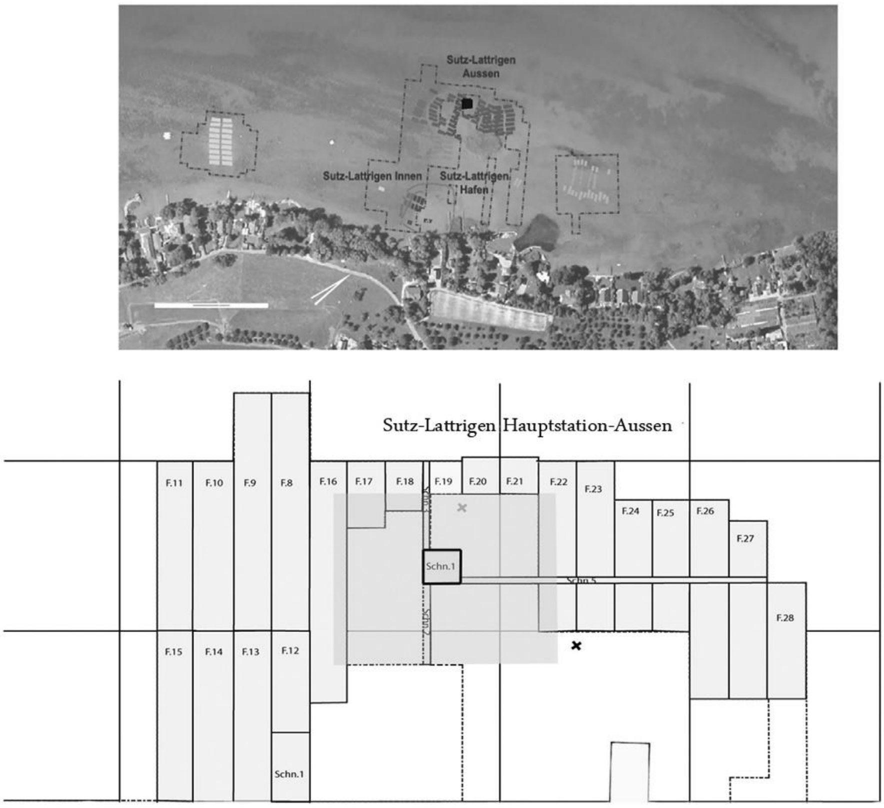

Fig. 2. The bay of Sutz-Lattrigen and the location of Sutz-Lattrigen Aussen (studied material come from Schn.1). After A. Hafner 2012, revised.

Table 1
List of use-wear analysed artefacts from Sutz-Lattrigen Aussen.

Site	Species	Body part	Typ
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Pig	Rib	Point
SL Aussen S1	Large Ruminants	Rib	Point
SL Aussen S1	Sheep/goat	Rib	Point
SL Aussen S1	Sheep/goat	Rib	Point
SL Aussen S1	Pig	Tibia	Chisel
SL Aussen S1	Medium-size Ruminant	Metapodium	Awl
SL Aussen S1	Canid	Fibula	Needle
SL Aussen S1	Red deer	Antler	Bevel
SL Aussen S1	Red deer	Antler	Bevel
SL Aussen S1	indet	indet	Hafted-Point

flat surface and the other edge hit with a pebble. The rib separates into two longitudinal parts and brings the bone support to the required dimensions (Fig. 7E–F). Both parts could be used in production of points. This procedure seems to be very efficient and fast. We were able to fracture the rib and modified the received bone support into two pointed tools in approximately 30 min. Some ribs were soaked in water for 18 days but these became too soft and fragmented easily during splitting. From these ribs we could normally rescue only one part. Thus the soaking of ribs for a short time helps in obtaining the required fragmentation, however prolonged soaking causes the bone to become too supple and reduces the success of fragmentation.

In the case of cattle ribs the procedure was longer and more difficult as the bone is large and robust. Sidéra (1993: 148–151) previously performed similar experiments on fresh ribs and it was reported that the manufacturing of bone support by debitage of rib edges was very long and costly. We too concur with these observations but it seems that the soaking facilitated the preparation of the ribs when using a flint blade. Firstly, we tried to fracture as in the previous experiment, using a pebble on the fresh and soaked ribs. In both cases bones started splintering, thus it was decided that partially or wholly sawing the length of the bone edge. On reaching the spongiosa a thin bone chisel was inserted into the sawn gap and slowly prizing the desired length from the bone. Using this methodology both sides of the rib could be used in production of points (Fig. 7A–D).

Nevertheless, in both cases, the soaked and fresh bones were very elastic and easy to shape using firstly coarse grained sandstone reverting later to a finer grain for polishing. The three points made on pig ribs and three made on cattle ribs were chosen for further experiments and investigated microscopically to record the development of manufacturing striations and polishes, as well as any possible fractures. One tool from each species were then used in the following experiments; piercing lightly humidified leather; polishing small bowls made of dry clay and piercing outer bark of birch and pine trees.

The points on both pig and cattle ribs broke after about 15 min of

Table 2
The experimental tools and undertaken activities.

Tool category	Raw material	Worked material	Activity	Time
Chisel 1	Metacarpal/red deer	Fresh skin	Degreasing	1.5 h
Chisel 2	Metatarsal/red deer	Dry clay	Scraping surface	1.5 h
Chisel 3	Metatarsal/red deer	Splitting ribs	Chiselling	30 min
Point 4	Pig rib	Humidified leather	Perforating	15 min
Point 5	Pig rib	Bark	Punching	1.5 h
Point 6	Pig rib	Dry clay	Scraping surface	30 min
Point 7	Rind rib	Dry clay	Scraping surface	45 min.
Point 8	Rind rib	Bark	Punching	1.5 h
Point 12	Rind rib	Humidified leather	Perforating	45 min.
Awl1	Metatarsal/sheep	Humidified leather	Perforating	1.30 h
Chisel	Antler/deer	Fresh wood	Chiselling	1 h
Unpolished tool 1	Pig rib	Dry clay	Scraping surface	1 h
Unpolished tool 2	Antler/deer	Fresh skin	Degreasing	1 h

Fig. 3. Manufacturing bone tools: A-removing the meat remains using flint blades from an ovid metacarpal; B-cutting a deer metacarpal along its length using flint blades; C-splitting a red deer metacarpal using a bone chisel; D-cleaning the inside of a metacarpal; E, F-shaping the metacarpal awl on sandstone.

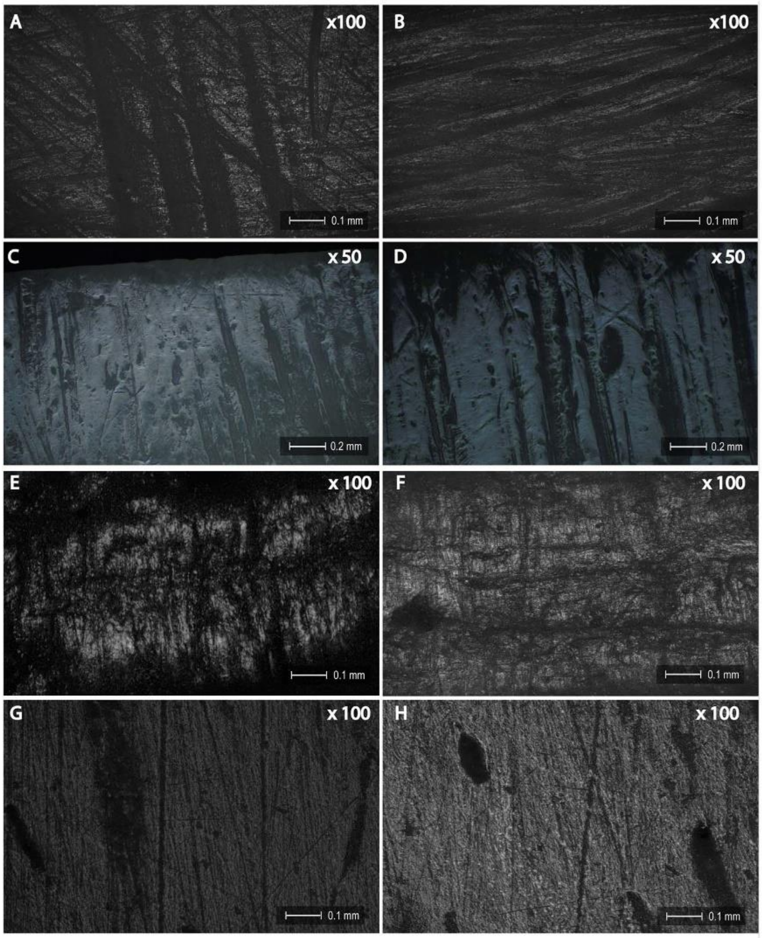

Fig. 4. A-striations and polish developed on the chisel made of red deer metatarsal after polishing its surface on sandstone; B-striations and polish developed on a rib point after its shaping and polishing on sandstone; C, D-polish developed on the bone chisel used in degreasing fresh skin; E, F-transversal striation and characteristic polish developed on a rib point (E) and awl made on metacarpal (F); both tools have perforated lightly humidified leather using a rotating motion; G, H-striations and polish developed on the surface of rib points, G-point made on a cattle rib, H-point made on pig rib;

Fig. 5. Manufactured bone tools used in experiments.

perforating leather and were resharpened to a new point on the sandstone. This breakage repeated after a further 15 min of use. Evidently these tools were too fragile to process of leather. In all cases typical hide polishing and transversal striations, related to a rotating motion, developed on the surface (Fig. 4E–F).

The edges of two points, one from either species, was used to smooth the surface of a dry clay bowl, the results were satisfactory. The polish formed slowly but striations developed quickly and numerously due to the addition of an adjuvant (degreaser) to the worked clay.

The last rib points were used to perforate bark in a punching motion. An extensive polish developed on the upper and ventral surface as well as on the edges. Striations were mainly longitudinal; grooves were also formed (Fig. 4G–H).

Presently, it seems that microwear visible on all the manufactured tools developed in the same way. This means that points made from cattle and pig ribs used in the processing of leather, clay, or bark present the same changes in their micro topography and the motion and worked material can be recognised with confidence independent of animal taxa.

4. The concluded activities

4.1. Bark working

14 bone points (17% of all rib points) from flat ribs were analysed using a functional approach (Fig. 8). Such pieces were in the past frequently discovered on Neolithic wetland sites, and were banded

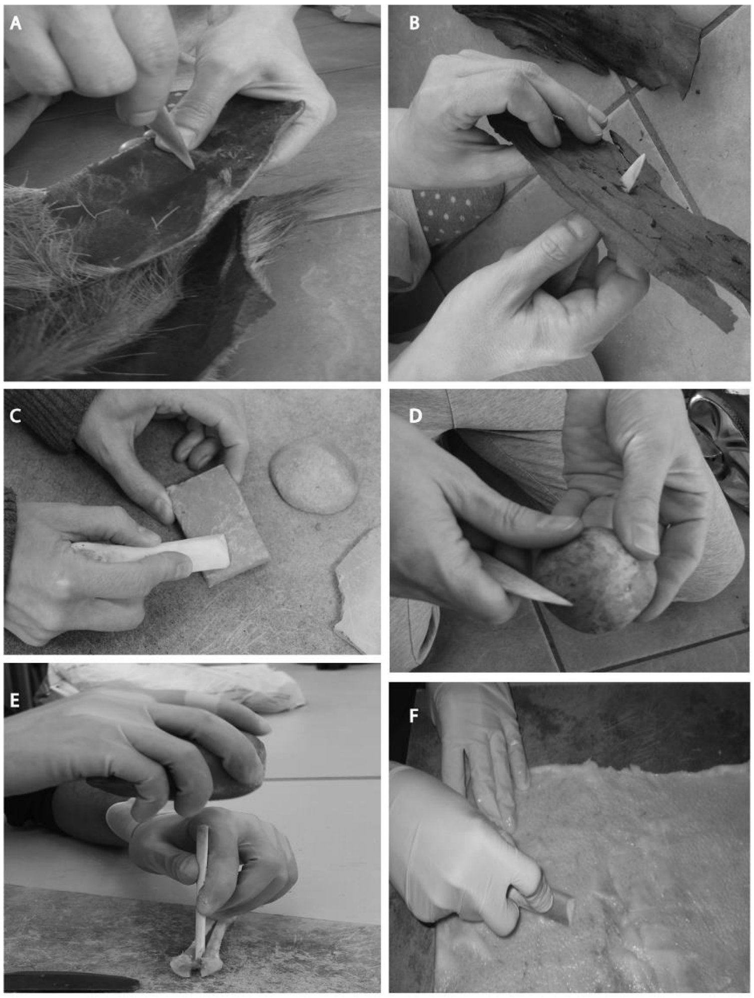

Fig. 6. Experiments undertaken with bone tools: A-perforating a slightly humidified leather using rib point in a rotating motion; B- punching holes in bark with a rib point; C-scraping dry clay with a chisel; D-polishing little bowl made of dry clay using a rib point; E-splitting a sheep metacarpal with bone chisel; F-degreasing fresh skin with bone chisel.

together and interpreted as a comb for fibre production from flax (Gross et al., 1876: 6, Sidéra, 1993, 2000; Maigrot, 1997; Médard, 2004, 2006; Schibler, 2013) or for cereal seeding (Reinhard, 2000). However, recent use-wear studies have shown that some of these tools recovered from Neolithic lake-dwelling sites from western Switzerland (Mayca and Bailly, 2013) and from France, Chalain 4 (Maigrot, 2003, 2010) have been used for tree liber procurement or processing products of bark or even for polishing ceramic rather than carding fibres. Additionally, experiments and analysis using scanning electron microscopy(SEM) of carbonised fibre material from Neolithic wetland settlements in eastern Switzerland to investigate the fibre processing stages showed that there is no hackling or combing of threads which was used to remove the short fibres, leaving only the longer fibres to be processed (Leuzinger and Rast-Eicher, 2011).

All analysed pointed ribs here appear to form a quite homogenous group in terms of their morphology and manufacturing. Their transformation into a pointed tool seems to be rather short and simple. The rib has been split longitudinally (along the grain of the bone). This debitage is followed by short shaping phase which mainly focuses on sharpening the distal part by grinding its lateral surfaces on coarse and fine-grained sandstone. It appears that in some specimens the upper side is also slightly modified, while the lower surface remains natural. A single piece displays tiny notches on its distal part.

On both sides of investigated tools striations of manufacturing are highly conspicuous. They are broad, deep and rough-bottomed. They are also rounded. They cannot be confused with use-striations due to their dimensions and orderliness. Yet, their upper surfaces seem to be polished and slightly flattened, whilst the bottoms appear rough (Fig. 8C and 9B). Again, this polish is related to the manufacturing processes. Edges show a characteristic indented macroscopic rounding (Fig. 8B). At high magnification, the surface of tool tip appears regular and well striated, relatively bright and above all rounded. Striations are numerous and mainly unidirectional, narrow, medium to long in length and also rather deep. Their direction suggests longitudinal and occasionally transversal motion, but sometimes they are also randomly oriented (Fig. 8A, D). The polish is highly linked or covering, and visible with the naked eye. This developed on the distal part of all pieces usually on the dorsal and ventral surfaces as well as on both sides. Starting at the pointed tip of the tool, the polish covers about a quarter of the length of the tool (from 1.5 to 3 cm of the surface). On the ventral

Fig. 7. Manufacturing rib points: A-cleaning the meat remains from a cattle rib; B-cutting the rind rib on its lateral side with flint blade; C-using a bone chisel for splitting the cattle rib; D-support received from the cattle rib bone for manufacturing flat points; E-splitting pig rib using a pebble; F-shaping and polishing rib points on sandstone.

surface the spongiosa is well polished, edges of trabeculae are clearly smoothed (Fig. 8A). Moving along the piece, the rest of the spongy bone is not smoothed and the difference between polished and non-polished spongy bone are very clear. The polish emerges on the entire distal part of these pieces, especially on their underside and on their profiles. Such characteristics do not indicate a gesture of carding or weaving. Features resulting from experimental carding or weaving of fibres (Mayca and Bailly, 2013; Legrand and Radi, 2008) allow an insight into the characteristics observed on the archaeological implements investigated here. Furthermore, traces obtained on rib points during our experiments of punching outer bark are comparable to those seen on the archaeological points from LA (Fig. 4G–F). Thus rib points from LA, at least at the end of their use-life, have been used in bark working, possibly processing bark-made products.

4.2. Pottery working

One rib point made has been used to process pottery. Although it seems that the piece was recycled and originally used in bark processing. The left side of the item shows deep transversally oriented striations which partially covered this surface with a pattern characteristic of bark working (Fig. 9C–D). These features are restricted to an area of 2 cm above the tip and decrease numerically further up the tool (Fig. 9). Microwear marks obliterate the natural bone grooves that are still visible on the rest of the implement. This pattern is comparable to that documented in experimental tools used to smooth ceramic for a period between 30 min and 1 h (Fig. 10). Though the striations recorded in experimental work are shallower than those visible on the archaeological material. This difference may be caused by the use of an alternative temper type (Buc and Loponte, 2007; Maigrot, 2010) or intensity and time of labour.

4.3. Wood working

Two bevel–ended tines had contact with hard material, most probably used in woodworking (Fig. 11). The distal end of both tools seems to be rounded (Fig. 11D) and one of them is also slightly chipped. The section of the distal edge forms an acute-angled triangle, partly and indistinctly rounded. Striations are highly perceptible, these are long and generally oriented perpendicular to the edge suggesting transversal movements. Polish is bright and smooth with a domed topography and developed on both parts of the bevel end (Fig. 11A, B, C). The distal edge seems to self-sharpen during the utilisation of the tool.

4.4. Hide working

Three bone implements have been used in processing hides, typologically an awl, a chisel and a needle (Fig. 12).

Awls seem to be the one of the most ambiguous categories among archaeological bone tools. Functional analyses have shown the divergent uses of awls within a single morphological type, whilst awls of different morphological types exhibit signs of analogous use (Chomko,

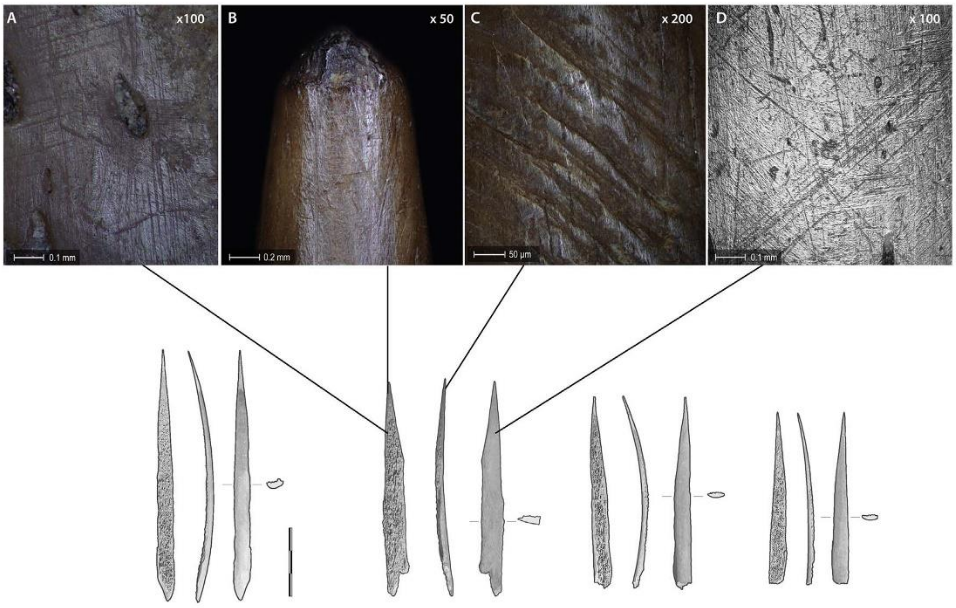

Fig. 8. Some investigated rib points: A-ventral surface smoothed and polish with some striations; B-rounding of the distal part; C-manufacturing striations; D-striations and polish related to use (drawing by Christine Runnger).

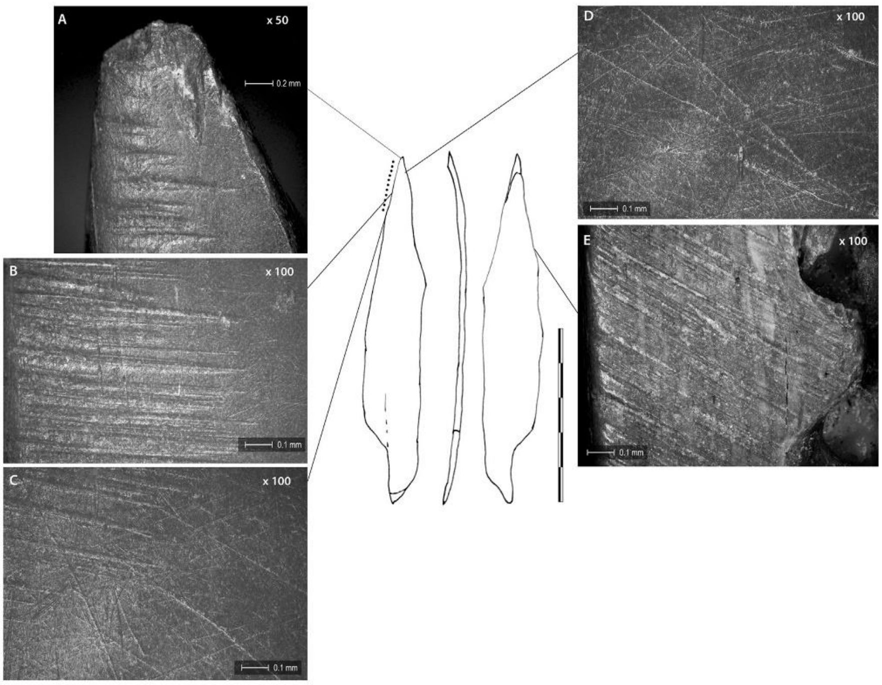

Fig. 9. Rib point used at the end of its life for pottery processing (dots indicate the exploited part): A-Tip with transverse striations already visible at the magnification of x50; B-striations of ceramic working; C-the left part of figure shows the striations formed after working pottery and right side shows the previous surface, probably linked to bark processing; D- former surface with microwear pattern characterised for bark processing; E-manufacturing striations.

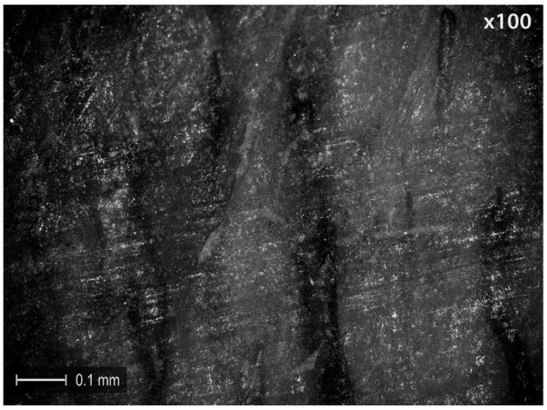

Fig. 10. The transverse striations recorded on the experimental rib point (point n°7) 45 minutes scraping a small bowl made of dry clay.

1975; Legrand and Sidéra, 2007; Olsen, 2007). The manufacture of the awl implies a careful design.

One pointed awl was made on the metapodial of medium-sized ruminant. Microscopic striations visible along its shaft suggest that they were manufactured by grinding the bone with or on a coarse grained stone. They are broad, deep and rough-bottomed. They are also slightly rounded and polished. When observed at low magnifications the tip of awl is smooth and well-polished (Fig. 12E) and numerous use striations formed on the polished surface become visible with 5 × magnification. They are mainly longitudinal and parallel to the longitudinal axis of the tool and cover almost the entire surface. Some micro-pits as well as rough-bottomed depressions are also noticeable. At 100 × magnification the surface of the distal part of the tool shows an irregular topography due to diversity in dimension and direction of the striations, depressions and micro-pits. The elevated points seem to be smoothed and slightly polished showing a domed profile. Abundant striations are visible, exhibiting as short or long, superficial or continuous as well as rather broad and deep. All striations show smoothed edges, and their bottom is generally not affected by polish. Further from the tip the use-wear features are quite similar, the depressions, micro-pits seem to be more frequent. The diverse direction and dimension of striations suggest the transversal and longitudinal motion, most likely perforation. On one of the side of tool small patches of black residue were visible as well, but no chemical analysis has been undertaken.

The experimental processing of hide shows that an irregular topography, rather homogenous micro-relief and the presence of micro-pits and non-linear depression are commonly observable on the tool's working surfaces. Perforation of hide produces striations of variable dimensions and shape as well as variable directions (Peltier and Plisson, 1986; Plisson, 1993; Maigrot, 2003; Legrand, 2007; Legrand and Radi, 2008; Petrullo and Legrand-Pineau, 2013). All these features have been recognised on the surface of the awl from LA. This awl seems to be used in processing of hides, most probably involving piercing movements.

A typological needle; a slightly pointed implement made on the fibula of small canid. The manufacturing traces are easily identifiable. Well developed, covering and rough, heavily striated polish with many micro-pits indicates contact with hide. The abundant, short and smooth striations transversal to the tool axis are sometimes cut by the striations parallel to the tool axis (Fig. 12C). The striations are highly visible on both ends of the tool indicate rotating motion, suggesting together with the polish characteristics that the specimen was used to perforate hides (Fig. 12A, B, D). Traces recorded from an experimental rib point and an awl used in perforation of leather is very similar to ones seen on this needle (Fig. 4E, F).

A chisel made on a long bone. Ridges of the distal part of the tool are smoothly rounded and covered by rough, domed polish with some micro-pits. Striations are evident, forming occasionally a network, they are narrow and mostly parallel to the edge suggesting longitudinal motion. This tool has been used in processing hide.

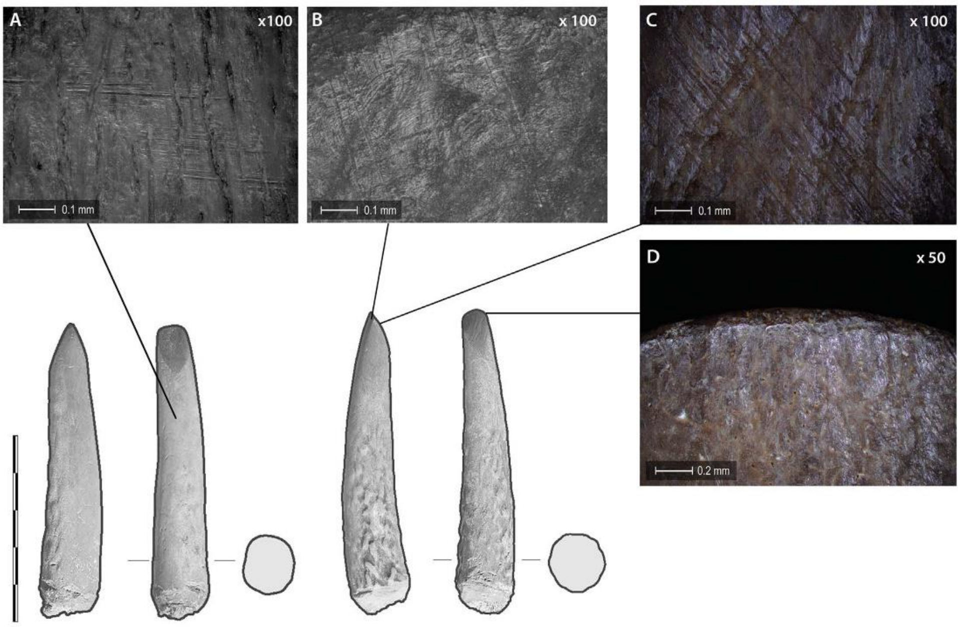

Fig. 11. Two antler chisels used in processing wood. A, B, C-striations and polish developed on dorsal face of both tools which has been in direct contact with worked material; D-light rounding of distal part (drawing by Christine Runnger).

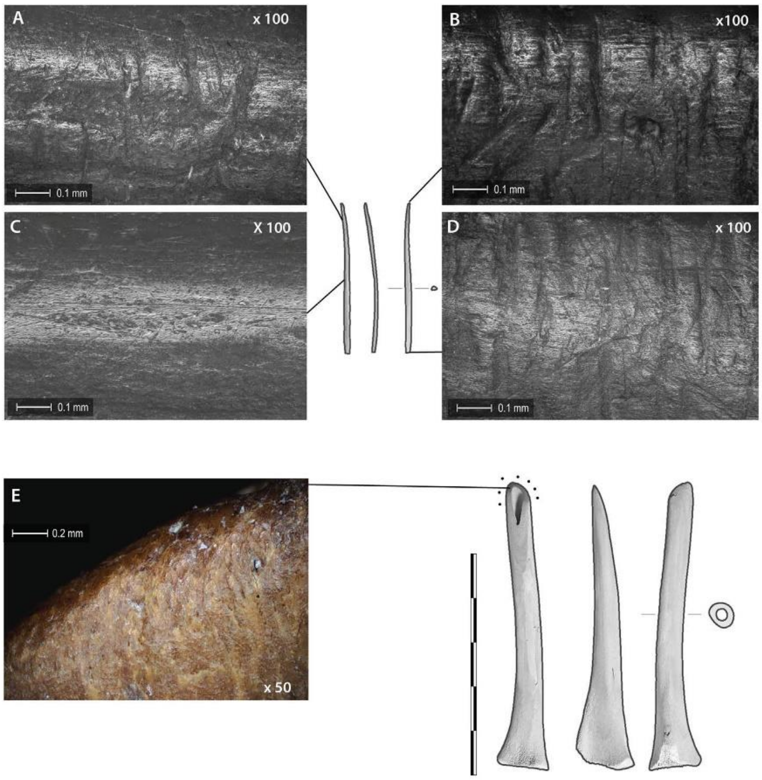

Fig. 12. Two tools used in hide processing. A, B, C, D-striations suggesting rotating motion and a well-developed hide polish; E-rounding of distal part of awl (drawing by Christine Runnger).

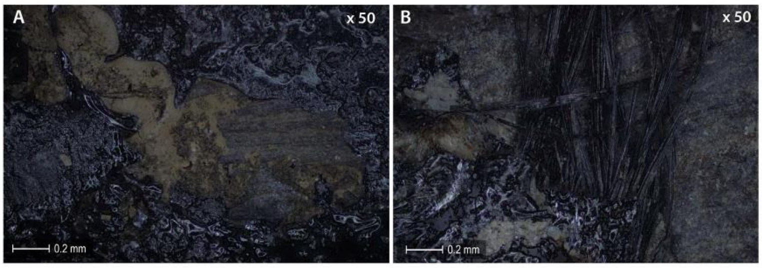

Fig. 13. Bone point: A-birch tar visible on proximal and mesial part of the artefact; B-vegetal binding observable on the point surface.

4.5. Other activities

A bone point hafted to an arrow or spear shaft. Hafting was probably achieved using birch tar and vegetal binding (Fig.13). Birch tar was commonly used in Neolithic. It is assumed that birch bark was heated in order to yield a sticky tar (Mercier and Seguin, 1939; Vogt, 1949; Clark, 1954; Van Gijn and Boon, 2006) and is supported by chemical analyses (Binder et al., 1990; Regert, 1996; Regert et al., 1998; Rageot et al., 2013). Evidence for the production and use of fibres also exists in the Neolithic, such as a wooden haft fixed with pine twigs and blocked with fine thread (Bocquet, 1984; Petrequin and Petrequin, 1988), or flax cord fibres and oak bark thread (Petrequin, 1986).

5. Conclusions

The wear trace analyses of a small number of bone tools from late Neolithic site of Sutz-Lattrigen Aussen showed that they were used in a variety of activities. Some of these activities are not detectable from actual artefacts gathered on site, but are only represented indirectly by micro-wear traces observed on the investigated specimens. Examples are bark and hide processing.

One of the main features of this assemblage is the presence of a significant number of formally worked pointed implements. They seem to have been used for working with plant and animal material, but further use-wear studies should be undertaken to shed more light on their function. The results of the use-wear analyses of bones and antler implements could complement those of the functional, technological and typological analyses of the other artefact categories, particularly flint and stone as well as wood and vegetal fibres. The combined study of traceological, technological, experimental and typological approaches on all artefact categories would help to reconstruct, as entirely as possible, the principal economic and technological activities of Neolithic populations (Kerdy et al., in preparation).

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Hunting, Husbandry, and Human-Environment Interactions in the Neolithic Lakeshore Sites of Western Switzerland

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ABSTRACT

The lakeshores of western Switzerland are one of Europe's best-known Neolithic settlement areas, thanks to dendrochronological dating and the exceptional preservation of organic materials. Against this outstanding background, this study uses zooarchaeological data to answer a series of questions regarding the Neolithic economy, environment and human-environment interactions at these lakeshore sites. It also discusses, within an interdisciplinary framework, the possible impact climatic fluctuations, cultural influence, topographical conditions, and demographic growth had on economic change. The results show that the faunal economy was mainly based on animal husbandry, with fluctuations in the cattle-pig ratio. Hunting also played an important role in the food system and focused mainly on large game, especially red deer, which contributed significantly to the meat supply. The results from comparing these animal bone remains also show that multiple factors, such as topography, climatic conditions, and cultural influence, played a part in the socio-economic organisation of the Neolithic communities. Exploratory procedures such as correspondence analysis support these interpretations.

Keywords: Neolithic, western Switzerland, lakeshore settlements, faunal remains, hunting, husbandry

INTRODUCTION

In recent years, numerous studies of animal bones from sites at the lakes of Bienne, Morat, Burgäschi, and Neuchâtel in Switzerland have greatly enriched our knowledge of the Neolithic period (Stampfli, 1980; Becker & Johansson, 1981; Glass & Schibler, 2000; Hafner & Suter, 2000; Stampfli et al., 2003; Chiquet, 2005; Reynaud Savioz, 2005; Schibler, 2006; Chiquet, 2012; Schibler, 2017). By summarizing and synthesizing these data, this article aims to investigate the subsistence practices of hunters and herders between 4000 and 2500 cal. BC.

The majority of the assemblages studied were from the lakes of Bienne and Neuchâtel but data from Lake Morat and Lake Burgäschi were also used. The sites, their dating, and dating methods are listed in Figure 1 and Table 1. The zooarchaeological results are based on hand-collected animal bones only, excluding fish, amphibians, reptiles, and the smallest mammals, given the lack of sieved soil samples at most sites. The exceptional quality of the preservation below the water table meant that the large mammal bones were recovered in a perfect state of conservation.

As Schibler (2006) remarks, marked fluctuations in the importance of game

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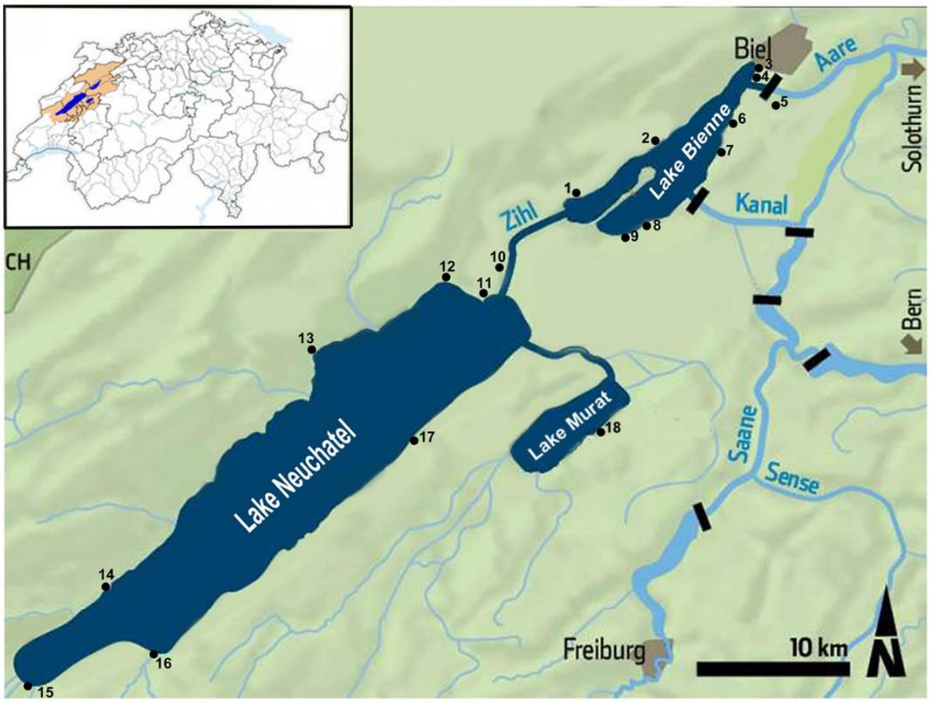

Fig. 1 - Colour online, B/W in print

Figure 1. *Distribution of Neolithic lakeshore sites in western Switzerland. 1: La Neuville; 2: Twann; 3: Port; 4: Nidau; 5: Port-Südeli; 6: Sutz-Rütte; 7: Sutz-Lattrigen; 8: Lüscherz; 9: Vinelz; 10: Thielle; 11: Marin les Piécettes; 12: Saint-Blaise; 13: Auvernier; 14: Concise; 15: Yverdon; 16: Yvonand; 17: Portalban; 18: Muntelier. Most of these sites comprise several settlement phases. For settlement phases and dating see Table 1.*

animals can be recognized throughout the Neolithic lake dwelling period. These fluctuations coincide with climatically induced economic crises, which, because of the threat of starvation, forced people to intensify hunting and gathering. On the other hand, Arbogast and Jeunesse (2013) point out that the different exploitation strategies of livestock and the integration of hunting into the meat supply coincided with the distributions of cultural groups as categorized by pottery styles and burial practices. It is assumed that cultural identities include both behaviour and food production.

In this study, the zooarchaeological data were compared chronologically, culturally, and geographically in order to find potential reasons for the differences in animal husbandry and hunting practices, or in individual domestic or wild mammal species. The zooarchaeological evidence was also used to explore possible environmental, cultural, or social relations.

Material and Methods

The data discussed here come from 38 settlement layers located on both sides of Lake Bienne and 17 settlements on both sides of Lake Neuchâtel; they are complemented by two settlement layers each from Lake Morat and Lake Burgäschi (Figure 1). Among these 59 settlement layers, 49 have been dated precisely by dendrochronology. The others have been dated by

Table 1. *List of waterlogged site and settlement phases at the lakes of Bienne, Neuchâtel, Morat, and Bürgäschi (sites references in Schibler et al. 1997).*

Site	Dating method	Date BC
Lake Bienne		
Sutz-Lattrigen Hafen US	Dendrochronology	3834–3820
Twann E1 + 2	Dendrochronology	3838–3768
Twann E3	Dendrochronology	3702–3687
Port-Südeli US	Dendrochronology	3686–3638
Twann E4	Dendrochronology	3663–3658
Twann E5	Dendrochronology	3643–3631
Sutz-Lattrigen Hafen OS	Dendrochronology	3641–3631
Twann E5a	Dendrochronology	3622–3607
Sutz-Lattrigen VII Hauptstation Innen	Dendrochronology	3613–3566
Twann E6	Dendrochronology	3596–3573
Twann E7	Dendrochronology	3596–3573
Port-Südeli OS	Dendrochronology	3560
Twann E8	Dendrochronology	3563–3532
Twann E9	Dendrochronology	3563–3532
Nidau 5	Dendrochronology	3406–3398
Twann UH	Dendrochronology	3405–3391
Sutz-Lattrigen VI	Dendrochronology	3393–3388
Sutz-Lattrigen Aussen	Dendrochronology	3201–3147
Twann MH	Dendrochronology	3176–3166
La Neuville- Chavannes	Dendrochronology (?)	3171–3058 (?)
Lüscherz-Binggeli	Dendrochronology	3156–3122 (?)
St. Blaise Bains des Dames 9	Dendrochronology	3176–3112
Portalban Les Grèves	Dendrochronology	3171–3095
Twann OH	Dendrochronology	3093–3072
Nidau 3	Dendrochronology	2977–2958
Vinelz Grabung Strahm 1960	Dendrochronology	2853/2848/2833/2808
St. Blaise Bains des Dames 7	Dendrochronology	2797–2679
Lüscherz Fluhstation	Dendrochronology	*c.* 2736
Lüscherz Dorf, Aüssere Station	Dendrochronology	2792–2709
Vinelz-Hafen	Dendrochronology	2774–2703
Sutz Rütte	Dendrochronology	2759–2746/2757–2754/2726–2689/2714–2696/ 2646–2627
Vinelz Alte Station NW	Dendrochronology	2735–2626 (?)
Lake Neuchâtel		
Yvonand III 1 + 2	Typology	Classic Cortaillod, *c.* 3800
Auvernier Port Vb–c	Dendrochronology	3791–3785
Thielle-Mottaz		3719–3699
Auvernier Port Va	Dendrochronology	3728–3679
Concise E2B	Dendrochronology	3692–3676
Concise E3B	Dendrochronology	3666–3656

Table 1. (*Cont.*)

Site	Dating method	Date BC
Concise E4A	Dendrochronology	3645–3636
Yverdon Garage Martin 18–20	Typo-stratigraphy	*c.* 3600
Yverdon Garage Martin 14–16b	Dendrochronology	3588–3581
Auvernier Port III	Dendrochronology	3627–3621/3560–3550
Concise E6	Dendrochronology	3533–3516
Marin les Piécettes	Dendrochronology/C14	3504–3483/3435
Yverdon Garage Martin 11–12	Typology	2800–2750
Yvonand IV	Dendrochronology	2784–2740
Auvernier Brise-Lames	Dendrochronology	2792–2778/2767/2756–2750/2740–2701
Thielle Wavre, Pont-de-Thielle	Dendrochronology	2701 (3750–3700)
Auvernier La Saunerie	Dendrochronology	2606–2440
St. Blaise Bains des Dames Auv.	Dendrochronology/ stratigraphy	2550–2500
St. Blaise Bains des Dames E	Dendrochronology/ stratigraphy	2550–2500
St. Blaise Bains des Dames F	Dendrochronology/ stratigraphy	2550–2500
St. Blaise Bains des Dames G	Dendrochronology/ stratigraphy	2550–2500
St. Blaise Bains des Dames H	Dendrochronology/ stratigraphy	2550–2500
Lake Morat		
Muntelier-Strandweg		3851–3837
Muntelier-Fischergässli	Dendrochronology	3842–3819
Lake Burgäschi		
Burgäschisee SW	Dendrochronology	3760–3748
Burgäschisee Süd	Dendrochronology	3760–3748

radiocarbon or typological methods (Table 1). The settlements are all fairly evenly distributed between the Middle Neolithic (4000–3400 cal BC. (30 instances) and the Late Neolithic (3400–2500 cal. BC (29 instances), but data from the twenty-seventh century, the twenty-ninth to the thirty-first, or the thirty-third to the thirty-fifth centuries cal BC are rare or even missing (Table 1). In total, 59 settlement layers from 34 sites are included in the database, which contains a total of about 189,000 identifiable animal bones (Figure 1 and Table 1).

The comparison between the assemblages was based on the number of identified specimens (NISP, bone fragments). Although NISP has some disadvantages when comparing quantities of bones between large assemblages, because it can lead to overestimating the number of individuals, especially when the bones are highly fragmented (Marshall & Pilgram, 1993), it was not a concern for this study.

To investigate the economic aspect of food in more detail, factorial correspondence analysis was used to include and compare the importance of the different animal species in one diagram (Vaillé, 2011). This multivariate statistical approach made it possible to investigate the underlying structure of the dataset and to describe the most significant trends in the animal economy.

In order to describe the diversity of mammals exploited at the different sites, nine variables were retained: cattle (*Bos taurus*), pigs (*Sus domesticus*), dogs (*Canis familiaris*), aurochs (*Bos primigenius*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), and the species groups sheep (*Ovis aries*)/goat (*Capra hircus*) and 'various wild species', the latter primarily containing various carnivores, as well as beaver, hare, or even moose.

Results

Husbandry and domestic animal meat

One of the most obvious aspects of the faunal spectra was the high frequency of domestic animal remains (Figure 2). In the Neolithic sites around Lake Bienne, husbandry mostly contributed to the supply of meat: more than two thirds of the settlements contained over 70 per cent of domestic animal remains (Figure 3). This feature especially concerns the husbandry of cattle and pigs, as the meat of these two domestic species was the most frequently consumed (Figure 4). The frequency of bones from domestic animals fluctuates remarkably during the time of the Cortaillod culture (3900–3400 cal. BC), between 28 and 76 per cent. During the period of the Horgen and Lüscherz cultures (3400–2800 cal. BC, the proportion of domestic animals is high, comprising over 75 per cent of the identified bone material. And during the timespan of the Auvernier culture, the importance of domestic animals reached its highest level (e.g. 80 per cent at Vinelz-Alte Station). Compared to the Lake Bienne region, the proportion of domestic animals was slightly lower in the Lake Neuchâtel basin (Figure 5): in most assemblages the percentage varied between 50 and 70 per cent.

From 4000 cal. BC to 3400 cal. BC, cattle were the dominant domestic species exploited in Neolithic lake dwellings in western Switzerland (Figure 4). The proportion of cattle bones is greater than that of any other domestic species at the beginning of the fourth millennium, with more than half of all the remains being those of cattle at most sites on both lakes. At the beginning of the thirty-fourth century, the proportion of cattle bones decreases in favour of pig bones. Smaller proportions of cattle bones and higher proportions of pig bones are therefore typical in the second half of the fourth millennium and the first half of the third millennium BC. This trend is common to sites on both lakes. The ratio of cattle bones in both lake settlements is also quite similar, confirming that this was a chronological trend and not a reflection of geographical and topographical differences between the two regions (Figure 4). On the other hand, when finds' densities (number of bones per m^2) from sites near Lake Zurich are considered, no decrease in cattle bones during this period can be seen (Schibler, 2017).

Between the thirty-ninth and the thirty-fourth centuries BC, pig bones make up less than one third of all domestic animal bones (Figure 4), except at the settlement of Concise E4A dated to the thirty-seventh century BC. From the beginning of the Horgen culture at Lake Bienne (*c.* 3400 cal. BC), a significantly higher proportion of pig bones can be recognized (Schibler, 2006; 2017): pig bones account for 80 per cent of the domestic animal remains. In contrast, during the same period at Lake Neuchâtel, the importance of pig bones is much lower, averaging around 40–50 per cent (Figure 6). With the beginning of the third millennium, pigs decrease again in favour of cattle.

During the Cortaillod culture (until the thirty-fourth century BC), sheep and goats are represented in stable proportions of up to 20 per cent at most sites. From the beginning of the third millennium, the

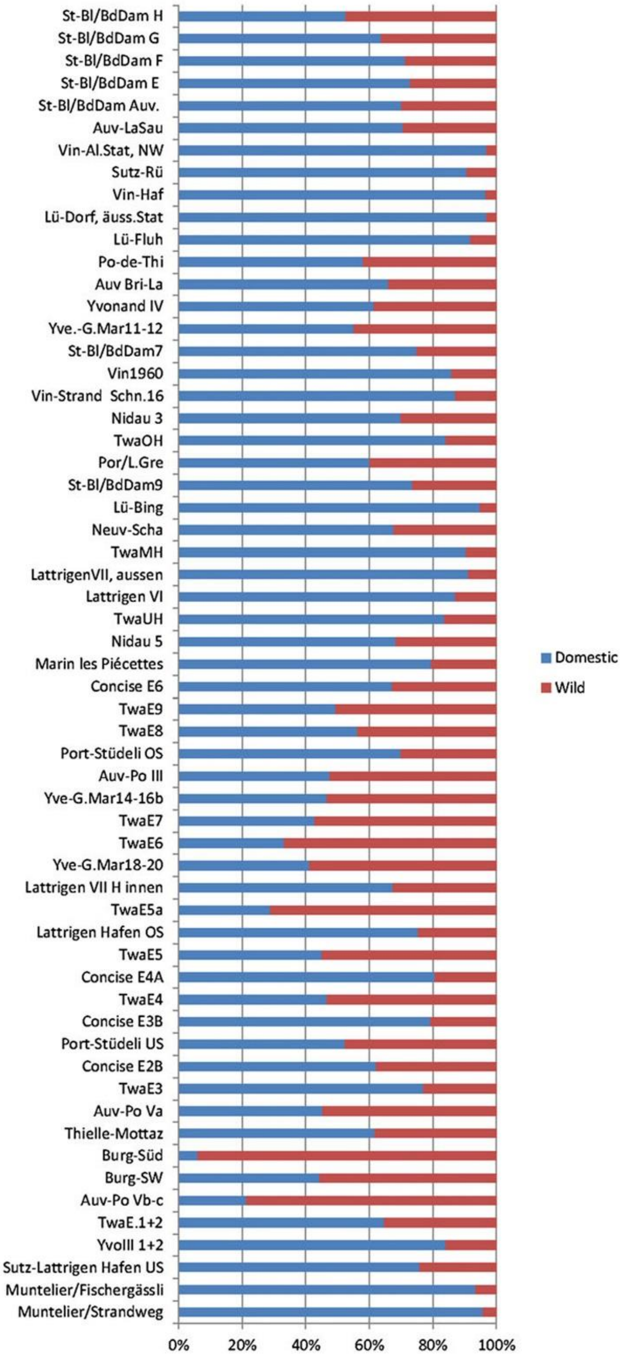

Fig. 2 - Colour online, B/W in print

Figure 2. *Importance of domestic and wild animals according to the number of bone fragments in Neolithic western Switzerland (100% = domestic and wild animals).*

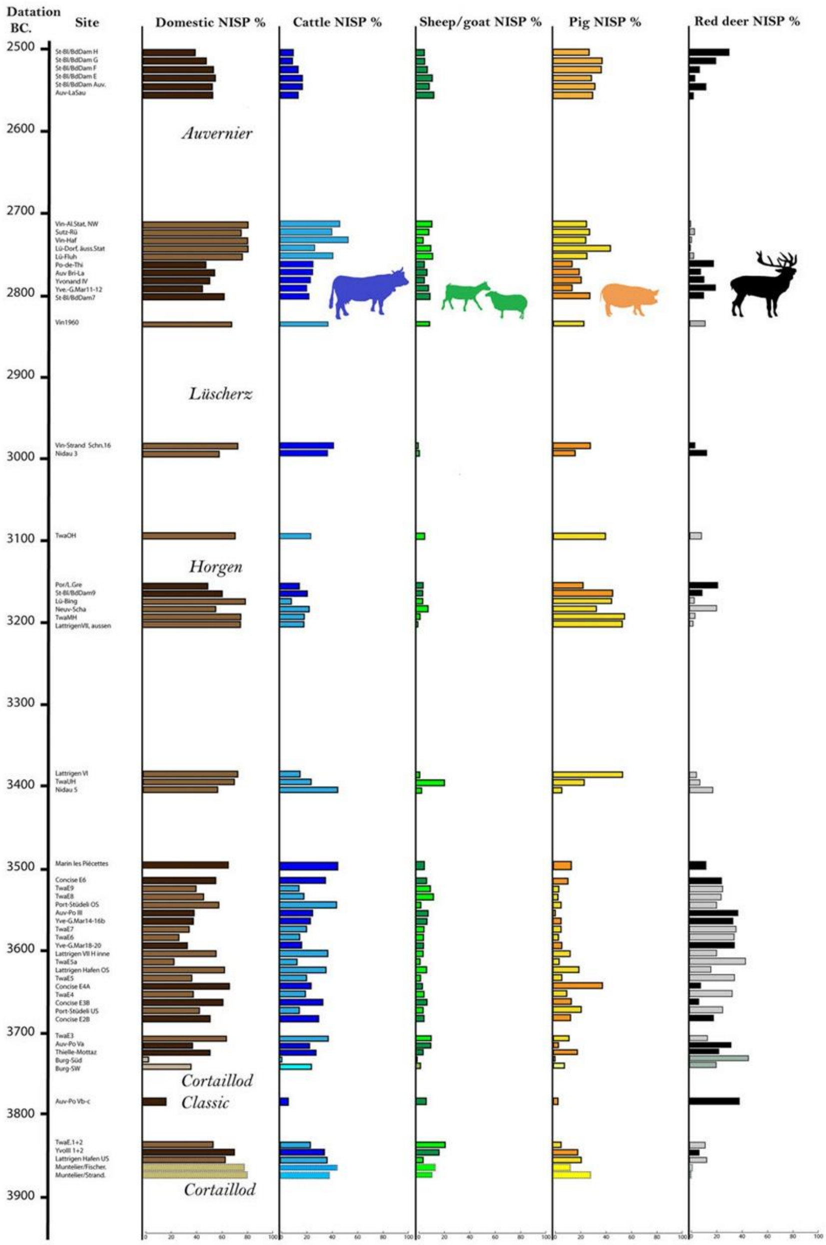

Fig. 3 - Colour online, B/W in print

Figure 3. *Importance of cattle, pigs, sheep/goats, and red deer at Neolithic lakeshore sites in western Switzerland (shown in their cultural sequence), according to percentages based on fragment numbers (100% = domestic and wild animals). Dark shading represents sites on Lake* Neuchâtel, *light shading represents sites on Lake Bienne; the two sites on Lake Morat and the two sites on Lake Burgäschi are marked by even lighter shading.*

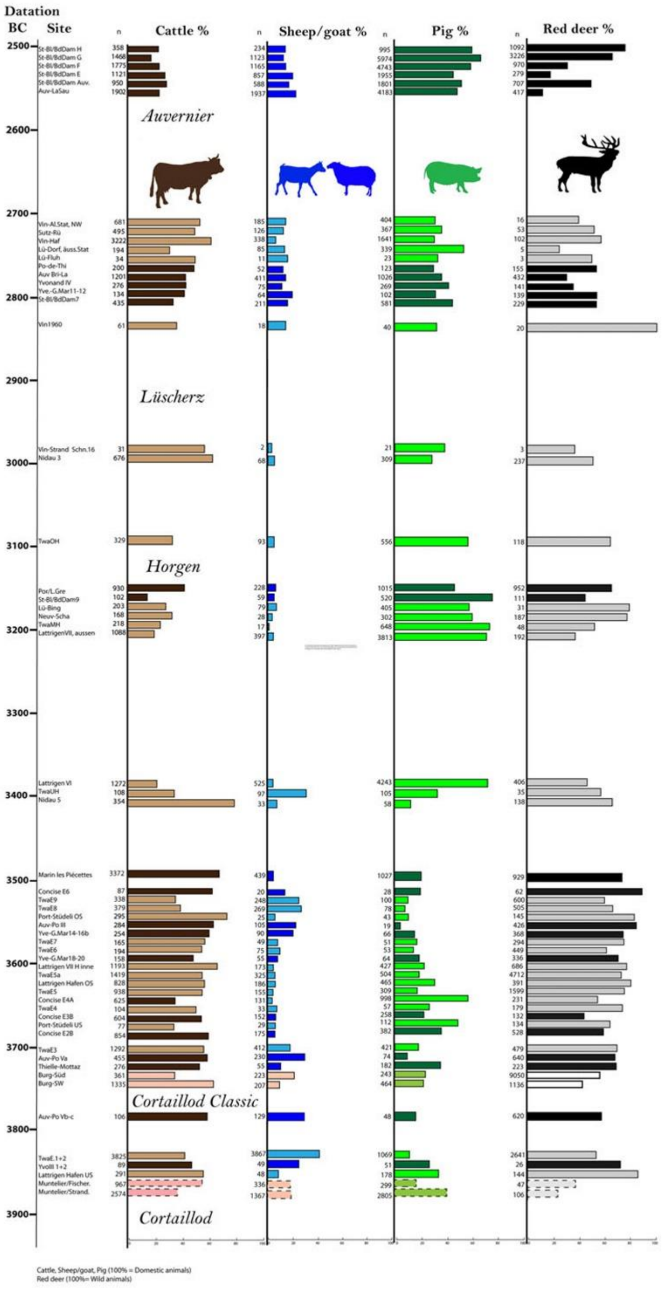

Fig. 4 - Colour online, B/W in print

Figure 4. *Importance of domestic animals based on the number of bone fragments at Neolithic lakeshore sites in western Switzerland, shown in their cultural sequence: cattle, sheep/goats, and pigs (100% = domestic animals); red deer (100% = wild animals). Dark shading represents sites on Lake* Neuchâtel, *light shading represents sites on Lake Bienne; the two sites on Lake Morat and the two sites on Lake Burgäschi are marked by even lighter shading.*

Fig. 5 - B/W online, B/W in print

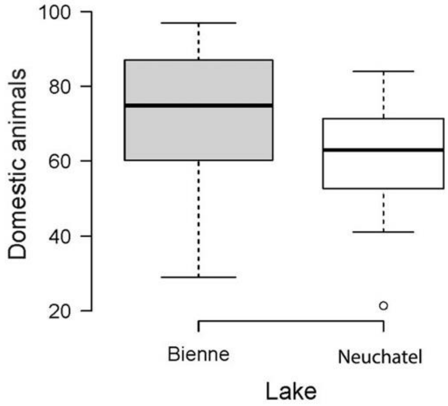

Figure 5. *Mean value of the importance (% of fragment numbers) of domestic animal remains at Lake Bienne and Lake* Neuchâtel.

Fig. 6 - B/W online, B/W in print

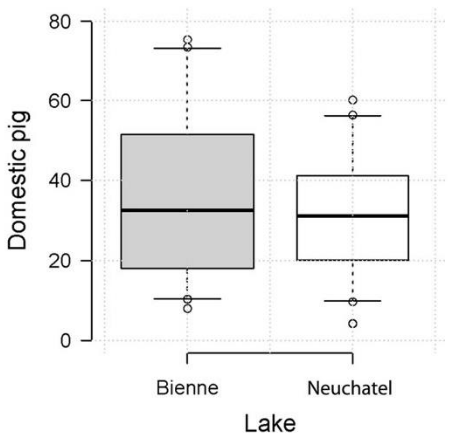

Figure 6. *Mean value of the importance (% of fragment numbers) of domestic pig remains at Lake Bienne and Lake* Neuchâtel.

importance of sheep and goats increased again (Figures 2 and 3).

Hunting and wild animal meat

Wild mammal remains were recovered on all the sites studied, but their importance fluctuates strongly between 2 and 95 per cent (Figure 3). The percentage of wild mammals makes up to one third of the identified bones at the beginning of the thirty-ninth century BC on sites around Lake Bienne (Stampfli, 1980; Becker & Johansson, 1981; Glass & Schibler, 2000). Red deer was the dominant species (Figure 4), with aurochs, roe deer, and wild boar being of minor importance. During the thirty-seventh and thirty-sixth centuries BC, the percentage of wild mammal bones increased abruptly by up to two thirds of the assemblage. In the Late and Final Neolithic, the proportion of wild animals decreased again to 5–20 per cent of the identified bones (Kerdy, in prep.; Brombacher & Marti-Grädel, 1999: Schibler, 2006, 2017).

The sites around Lake Neuchâtel gave different results. Higher percentages of wild animals are present on most sites from the beginning of the thirty-eighth century until the twenty-fifth century cal. BC, with an especially high proportion of red deer bones on these sites in those centuries. Other wild animals, mainly carnivores, i.e. foxes and wolves, but also beavers and hares have been identified, but only in small numbers. Some cut marks found on these carnivore bone remains indicate that their meat was also eaten, even if they were primarily killed for their skins and fur (Chiquet, 2012).

Food economy: a multiplicity of factors

(Figure 7) To concentrate more fully on the meat economy as a whole (rather than just on a single species) and to further explore the economic aspects of food, this study examined the results of correspondence analysis. The information shown by the first two axes on Figure 7 reaches almost 63 per cent, which is a high score indeed.

The sites on axis 1 are distributed in chronological order. The Middle Neolithic sites (red to pink symbols) are positioned on the right half of the diagram, while more

Fig. 7 - Colour online, B/W in print

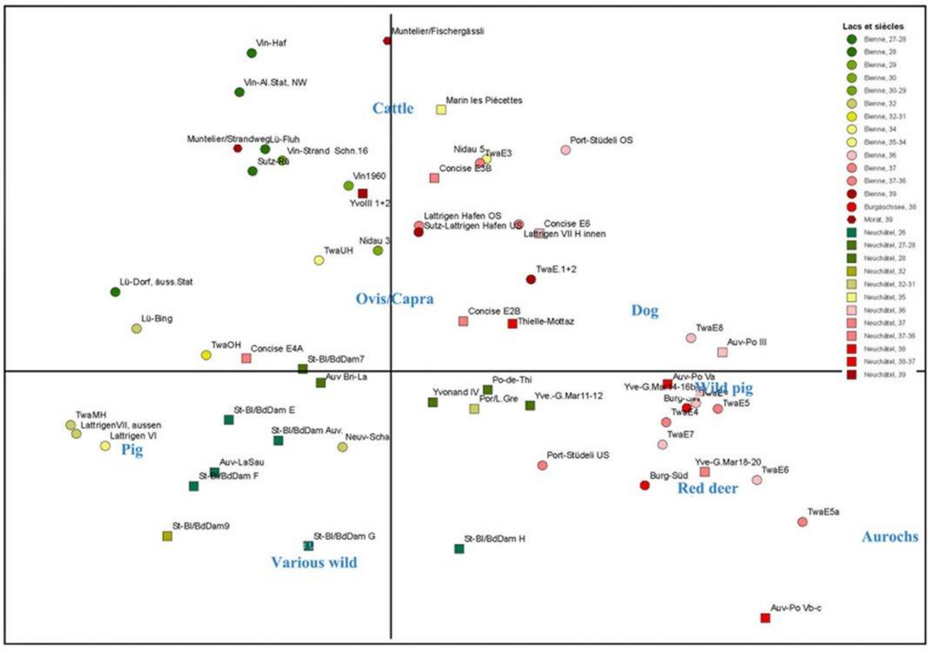

Figure 7. Correspondence analysis of the faunal composition at lakeshore sites located in western Switzerland (Bienne, Neuchâtel, *Morat, and Burgäschi). See text for an explanation of the symbols.*

recent sites (yellow to green symbols) are on the left.

Looking at the animal species, axis 1 is dominated by two variables, i.e. pigs (left side) and red deer (right side); the two animal species account for more than 82 per cent of the contributions. In addition, red deer is associated with two other wild species that also provide high amounts of meat: wild boar and aurochs.

Axis 2 seems to have some geographical significance. A dichotomy between sites located around Lake Bienne (circles: mostly upper part) and sites located on Lake Neuchâtel (squares: mostly bottom part) can be recognized.

Regarding the species, wild animals can be found in the lower part of axis 2, where only one domestic species can be recognized: the domestic pig.

The Lake Bienne sites (circles) show a much stronger correlation with husbandry (axis 2), especially with cattle remains, which alone make up 59 per cent of the contribution.

For wild animals, the correspondence analysis shows two aspects: first, wild animals are more frequently associated with earlier sites that are dated to the first half of the fourth millennium BC; second, more wild animals, especially red deer, are observed on sites on the northern shores of the lakes of Bienne and Neuchâtel. Red deer and wild boar are the most hunted animals across all sites.

Discussion

The ratio between the number of domestic and wild animal bones fluctuates considerably during the fourth and the first half of the third millennium, with a remarkable increase in wild animal proportions during specific phases of intensified hunting (Figure 3). It appears that in some periods farmers had to rely on wild resources to cover their routine demand for meat, specifically during the thirty-seventh and thirty-sixth centuries BC. In these periods, a concentration of large animal species, such as red deer, can be seen, as is the case in the Zurich region (Schibler & Jacomet, 2010). This phenomenon could be a sign of economically driven hunting, whose only goal was to 'produce' as much meat as possible during periods when other foodstuffs (e.g. cereals) were rare (Schibler, 2017).

Hunting wild animals was part of the exploitation strategy integrated into the economy of the lake settlements, and it offered people a valuable source of meat during periods of food shortages. This remarkable relationship—between the intensity of hunting and short-term climatic fluctuations—has been demonstrated for the Neolithic lakeshore settlements in the Zurich region (Schibler et al., 1997; Hüster-Plogmann et al., 1999). Short-term climatic deterioration may have been responsible for agricultural catastrophes which could have caused crop failures. Strong evidence for the highly specialized, economically stimulated hunting of large-sized mammals has been noticed at several lake sites already. The higher the quantity of wild animal remains found, the lower the diversity of wild animal species is observed in favour of larger species (Schibler & Jacomet, 2010). Furthermore, at the lakes in western Switzerland, hunters focused on species that offered the highest possible meat yield, that is, mainly red deer but also wild boar and aurochs (Figure 3).

Later, during the second half of the fourth millennium, the proportion of wild animal remains decreases significantly. This decline could have two reasons: first, an increase in some plant food species that are more tolerant of bad weather conditions (Brombacher & Jacomet, 2003), and second, an increase in pig keeping, from the thirty-fourth century BC onwards, which greatly increased meat production. This chronological replacement of hunting large wild animal species by intensive husbandry of domestic pigs is also convincingly supported by the result of the correspondence analysis. It shows a strong dichotomy between wild animals and domestic pigs on the first axis with a solid chronological correlation between a greater frequency of hunting at older settlements of the first half of the fourth millennium BC and a higher importance of pigs at more recent sites of the second half of the fourth and third millennium BC (Figure 7). A comparison between the importance of wild animal bones and cultural boundaries shows clearly that there was no relationship, which signifies that the importance of hunting is not culturally determined (Schibler, 2006: fig. 2).

From the middle of the fourth millennium BC onwards, an increase in the proportions of domestic animals can be seen. After the fluctuation in the share of wild/domestic animals in the Cortaillod period, the proportion of domestic animals in the Late Neolithic is visibly higher. However, not only does the ratio of wild to domestic animals fluctuate, but so do the proportions of different domestic species. The share of cattle bones is greater than that of other species in the Middle Neolithic (Figure 4: 4000–3400 cal. BC). Cattle proportions are constantly high at the beginning of the fourth millennium at all the lakeshore sites studied. It seems that not only were Neolithic cattle used as producers of meat but also as draught animals and for providing milk. The fatty acids from cow's milk discovered on pottery sherds suggest that cow's milk was being systematically used from at least 3400 cal. BC onwards (Spangenberg, 2004; Spangenberg et al., 2006; Schibler, 2006).

A significant increase in pig bones from 3400 cal. BC onwards was also detected. Pigs, being highly reproductive and having large litters, are perfect animals for the production of meat; therefore, larger quantities of meat can be produced in a relatively shorter time than is needed for cattle (Serjeantson, 2011). Moreover, the decision to exploit more pigs among the available domestic resources may also have resulted from the discovery that rearing pigs is the only form of farming that requires little space or additional fodder; pigs can be kept on fallow land and fed with household refuse, or they can be let loose in the forest to browse and then attracted back to the village, using fodder, when their meat is needed (Schibler & Schäfer, 2017). Additionally, keeping pigs was not only a source of protein, but also a way of tilling the arable farmland, as pigs have an instinct for rooting in the ground (Schibler et al., 1997). While pigs were of particular importance for bulk manure, other livestock, mainly cattle, goats, and sheep only made a complementary contribution to intensive cultivation (Bogaard, 2012). Cattle, goats, and especially pigs also contributed to the clearance of forest vegetation and weeds on arable land, and they deposited manure through penning on arable land (Bogaard, 2012). Therefore, pigs proved tremendously adaptable and enabled households to have a 'refuse compactor' which converted domestic waste, forest products, and field remains into meat (Bogucki, 1993). The importance of pig keeping, therefore, may have been because it was the only practicable solution for producing more meat without greater effort. The existing arable farmland and the marshy/sparsely-wooded floodplain around the settlements could all have been used as pastures for pigs (Schibler et al., 1997; Pétrequin et al., 1998; Hüster Plogmann et al., 1999; Serjeanston, 2011).

Furthermore, intensive pig keeping made it possible to replace the hunting of large wild ungulates (red deer, wild boar, and aurochs). This shift from hunting wild ungulates to pig husbandry was developed in eastern Switzerland during the time of the Pfyn culture between 3800 und 3400 cal. BC and was been adapted in western Switzerland during the Horgen culture in a very short time (in the thirty-fourth century), as the settlements at Lake Bienne and in Concise (Lake Neuchâtel) demonstrate (Chiquet, 2012; Schibler, 2017). This change obviously allowed better control of available protein resources. This growing interest in pig husbandry has been recorded in other regions, such as the French Jura region, and it reflects a more supra-regional or even cultural tendency (Arbogast et al., 2006; Arbogast, 2008; Schibler, 2006; Kerdy in prep.).

Sheep and goat proportions fluctuated less strongly than those of cattle and pig. A high proportion of sheep and goats was typical in the early settlements of the fourth millennium, as at Twann and Auvernier Port and some sites of the Jura lakes (Arbogast, 2008). Later, smaller proportions of sheep and goats (less than 25 per cent) remain stable until the Late Neolithic. During the final period of the Neolithic, the slightly higher importance of sheep (and goats) was possibly due to the exploitation of wool. This impression is supported by the fact that larger animals and older slaughter ages can be recognized, at least in the Zurich region (Hüster-Plogmann & Schibler, 1997), and by the first evidence of bone and antler needles and buttons at Corded Ware and Auvernier sites (Schibler et al., 1997b; Schibler, 2017).

Dog bones were found on all lakeshore sites in Switzerland. Usually the percentage lies between 1 and 10 per cent of the domestic animal remains. Yet, by looking at the proportion of dog remains, significant

Fig. 8 - Colour online, B/W in print

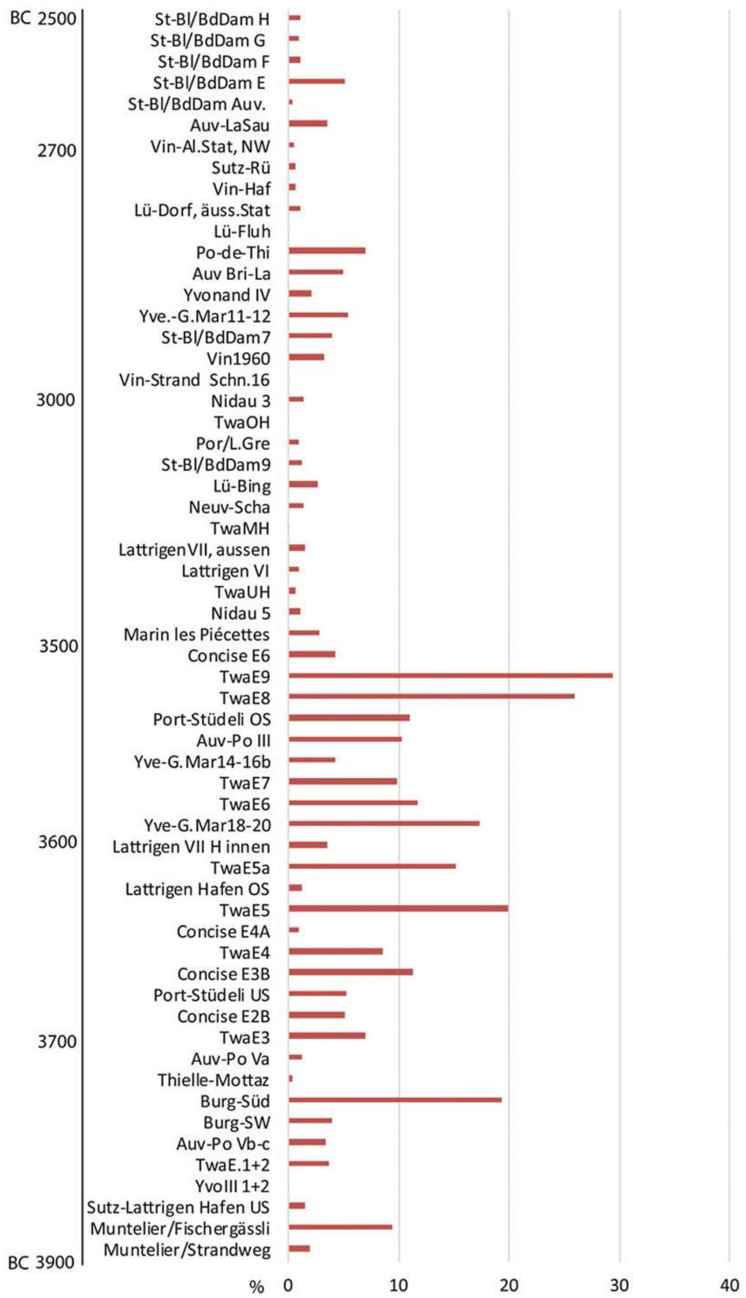

***Figure 8.** The importance of dogs (*Canis familiaris* L.) at Neolithic lakeshore sites in western Switzerland according to percentages based on fragment numbers (100% = domestic animals).*

increases in dog bones were noticed in the western Swiss sites dated to between 3700 and 3500 cal. BC (Figure 8). However, if all Neolithic lakeshore sites in Switzerland are considered, no correlation between the proportion of dog remains and wild animal bones can be observed (Schibler, 2006).

Higher frequencies of dog bones with cut marks in the period between 3700 and 3400 cal. BC and the young age of the dogs could indicate that dogs were used as additional meat sources during periods of food crises (e.g. starvation). Based on the tooth-wear classification of Habermehl (1975), 43 per cent of the dogs in the upper layer at Sutz-Lattrigen Hafen were killed just after their first year. At the site of Concise, E2B, half of the dogs were killed before they had even reached 6 months (Chiquet, 2012). These results indicate that dog meat was an additional source of food during periods of economic problems. This scenario is observed at sites around Lake Zurich, e.g. at Opera Parkhouse, layer 13 (Schibler & Schäfer, 2017). In both regions, i.e. western Switzerland (end of the second half of the fourth millennium BC) and eastern Switzerland (first half of the third millennium BC), the increase in dog bone proportions, as well as pendants made from dog metapodials and canine teeth (Schibler, 1981; Deschler-Erb et al., 2002), indicate that special relations existed between dogs and humans.

As stated above, farmers in western Switzerland faced many challenges to meet their daily food demands. These challenges could be caused by natural factors (e.g. weather conditions); however, topographical situations or cultural tradition could also have been factors that influenced the Neolithic economy. At sites like Twann or Auvernier, located on the steeper northern slopes of the lakes of Bienne and Neuchâtel, hunting was important. On the southern side of the lakes, i.e. the flatter southern shore, different results were obtained, with lower proportions of wild species and higher proportions of domestic animal remains. The steep northern shores of the lakes obviously influenced the strategies of the farmers, restricting the intensity of husbandry and agriculture. Farming, especially cattle and pig husbandry, on steep slopes is much more challenging and would have made this region less favourable for domestic animals. On the other hand, the inhabitants were surrounded by wider areas of forests which offered an increased range of hunting opportunities. Farmers on the steeper northern lakeside were also more influenced by climatic conditions, which could have reduced their already restricted productivity of cultivated plants. Conversely, the undulating southern shore was an ideal place for farming and offered better possibilities for cultivation (Marti-Grädel & Stopp, 1997; Kerdy, in prep.).

Conclusion

This review has brought together zooarchaeological data from Neolithic settlements established on the shores of two large (Neuchâtel, Bienne) and two small (Morat, Burgäschisee) lakes in western Switzerland. The results illustrate profound changes in the subsistence strategies used by the communities that lived in this region between the thirty-ninth and the twenty-sixth centuries cal. BC.

The archaeological data point to a period of economic crisis in the thirty-seventh and thirty-sixth centuries cal. BC, which could have been caused by climatic deterioration. The resulting decrease in available crops forced the farmers to intensify their exploitation of wild resources. However, when hunting did take place, it generally targeted the most abundant and meat-rich animals such as the red deer. Wild plant gathering also intensified markedly.

During periods of favourable conditions, the animal economy of the Neolithic famers was mostly based on keeping domestic animals. Cattle were the most common animals in the first half of the fourth millennium. The economic importance of domestic pig starts to increase from the beginning of the thirty-fourth century cal. BC, replacing the meat supply previously provided by hunted wild ungulates. Neolithic farmers probably intensified pig husbandry because pigs were more easily fed with household refuse, or by browsing the harvested fields or the adjacent forest. In addition, keeping cattle, sheep, goats, and pigs on harvested fields provides manure to fertilize the land. Sheep and goats were kept more frequently during two periods: the beginning of the fourth millennium cal. BC and the beginning of the third millennium cal. BC. In the earlier period, meat and milk are the most plausible reason for this increased frequency; during the later period, the earliest evidence of the use of wool is the most likely explanation. Increased frequencies of dog bones, correlated with cut marks and the preferred slaughter age at one year old, make it probable that dogs were also a source of meat during periods of economic crisis in the first half of the fourth millennium cal. BC.

In conclusion, the economy of the lakeshore sites in western Switzerland was influenced by many sub-regional trends and local factors. Short climatic fluctuations correlate well with the varying importance of hunting. The significant factor influencing the relative importance of domestic animal species is the topographical location of the sites (steep or lower hills). Obviously, environmental, topographic, and material cultural factors were responsible for the complex system that created the faunal composition at each individual settlement. To fully understand this system, further investigations in neighbouring regions are necessary. The evidence of contact and even displacement across the Jura Mountains during the Neolithic period offers the possibility of new research perspectives on these fundamental issues (see Burri, 2007; Chiquet, 2012, Burri-Wyser et al., 2015; Pétrequin et al., 2015; Schibler, 2017).

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Chasse, élevage et interactions entre hommes et environnement dans les sites littoraux des lacs de Suisse occidentale

Les sites littoraux suisses sont parmi les sites néolithiques les mieux connus d'Europe grâce à la dendrochronologie et du fait de l'excellent état de conservation des matériaux organiques. Dans le cadre de cet article, nous aurons recours à ces données hors du commun afin de répondre à une série de questions concernant l'économie néolithique, l'environnement et les interactions homme-milieu. Il s'agit de discuter, dans une perspective interdisciplinaire, de la possible incidence des fluctuations climatiques, des affinités culturelles, des conditions topographiques et de la croissance démographique sur les changements économiques qui s'observent dans la région des lacs de Suisse occidentale. L'économie animale de ces communautés repose principalement sur l'élevage, avec toutefois des variations dans le rapport bœuf/porc. La chasse joue également un rôle important dans le système alimentaire. Elle se concentre en particulier sur le grand gibier, notamment le cerf qui contribue de façon non négligeable à l'approvisionnement carné. Une comparaison des résultats obtenus à partir des restes de faune montre que de multiples facteurs, que ce soit la topographie, les conditions climatiques ou l'ancrage culturel, ont joué un rôle dans l'organisation socio-économique de ces communautés néolithiques. Des procédures exploratoires comme l'analyse des correspondances corroborent ces interprétations.

Mots-clés: Néolithique, Suisse occidentale, sites littoraux, restes de faune, la chasse, l'élevage

Jagd, Tierhaltung und Mensch-Umwelt Interaktionen in neolithischen Seeufersiedlungen der Westschweiz

Die Seeufersiedlungen in der Westschweiz sind dank der möglichen dendrochronologischen Datierungen sowie aussergewöhnlichen Erhaltung von organischen Resten eines der bekanntesten neolithischen Siedlungsgebiete Europas. Anhand von archäzoologischen Daten kann eine Reihe von Fragen zur neolithischen Wirtschaft, Umwelt und zu Mensch-Umwelt-Interaktionen an diesen Seeufern beantwortet werden. Darüber hinaus werden in einem interdisziplinären Rahmen mögliche Auswirkungen von Klimaschwankungen, kulturellem Einfluss, topografischen Bedingungen und demografischem Wachstum auf den wirtschaftlichen Wandel diskutiert. Die Ergebnisse zeigen, dass Faunenwirtschaft, mit Schwankungen im Rinder-Schweine-Verhältnis, hauptsächlich auf der Tierhaltung basierte. Die Jagd spielte im Nahrungssystem ebenfalls eine wichtige Rolle und konzentrierte sich hauptsächlich auf grosse Tiere, insbesondere den Hirsch, der wesentlich zur Fleischversorgung beitrug. Darüber hinaus lässt sich *zeigen, dass mehrere Faktoren, wie Topografie, klimatische Bedingungen und kultureller Einfluss, eine Rolle in der sozioökonomischen Organisation der neolithischen Dörfer spielten. Explorative Verfahren wie die Korrespondenzanalyse unterstützen diese Interpretationen.*

Stichworte: Neolithikum, Westschweiz, Seeufersiedlungen, Faunenreste, Jagd, Tierhaltung

Skilled Resource Management. Exploitation of bone and antler raw materials in Neolithic pile dwellings of Sutz-Lattrigen, Switzerland. In preparation.

Manar Kerdy, Jörg Schibler

Abstract

This paper deals with bone and antler tools from Neolithic lakeside settlements at the southern shores of Lake Bienne. The bay of Sutz-Lattrigen holds one of the best known Neolithic wetland sites in the western part of Switzerland. During excavations, numerous bone and antler artefacts as well as waste material from manufacturing activities came to light from three settlements: Sutz-Lattrigen Hafen lower layer US, upper layer OS and Sutz-Lattrigen Aussen.

Tool production consists not only of manufacturing activity aimed at particular tasks, but also comprised traditions of manufacturing know-how in production techniques for exploiting the available fauna sources. The intent here is to present these magnificent assemblages by focusing on the artefacts from resource exploitation. Raw material efficiency, technical style, knowledge of production and availability are the reasons a skeletal element from one species or another might have been chosen to manufacture a specific artefact type. Raw material properties played a certain role in the choice of materials and technologies for producing bone artefacts leading to a non-culturally determined standardisation of ancient artisans' techniques. The development of tools made of red deer antler was a response to maximise the use of available raw materials resulting in a decrease of waste. Exploratory procedures, such as exploitation-factor support these interpretations.

Keywords

Neolithic, lakeside, Sutz-Lattrigen, Raw Material, Bone and Antler tools.

Introduction

Where and how did people in the Neolithic get their raw material for producing tools? What are the criteria for selecting certain raw materials? Was the choice of raw material influenced by rational reasons like shape, size, solidness, strength or technological advantages or were people following "cultural stereotypes" dependent on cultural traditions? Why was antler chosen to produce artefacts? How much influence did these factors (knowledge of production, availability, efficiency, symbolism, culturally attributed properties) have on the tool production system? Why did some available animal bones remain unused?

The present study aims to find answers to the questions what is the most important criteria of raw material selection for producing bone and antler tools. Was raw material selection only based on availability, on cultural influences or on technological advantages and how important are these criteria?

The bone and antler tools discussed in this paper come from three lakeside settlements located on the southern shore of Lake Bienne: Sutz-Lattrigen Hafen site comprises two layers; lower layer US (3834-3820 BC) and upper layer OS (3641-3631 BC) both layers belong to the Cortaillod Culture, and Sutz-Lattrigen Aussen (3201-3047 BC) assigned to the Horgen Culture.

Sutz-Lattrigen sites are located on the southern shore of the lake, 4 km southwest of the lake's outflow (Fig. 1). The sites are situated some 150m from each other and were originally found on the shore of a large, shallow bay (Hafner and Suter 2000). The rich assemblages that came to light at Sutz-Lattrigen settlements were collected during an underwater excavation conducted by the archaeological service of the canton of Berne in 1988 to the beginning of the present century. These settlements are ideal for this kind of research because of the excellent conditions of preservation of organic material and the possibility of exact dating by dendrochronology due to anaerobic conditions below the water table (Choyke and Schibler 2007). Rescue excavation at the sites therefore revealed very well preserved organic remains such as botanic remains, wooden artefacts, animal bones/tooth and antler tools as well as ceramic potsherds (Fig. 2).

Material and Methods

During the excavation of the Cortaillod settlement of Sutz-Lattrigen Hafen US, 63 osseous and 36 antler tools were found. In the Cortaillod settlement of Sutz-Lattrigen Hafen OS, 149 osseous- and 53 antler tools were identified, while in the Horgen settlement of Sutz-Lattrigen Aussen 604 osseous 217 antler tools were registered.

First, the tool assemblages were osteologically identified to their animal species and skeletal parts. Due to the fact of the minor number of artefacts in both Sutz-Lattrigen Hafen assemblages, bone artefacts are summarised to large zoological groups e.g. (large ruminants, small ruminants, *Suidae*, *canidae*, and indet). The size grouping of osteological undefinable bone artefacts offers the advantage that even these artefacts can be used for analysing the question if for certain artefact types a certain compactness of bones must be used. On the other hand, the identification of the skeleton part tells us if certain forms of skeleton parts are more appropriate for certain artefact types or offer an easier and/or a faster production of the artefact. Therefore, this classification offers insights into raw material exploitation and the technical chains of operation available to craftspeople. The typological identification of the bone-and antler tools was based on the grouping system used for the worked bone and antler assemblage from the sites of Twann (Schibler 1981; Suter 1981) and the expanded system used in the study of Lake Zurich site materials (Schibler 1997).

In order to be able to decide whether certain animal species or skeleton parts have been preferred for the production of artefacts, the archaeozoological analysis of the "normal" faunal remains also have to be integrated in this analysis (ca. 1250 from Sutz-Lattrigen Hafen US, 3700 from Sutz-Lattrigen Hafen OS and 10,000 from Sutz-Lattrigen Aussen). A comparison between the percentage values for the animal species and/or skeleton parts of the bone artefacts and the animal bone waste allows to calculating "exploiting-factors" (Schibler 1980). The percentages of the same animal species or skeleton part of the two lists are divided in the way that the larger number of the lists is always in the numerator and the smaller one in the denominator; so always a value over one (>1) will result. If the value of the artefact list is larger and therefore is in the numerator, the exploitation-factor gets a positive-sign (+). If the value of the bone waste is larger and, therefore, is in the numerator, the exploitation-factor gets a negative-sign (-). Animal species or skeleton parts with a positive exploitation-factor are over-represented in the artefacts list and therefore may be considered to be specially selected for the production of artefacts.

$$E = +\frac{A}{W} \quad or \quad \boldsymbol{E} = -\frac{W}{A}$$

E = Exploitation-factor

A= Value percentage of species or skeleton parts in the artefacts list

W= Value percentage of species or skeleton parts in the waste bones list

Results

The know-how of resources management

The raw materials required for the osseous tools produced at Sutz-Lattrigen settlements come mainly from large ruminants such as cattle (*Bos taurus)* and red deer (*Cervus elaphus).* Bones from small ruminants such as sheep (*Ovis aries)*, goat (*Capra hircus)* or roe deer (*Capreolus capreolus*) were also strongly exploited. Domestic pig (*Sus dom*esticus) and wild boar (*Sus scrofa)* were as well frequently used as raw material sources, while dog (*Canis familiaris*) bones or smaller size animals played a minor role in the tool production (Fig. 3).

All these species were exploited for their meat as well as for other by-products. In both layers at Sutz-Lattrigen Hafen ca. 70% and in Sutz-Lattrigen Aussen ca. 90% of the slaughtered animals were domestic animals (Kerdy *et al.* 2018), indicating that bone and teeth of domestic animals as raw materials were easily accessible within the settlement. The species examination of the bone artefacts from the three settlements (two Cortaillod and one Horgen) correlate nicely showing that there was in the Horgen settlement a progressive increase with which domestic animal bones were made into artefacts (Fig. 4).

Among the large ruminants, a decrease in the frequency with which these animals were used as raw material is significant. Cattle and red deer bone were more used in the Cortaillod culture than later on in the Horgen culture. On the other hand, the number of tools made from pig bones, mainly domestic pig, has increased massively since the end of the 4^{th} Millennium. This can also be observed for the faunal material in the Horgen period. Based on NISP domestic pig bones comprises up to 90% of the domestic assemblage in the Horgen period. Similar results were observed at the, more or less contemporary site of Twann in the Horgen units (Furger 1981). The comparison of raw material exploitation in the sites Sutz-Lattrigen and Twann show identical results for the selection of animal species and skeleton parts. Except for the pig in the Horgen period in Twann, no different results can be seen. The comparison shows that *Suidae* and small ruminants were favoured in the second half of the 4^{th} Millennium over cattle bones (Fig. 5).

The exploitation of the small ruminants, predominantly from sheep/goat is steady in all periods. Even though the proportion of sheep, goat and roe deer bones in all settlements is ca. 5% of the faunal remains, small ruminants, mainly caprine skeleton components were enormously selected to produce artefacts (up to 35% in Sutz-Lattrigen Hafen US) (Fig. 3).

This intensive exploitation of skeletal components of the small ruminants has resulted in high exploitation-factors. Sheep, goat and roe deer were the most valuable source of raw material to produce bone tools. For pig, the intensification of skeleton parts used as raw material source started with the 37^{th} century BC and kept being important in the 32^{nd} century BC in the settlement of Sutz-Lattrigen Aussen resulting in high exploitation-factors while large ruminant's importance remains low. (Fig. 6).

Body parts exploitation

The osteological examination of all bone artefacts without regard to the species in the three settlements of Sutz-Lattrigen shows that metapodials in both cultures are the most important body part for artefacts production (Fig. 7). The metapodials and especially metatarsus were massively used which may be the result of the sulcus at the coalescence suture between raw III and IV that facilitate cutting the bone in halves. This sulcus could serve as a guideway for a flint tool in the longitudinal division of ruminant bones, a customary procedure in the making of artefacts (Schibler 1980). The great importance of the metapodium and the tibia in the layer of Sutz-Lattrigen Hafen US is eventually connected with the importance of the large ruminants in this period. Later, the importance of metapodium has decreased to the favour of the ribs and other components such as the fibula and the teeth which corresponds with the increase of the importance of pig. Ulna, radius and the rest of the animal skeleton were used occasionally.

The significance of Antler as raw material sources

In contrast to the bone and tooth, other raw materials from animals were gathered seasonally. This is certainly the case for red deer antler. Red deer and other antler-bearing mammals typically shed their antlers around the same window of time, year after year. By early April most bucks will have dropped their antlers.

Antler as a raw material played a significant role at all pile dwelling settlements in Switzerland although the importance of antler greatly fluctuates during the fourth millennium BC. Yet, the number of bone and antler artefacts allow us to establish their proportion of each assemblage and their significance as raw material. It is possible to highlight a clear decrease of bone tools in favour of tools made from antler. The ratio percentage of bone to antler tools in both Sutz-Lattrigen Hafen assemblages is averagely 75% to 25% and in Sutz-Lattrigen Aussen 55% to 45% (Fig. 8).

These results correspond perfectly with trends observed at several other lake dwellings sites at lake Bienne between the 39th BC- and the 32nd BC. At the earlier settlements, bone was more frequently worked into tools, whereas in the later settlements antler was more regularly employed mainly to produce sleeves and sockets. This increase in the use of antler did not take place in a direct way. Several fluctuations in the use of antler appear mainly during the 39th and 37th, 36th centuries BC. These are the periods where red deer was over hunted during periods when food resources were scarce (Schibler 2001).

The lack of usable raw materials due to over-hunting of red deer lowered the availability of shed antler and therefore the proportion of antler artefacts that could be made. The ratio of bone tools therefore increased commensurately. Regular domination of bone tools over antler objects (up to 80% of the total worked osseous objects) has also been observed in sites on the shores of Lake Zurich and Constance during the 4th millennium (Deschler-Erb *et al* 2002; Schibler 1997). At the beginning of the 32nd century, antler became more common. Up to 50% of antler production was connected to the intensive production and the use of antler sleeves mostly during the Horgen and Corded Ware Cultures.

Antler sleeves were used as intermediate, shock absorbers to protect ground stone blades and the valuable wooden handle of axes and adzes. They were used to fit stone axes into the wooden handle socket (Schibler 2013). Sleeves also served to produce lighter tools and to save broken stone blades from getting lost. The sleeves and sockets were very rarely produced before 4000 BC in the northern alpine region as stone axes were embedded directly in the wooden handle (Schibler 2013). Then, during the first half of the 4th Millennium sockets became more produced in several shapes and used regularly.

However, despite the typo-chronological development of sleeve and sockets typologically observed between the first and the second half of the fourth millennium (Cortaillod and Horgen cultures) (Fig. 9), the manufacturing processes themselves remain relatively similar. From a technical perspective, the only feature that changes are the management of the raw material (the antler). The antler was exploited more precisely and efficiently especially by the intensification of using the middle and upper sections of the antler during the Horgen culture which caused a decrease in the refuse and maximises the use of antler (Fig. 10) after most of the Cortaillod tools were made from the basal part.

Red deer antler remains a valuable raw material through the Bronze Age, often used to produce elaborated, complex objects and ornaments while the quality of planned bone working is generally much reduced (Sofaer *et al* 2013; Choyke 2010).

Discussion

As Lemonnier (1993) and Luik (2009) puts it, the choice of a certain technique, raw material or tool type may sometimes depend on some attributed symbolic value as much as on their real physical properties. On the other hand, according to Luik (2011), when looking at bone tools carefully, even where the shape of the artefacts is similar, the manufacturing techniques were different. Do manufacturing differences represent craftspeople with different cultural traditions or did the craftspeople develop an easier, faster way to produce the same bone tools? Usually, species dominance reflects the application for certain functions of the artefacts. With bones from large ruminants, harder materials like wood or antler (Schibler 2001) can be worked. Bones of small ruminants were predominantly used for soft materials like leather or textiles. Also, the choices of raw materials made with respect to the manufacturing process could represent both Know-how skills and knowledge of properties.

Yet, the large number of tools made from metapodials of large ruminants is evidently connected with the fact these metapodials are long and straight and can easily be separated in two axially symmetric parts incorporating parts of the epiphyses as handles, making them suitable for producing a large variety of artefacts, especially points and chisels (Schibler 1980). Also the majority of the unidentified long bones may very well have come from metapodials. Other skeletal elements were also selected because they were used to produce tools connected to specific production activities. For instance, pig fibulae were often used to make pins and points. Pig as well as caprine tibiae were used to make scrapers. Ribs were most frequently used for producing artefacts with active pointed ends.

Further, the systematic choice of bony raw materials, mainly small ruminants metapodials, and pig canine teeth first separated from the animal body, perhaps when the hide was removed during the butchering process suggests that the bone industry at the Sutz-Lattrigen sites did not depend on kitchen waste but rather bones as raw materials were carefully chosen and extracted to be used later in tool manufacturing presenting a skilled knowledge of raw materials properties. The raw materials selected to manufacture the worked bone from the Neolithic pile dwellings sites in the west of Switzerland during the Cortaillod and Horgen cultures (e.g. Twann, Sutz-Lattrigen Hauptstation Innen, St. Blaise) (see. Schibler 1981; Suter 1981; Kissling 2010; Bartosiewicz and Choyke 1994) are very similar to the osseous materials selected for making tools at the Sutz-Lattrigen Hafen and Aussen settlements arguing strongly for the know-how of the common physical of the bony raw materials.

Choice of which animals and skeletal elements should be selected for making tools must have depended on several circumstances such as a combination of raw material physical properties, availability, appropriateness of the shape of the skeletal element and the implementation of the tool. The domination of ruminant body parts especially metapodials, lower canine teeth of a male pig and pig fibula have to be due to the physical characteristics of these elements. Pig teeth can be worked as a very sharp edged tool to be used in wooden work, such as scraping and scratching arrows or bows, or as a knife in order to expand the cancellous bone during the preparation of antler sleeve (Maigrot 2005) while pointed head tool from e.g. Fibula could be ideally used in textile production, playing drill function (Wojtczak and Kerdy 2018). On the other hand, the straightness, density, potentially usable length of the metapodials is ideally to produce tools especially awls or chisels. Metapodials from large ruminants have a thick compacta and a large regular area with a dense bone cortex that enables the extraction of thin rods to fashion points, pins and or sewing needles (Colominas 2013). Further, metapodials, not bearing meat, are often removed from the carcass during initial dressing (Binford 1978) while obtaining for example femurs rips would require a former removal of large amounts of meat. In fact, big massive points in the Sutz-Lattrigen settlements are made of bones from large species (red deer, cattle), while most points are made of bones from smaller species (sheep, goat, roe deer) which could be explained that points from large strong Ruminants were used to work hard material such as the wood and antler while points from small ruminants were mostly used for working softer materials e.g. textile and leather.

However, acquisition and management of raw materials changed also significantly as the economy changed. The rise in the numbers of pig individuals kept at the settlement of Sutz-Lattrigen Aussen automatically led to an increase of the tools made from pig bones showing that craftspeople have adapted their economic change of fauna and explored their raw material resourcefully.

However, both for economic and functional reasons, the physical properties and availability of raw materials are also possible reasons why particular skeletal elements were chosen for manufacturing tools.

Thus, human choice played an active role in the manufacture of bone artefacts as is readily apparent in the recurrent patterns of raw material choice found in Sutz-Lattrigen worked tool assemblages. This is not to suggest that decisions were made at every level for each tool. Most tool types were made on more than one kind of skeletal element. The choice of species and body part for the bone tools appears to be influenced by the practical consideration of shape, strength and obtainability in all of the assemblages as well as the advantage of production and ease of use. Metapodials and pig teeth are easy to fabricate into a tool which requires less labour in compared to other skeletal elements such as the humorous or tibia.

Nevertheless, in the matter of antler exploitation for producing tools, changes in the quantity of bone to antler artefacts is noticed. Antler has been shown to be more resistant to shock and more elastic than bone. It is much less likely to shatter when subjected to being struck and it requires considerably more strength to break it (Curry J. D. 1970), therefore antler was preferred for making sleeves. Thus, the archaeological record sees an increase in the use of antler as a significant raw material toward the end of the fourth millennium. At the beginning of the 32nd century, antler became more common. Up to 50% of antler production was connected to the intensive production and the use of antler sleeves mostly during the Horgen and cultures, when almost all stone axes were held in antler sleeves (Schibler 1997).

This increase is linked to and influenced by two factors: The fundamental efficiency of the tools produced for certain kinds of tasks; and the creation of more stable, functional and efficient tools that were produced from the whole antler. This led to an increased reliance on antler as a raw material and developed know-how of collecting probably only shed antler from the Late Neolithic period. Craftspeople in the Late Neolithic at lakeshore sites and at the site of Sutz-Lattrigen Aussen in particular profoundly changed their strategies for obtaining this raw material.

The economic and the availability of the raw materials also may affect the manufacturing process. J. Schibler (1997), in his study of the antler tools from Zurich lakeshore sites made a clear and direct connection between the exploitation of red deer antler as a raw material and the hunting intensification of red deer. During times of food equilibrium with low intensity of red deer hunting, the proportion of antler tools at these sites was greater than bone tools. On the other hand, during phases of economic crisis when red deer was intensely hunted and even bones of young red deer were abundant in the faunal material, the proportions of antler artefacts were low. Intense hunting of red deer, especially males, prevent the sustainable supply of antler that normally is guaranteed by collecting shed antler in late winter/early spring period.

Why? Weren't bone sources available enough? Why have people changed their strategies of raw materials exploitation? First, during the period of intensive hunting of red deer, several young deer were targeted resulting in the lack of antler from the adult, strong deer (Schibler 2001). A correlation between the increase of red deer bone proportion and decrease of artefacts made from antler can be noticed at the assemblages of Sutz-Lattrigen. Second, most of the tools made from antler in the assemblages of Sutz-Lattrigen comes from shedding red deer antler collected during the early spring when bucks drop their antler racks. This suggests that antler was not procured during this period by hunting but mostly by regular, planned collecting. Third, the antler raw material refuse has decreased during the Horgen period due to the use of the most parts of the antler and the high demand of antler tools for the wooded activities.

Conclusions

The evidence and discussion presented above allow us to conclude about how the Neolithic artisans of Sutz-Lattrigen developed and refined a system of the procurement and use of raw materials. The bone and antler analyses of assemblages indicate skilful toolkit production and development of innovative ways of using available raw materials to cover the raw material and functional demands of the tools they needed.

Raw materials properties, physical characterisation, length, shape, anatomical features and the availability of fauna around the settlement greatly influenced the technical choices people could choose from metapodials of caprinae, tibia, lower canine teeth of pig male animals, fibula and rips.

The choice of species for antler tools are regular and structured while the quality of the workmanship remains remarkably high, especially as concerns the skill needed to produce sleeves and sockets. This high level of the manufacturing technique suggests that technical innovations were probably first made by the more skilled members of the community and then adopted by the remainder of the population over time).

The manufacturing trends in traditions of bone tool production are markedly similar throughout all lakeshore sites in Switzerland reflecting a long-term continuity. Very likely, bone tool production represented a strong and widespread tradition and represents a technical continuum over broad regions and periods as parts of stable technological horizons. The technical style connected with antler tool production, however, is much more variable and associated with innovative technical approaches of woodworking that responded to new subsistence needs in everyday life at these lakeside settlements.

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Fig. 1: The location of Sutz-Lattrigen.

Fig. 2: The location of Sutz-Lattrigen Hafen both layers and Sutz-Lattrigen Aussen with the datation.

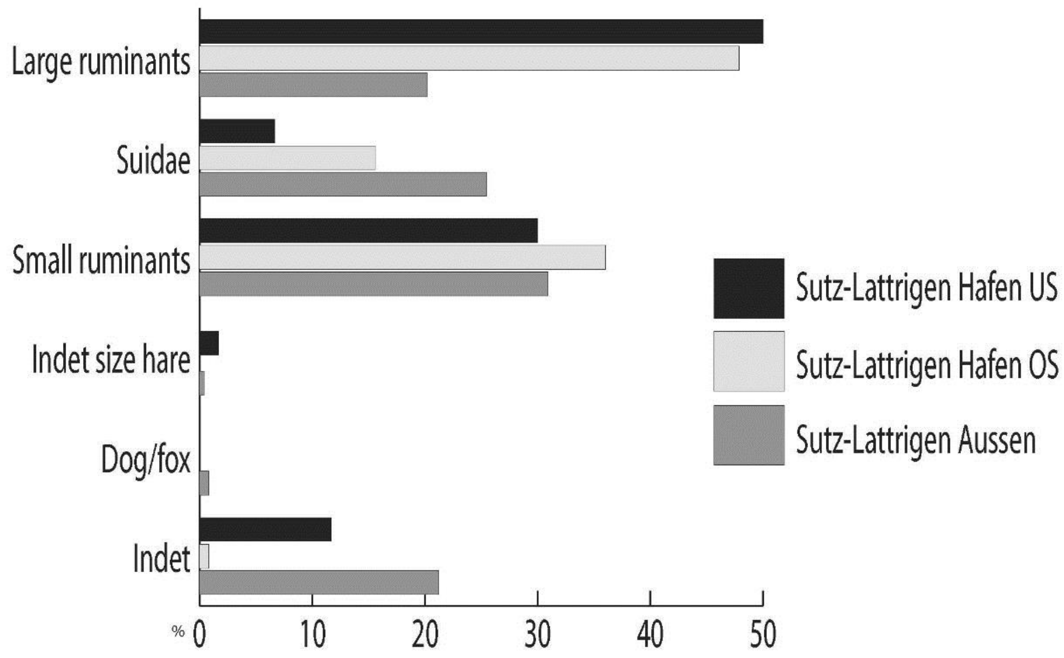

Fig. 3: The frequency of animal groups (Large Ruminant= cattle, red deer. Suidae= domestic and wild pig. Small ruminant= sheep, goat, roe deer) identified by the osseous artefacts.

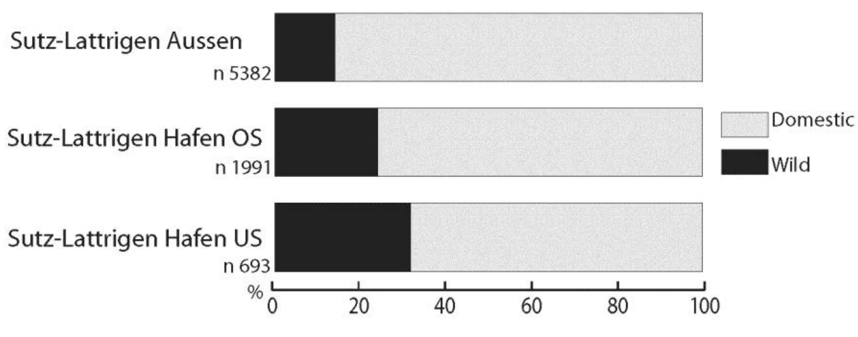

Fig. 4: The frequency of wild/domestic faunal remains as raw materials for producing artefacts.

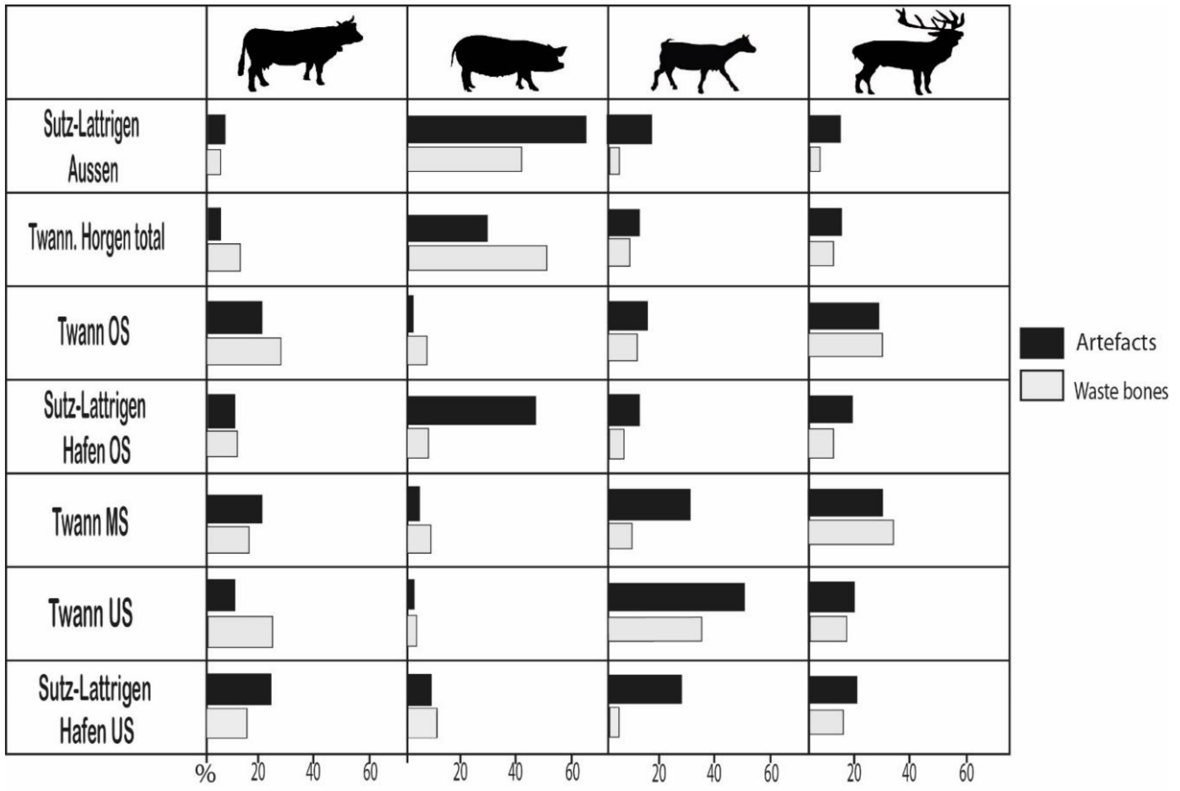

Fig. 5: The percentage of artefacts/waste bones of the most represent animal groups (cattle represents large ruminants, pig represents *Suidae* and goat represents small ruminants) in Sutz-Lattrigen settlements and Twann (Cortaillod and Horgen periods). Twann data after (Furger 1981; Schibler 1980).

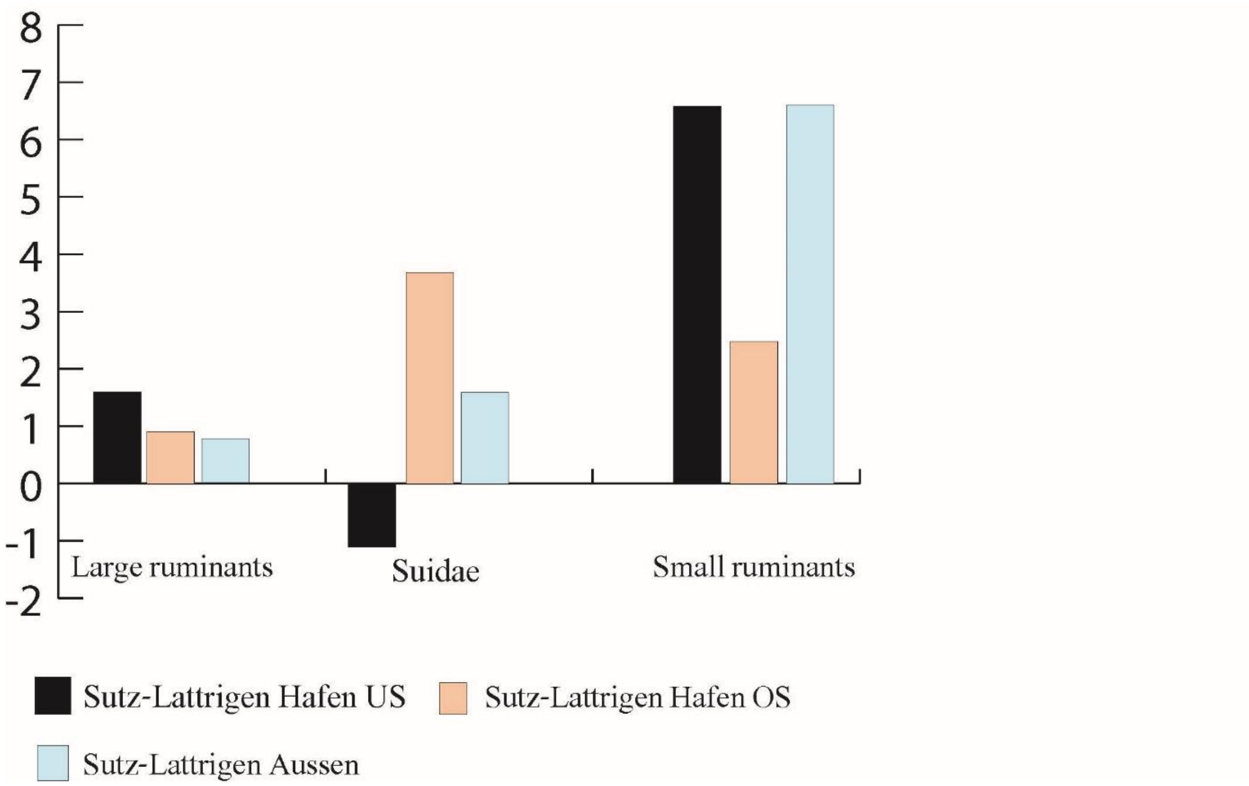

Fig. 6: Exploitation-factor of the most represented species.

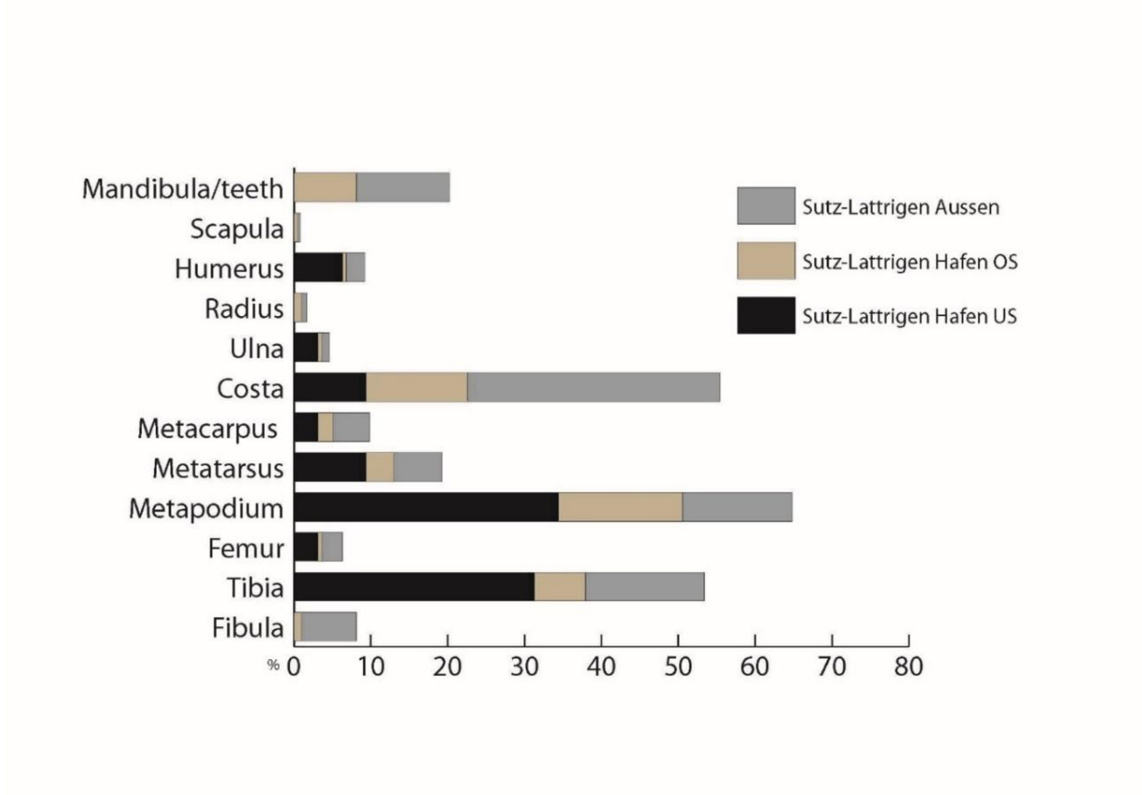

Fig. 7: The body parts used to produce bone artefacts. (regardless of animal species).

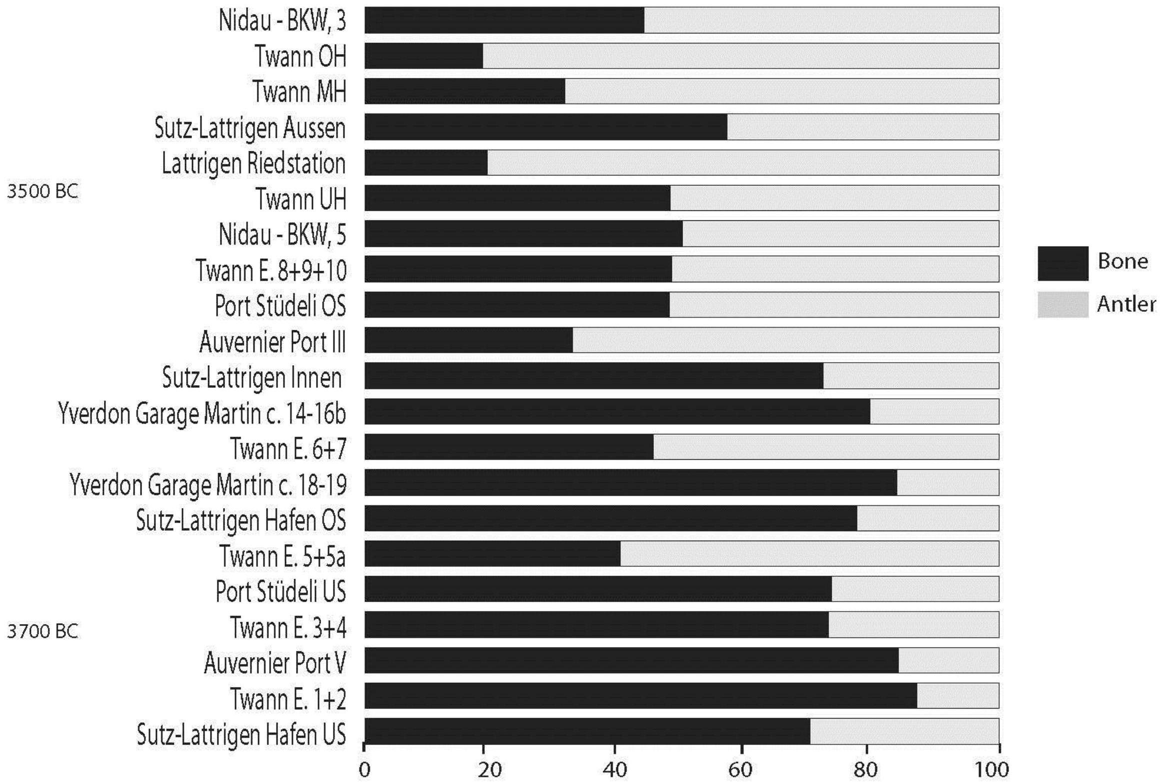

Fig. 8: The ratio of bone to antler tools in Sutz-Lattrigen and other lake sides around Lake Bienne. (Data after Schibler 2000; Hafner/Suter 2000; Suter 1981; Schibler 2003; Winiger 1991; Kissling 2010).

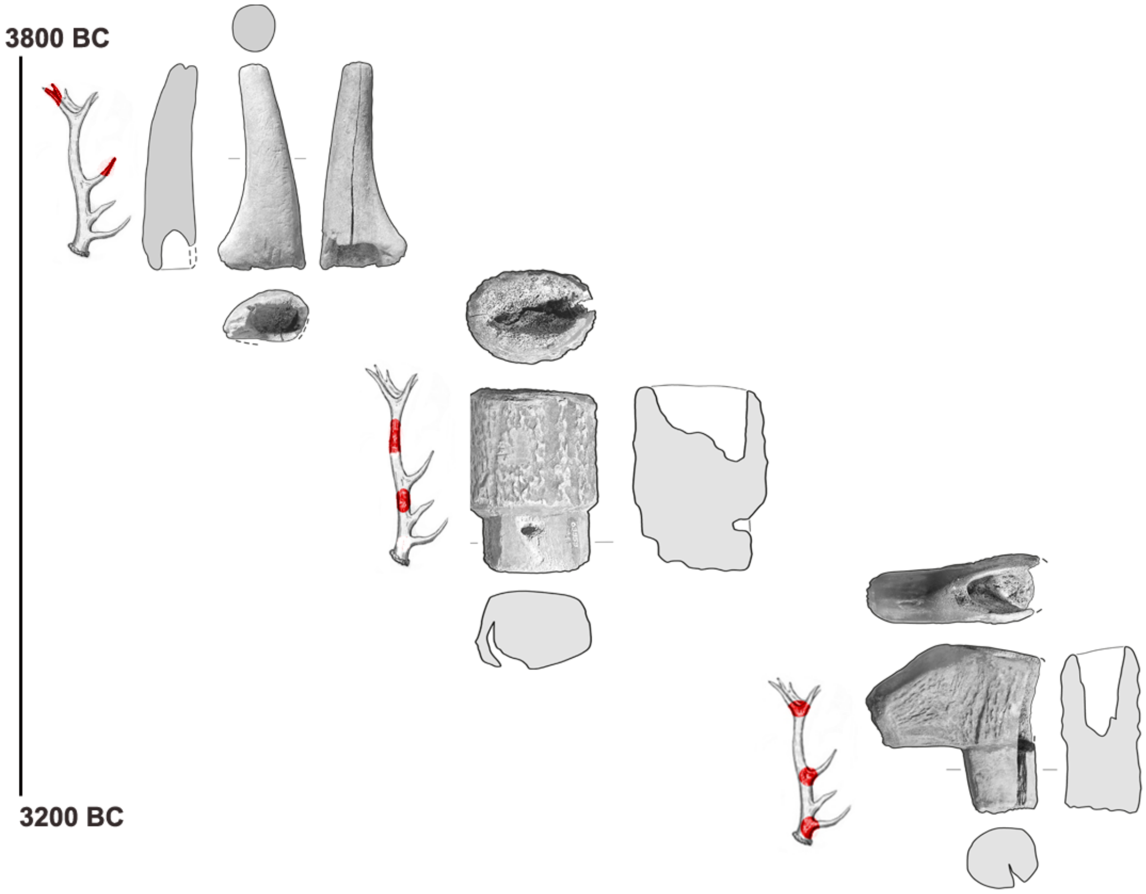

Fig. 9: The percentage of antler waste product.

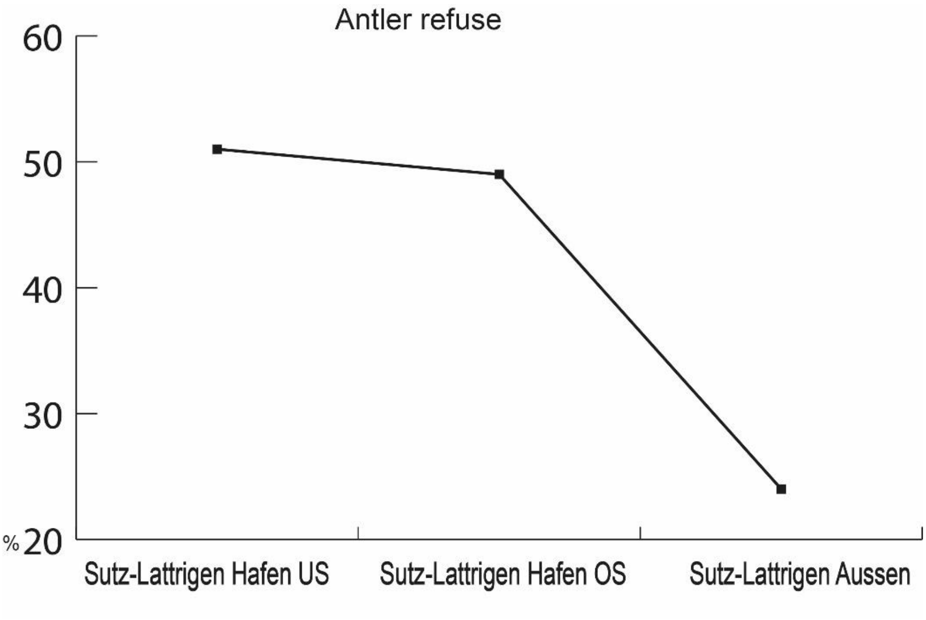

Fig. 10: The development of antler exploitation as raw material to produce variety of tools in the 4th Millennium.

4. Results

4.1 Specimens identification and ageing

Most of the identified specimens belong to mammals, mainly domestic, with about 25% of wild species in Sutz-Lattrigen Hafen both layers and ca. 10% in Sutz-Lattrigen Aussen. (Tab. 1-3) Domestic animals represent more than 75% of the NISP of all mammals identified in Sutz-Lattrigen Hafen US/OS layers and over 90% in Sutz-Lattrigen Aussen. The five major domestic animals, cattle, pig, sheep, goat, and dog, are found in all Neolithic assemblages of Sutz-Lattrigen for which bones have been recovered in any number, but over time, there were changes in the numbers and the ages to which they were kept. Horse remains are absent in all settlements. Domestic cattle, together with sheep, goat pig, and dog, have been present in Switzerland since the earliest Neolithic (ca. 5000 BC) (Schibler and Schlumbaum 2007). Like cattle and pig but unlike sheep and goat, they co-existed in Switzerland with their wild ancestor (*Sus scrofa*), (*Bos premiginius*). Among the wild mammals, red deer is predominant, followed by roe deer, wild boar, and aurochs. The other species (marten, fox, wolf, hare, beaver, and hedgehog) are represented only by a few remains.

4.1.1 Cattle

The remains of cattle in both settlements of Sutz-Lattrigen Hafen greatly outweigh the remains of all other domestic taxa dominating around 40% of identified faunal remains. When the assemblages are compared to the faunal remains of the Horgen period of Sutz-Lattrigen Aussen, the cattle fall below the domestic pig which makes about 60% of the identified faunal remains (Tab. 1-3). Table 5 and 6 indicate that there is no uneven distribution in the age classes of the domestic cattle remains. Very few bones are from calves of less than one year, and most of the unfused bones come from young animals of between 18 months and 3 years which is the optimum age of slaughter for meat. However, most of the bones of domestic cattle are fully fused (63%) in Sutz-Lattrigen Hafen US, (61%) in Sutz-Lattrigen Hafen OS and (56%) in Sutz-Lattrigen Aussen (Tab. 5), and, therefore, from animals of more than 3 years, which correlate with the results on the age of cattle from other Neolithic sites in western Switzerland (Becker and Johansson 1981; Clutton-Brock 1990).

Limb bone of cattle that was measurable in the assemblage of Sutz-Lattrigen Aussen (metacarpus III-IV-length 179 mm, gave an estimated withers height (after Maltosci 1970) of 109.6 cm. The measurement does show that the range in size is similar to that of Twann where the withers height ranged from 100.9-114.4 cm for the domestic cattle in the Horgen settlements (Furger 1981).

4.1.2 Sheep/goat

The goat and sheep remains from Sutz-Lattrigen assemblages are presented under three categories in the tables. The categories are: sheep/goat, sheep and goat - these groups have been made due to the difficulty of separating bones into sheep and goat. The remains of sheep/goat within these categories are similarly found in all the assemblages with about 8%. The small percentages of sheep/goat remain from Sutz-Lattrigen assemblages, compared to other domestic species such as pig and cattle, must be due to a number environmental and economic factors. Even though the hilly southern shore of Lake Bienne can be suitable for keeping sheep as a grazing animal, the importance of these species as meat sources is remarkably higher at the sites located on the northern steep side of Lake Bienne (Marti-Grädel and Stopp 1997). The importance of the sheep has increased later at the end phase of the Neolithic period possibly due to the exploitation of wool.

As is usual with domestic animals, a high proportion of the sheep and goat remains are from juvenile animals, as shown in (Tab. 7) for the state of epiphyseal fusion of the bones. In the assemblages of Sutz-Lattrigen Aussen, (53%) of the remains are non-fully fused or unfused bone. Due to the limited number of remains, no available statistic from teeth eruption was possible.

4.1.3 Domestic pig

Usually, Pigs are used as a source of meat and rarely skin but unlike cattle and sheep/goat offer a few profits of secondary products. According to the numbers of elements identified as domestic pig, wild pig and *Sus sp.*, swine were the principal meat-providing animals at Sutz-Lattrigen Aussen and second most important at both settlements of Sutz-Lattrigen Hafen (Tab. 1-3). The taxon *Sus sp.* or (domestic/wild pig) has been used for the bones and teeth of swine that were not distinguishable between the wild and domestic, either because they come from intermediate size or from young animals.

Pig remains have increased remarkably during the Horgen period of Sutz-Lattrigen Aussen. This phenome is discussed in this research paper (Kerdy *et al.* 2018). The high fecundity and multiple litters compared to cattle and ovicaprids mean that the slaughter of large numbers of individuals before or just after the body reaches maturation or optimum size has little impact on the group size (Frosdick 2014).

The bone and teeth ageing of domestic pig represent a high proportion of juvenile. This can be seen in (Tab. 8). In the assemblage of Sutz-Lattrigen Hafen US, (82%) of the bone remains have non-fully fused epiphyseal, while in Sutz-Lattrigen Hafen OS it drops to 69% and again with very high proportion of none-fully fused bone (79%) remains of pigs are found in Sutz-Lattrigen Aussen. Unfortunately, the teeth remain from premolars and molars are very minor (Tab. 9) and statistically not accurate to be considered as most of the pig teeth remains are canines which are hardly determined by their eruption. This results indicate that some breeding of the pigs was made within the settlement. The high proportion of Sub-adult and Juvenile is eventually connected to the fact that pigs are kept solely for their meat and will be slaughtered when the body reaches ideal size. This could be due to a backyard economy type strategy with each individual household keeping and raising a small herd of pigs.

4.1.4 Red deer

Among wild animals, a fluctuation is observed between the assemblages of the Sutz-Lattrigen Hafen and Sutz-Lattrigen Aussen. The proportion of red deer outweigh dominantly all wild animals in both Sutz-Lattrigen Hafen settlements. On the other hand, the diversity of wild animals remains in Sutz-Lattrigen Aussen has increased significantly reducing the proportion of red deer to ca. 30% of the wild animal remains (Tab. 3). Other wild species have played an important role in the Horgen culture; i.e. wild pig, red fox and fishes. The diversity of wild animals is linked to the minor role of wild animal meat in the food system in the Horgen period (see. 5.5.1).

Red deer were killed primarily for their meat as well as for their antler that was used as raw material to produce artefacts. The majority of the red deer were fully adult, with the epiphyses full fused when they were killed (Tab. 10). The date of the teeth eruption is here too very minor.

The size of red deer has changed over time. During the period of the food crisis, intensive hunting of red deer led to overexploitation of these animals and induced a strong negative selection: the size of adult red deer diminished (Schibler and Steppan 1999). Thus, the intensification of red deer exploitation during food crisis periods influenced the size variability of the red deer population. Measurements on the breadth of the phalanx 1 proximal have shown that the red deer was much smaller in the settlement of 37th century compared to those of the 32th century where hunting was practised inconsiderably (Tab. 15; Fig. 10) (see 5.1.1).

4.2. Butchering

The mammalian remains from Sutz-Lattrigen settlements can be separated into three groups; Domestic animals that were kept at the settlement as house animals, wild animals that were hunted for their meat and small animals and carnivores that were probably killed either for their furs or as a sources of food. The different functions of these groups of animals are reflected in their age structure, as it can be presumed from the bones and teeth, and by the butchery marks of the bones. The remains of the fur-bearing animals and the beaver show some butchery marks and they were all almost adult when killed. All animals appear to have been butchered at the sites because all body parts of the most important meat animals are represented (see 4.2.1). The technique of butchery in Sutz-Lattrigen sites matches closely to those described for other Neolithic lakeshore sites in Switzerland. The inhabitants of Sutz-Lattrigen settlements didn't smash bones with a stone to extract the valuable narrow but with great exactness, they made small "cut" in the shafts so they were able to lift it out. This butchery skill has been already witnessed in other lakeshore sites around Sutz-Lattrigen as illustrated by the sites of Twann (Becker and Johansson 1981), and from Yvonand (Clutton-Brock 1990). Similarly, the opening of a "shaft" in the ramus of the mandibles of pigs to obtain the rich piece of marrow tissue as well as the canine of the male pig is paralleled at many sites in Switzerland (Clutton-Brock 1990) (Hüster-Plogmann/Schibler 1997) (Fig. 11).

A high percentage of the bone material from the three Sutz-Lattrigen settlements falls into the category of residue from slaughter and consumption, while a small part was used for the fabrication of implements or for producing artefacts. More than 70% of the material consists of strongly fragmented bones, reflected for example in the average weight of unidentified specimens: 2.3g in Sutz-Lattrigen Hafen US, 2.5g in Sutz-Lattrigen Hafen OS, and 2.8g in Sutz-Lattrigen Aussen. This figure points to intensive exploitation of animal carcasses, although only around 8% in each settlement shows a cut-mark or other special evidence of disarticulation, butchering or meat processing besides the fragmentation. Very few bones show any sign of malformation or diseases.

4.3 Skeletal representation

4.3.1 Cattle

The data from Sutz-Lattrigen Hafen US shows that the humerus, femur, ribs, vertebra and metapodial were the best represented postcranial elements in the assemblage. (Tab. 11; Fig. 12). These elements, except the metapodials, are major meat bearing elements suggest that the cattle remain from this period are almost certainly derived from food waste. The high number of skull group remains is connected eventually with the number of loose teeth, which is usually resistant to taphonomic processes and tend to have a high survivability in the ground. Similar results are observed in the settlement of Sutz-Lattrigen Hafen OS. The Skull group, Trunk and Autopodium are the most represented groups which indicating that the utilisation of meat around these elements is important. Later on, in the settlement of Sutz-Lattrigen Aussen, the bearing meat elements dropped off, only the Autopodium group and the remains of the Skull which could deliver other reasonable amount of protein and fat sources such as the mandibular muscles and the brain are dominating that hint at other underlying processes (Fig. 12).

The same results are seen when the n% and g% are compared in body parts groups. Exceptionally, a light increase in the g% on Sutz-Lattrigen Hafen US is seen which could be resulted by the fragmentation number of the Autopodium body parts. The butchering technique has apparently changed in the later phase of the 4th Millennium. However, the wide range of elements in both settlements of Sutz-Lattrigen Hafen could also suggest that the whole carcasses are brought into the settlement to be slaughtered rather than slaughtering occurring elsewhere, while in Sutz-Lattrigen Aussen slaughtering appeared to be done out of the settlement and only elements that are used in other purposes than meat value such as making artefacts have been brought to the settlements.

4.3.2 Sheep/goat

The data of the sheep/goat body parts utilisation reflects different results than the cattle. The proportion of the skull group has very minor importance while the most meat-bearing elements are very well presented, especially in the settlement of Sutz-Lattrigen Hafen US (Tab. 12; Fig. 13). Humerus, radius, femur, tibia and ribs are the most important remains. These are elements that all carry a portion of meat. The most representative parts are the distal end of humerus and tibia, the proximal end of the radius and the mandible pointing out at very focus “meat winning” butchery technique. It seems that at all sites the sheep/goat are driven to the settlement, where slaughter and butchering occurs on-site.

4.3.3 Domestic pig

The oldest period of Sutz-Lattrigen Hafen data shows very high proportions of crania, mandible, humerus, scapula, tibia and femur. As discussed previously, these elements represent major meat bearing bones (Tab. 13; Fig. 14). The crania may have been exploited for the brain, which can offer a high amount of fat. The big number of loose teeth with their good preservation condition can influence the statistics. In all periods of Sutz-Lattrigen settlements, high proportions of Stylopodium and Zygopodium group elements are observed (Fig. 14), which correspond to the major meat-bearing elements and pointing to domestic food waste. Again this suggests that meat procuring is the main process in the formation of Sutz-Lattrigen assemblages.

4.3.4 Red deer

The data for the body part of the red deer seems to fluctuate clearly between the settlements of Sutz-Lattrigen Hafen and Aussen. A very similar data is observed in both Sutz-Lattrigen Hafen assemblages (Tab. 14; Fig. 15). The cranial and trunk group elements are the least important while the Stylopodium and Autopodium group elements are dominating. Very high number of humerus and Femur is noticed suggesting that only body parts that are rich in meat are brought back to the settlement after hunting. In Sutz-Lattrigen Aussen, the Skull group has much higher importance when looked at both, the n% and g%. Possibly, the whole cranium of the red deer was brought back to the settlement. The high number of Autopodium elements could be connected to the need of the metapodials as raw materials to produce artefacts. It could also suggest that during the butchering process, heavy, strong body parts such as the femur, humerus and tibia have been removed during the butchery out of the settlement and only the head, the body of the red deer without the heavy bones but with the meat and the feet were transported back to the settlement to be butchered.

4.4 Teeth, worked bone and antler

To describe the important interactions between available raw materials, produced forms and technologies, all artefacts from bone, antler, and teeth assemblages have been typo/technologically analysed. This kind of analysis is being often conducted in pile dwelling settlements around Switzerland and especially in the western part represented by Twann, Burgäschisee, Vallon des Vaux, Yverdon and Concise (Schibler 1981; Schibler and Stampfli 1988; Sitterding 1972; Winiger 1992). Due to various factors, the preservation of the bone and antler tools is excellent. Because both Lattrigen assemblages lie below the water table, aerobic bacteria, which are to blame for corrosion, cannot damage organic materials. Thus, fruits, seeds, wood or even fragments of textiles are frequently preserved. (Choyke and

Schibler 2007). 92% of the Sutz-Lattrigen Hafen and 89% of the tools surfaces are in so good preserved condition where the original bone/antler and teeth surface is visible and polishing and manufacturing traces could be clearly observed.

4.4.1 Teeth

14 tools made from teeth were recorded in the settlements of Sutz-Lattrigen Hafen US/OS and 35 pieces were in Sutz-Lattrigen Aussen. Most of the tools were made from pig teeth (*Sus domesticus and Sus scrofa*) while some pieces were finished from dog teeth and beaver. Depending on pig's gender, pig's male mandibular was open either through the whole corpus basis, or a small cut was made in the middle of the corpus to help to pull out the canine. This cut could be used to gain the marrow as well (Fig. 11). The teeth tools were processed in several ways; pig tusks were either split in half prepared as lamella with a pointed head shaped by abrasion or a side retouch was applied on one side of the lamella to win sharp-edged tool.

Assumable, teeth tools were used in-house and field activities, while pointed head tool was used in textile in playing drill function or as chisel, side sharped-edged were active in wooden work such as scraping and scratching arrows, bows or being used as a knife in order to expand the cancellous bone during the preparation of antler sleeve (Maigrot 2005). One canine tooth of fox, one of dog and one of pig have a hole at one side of the tooth. These could be considered as amulets, or decoration objects as they do not show any macro and micro traces of their potential use. In the case of canines, the convex part of roots has been initially significantly abraded and then the hole perforated. Furthermore, the lamella of pig tooth has been shaped on both sides using abrasion technique; manufacturing striations are shallow, parallels and regularly distributed on the part of each side of the artefact (Fig. 15). The use of pig canine teeth as a knife has great advantages because of the combination of hard enamel and soft dentin. The hole made in the lamella permitted to fix and to carry the specimen around the neck, hand or another part of the body as a pendant. Microscopic observations allow us to state that perforations were made using a mechanical drill. This comment is based on the morphology and technical features of the perforated holes: the symmetry of the holes (Fig. 16) are conical (it implies drilling only from one side); the occurrence in the inner sides of a perforation of a particular stepped profile. (Campana 1989; Bonnardin 2007; Gurova *et al.* 2013). Thus it seems that the preparation of charms/amulet objects also followed a specific, short chaine opératoir: the choice of tooth or extraction of intended part of tooth (in the case of lamella from pig tooth), shaping by the abrasion technique and the mechanical drilling of the hole (Wojtczack and Kerdy 2018).

4.4.2 Bone tools

The main raw material used for production was from medium-sized ungulates metapodials especially sheep/goat. The larger part of the artefacts was made from long bones. In (Sutz-Lattrigen Hafen US/OS-Sutz-Lattrigen Aussen) (20- 47) tibiae, (61-76, including 5-13 determinable metacarpal and 8-31 metatarsal bones) metapodial bones, (2 -22) fibulae, (2 -9) femuri, (2 -3) radii and (2–8) humeri. (29-98) Ribs, (1-2) scapula, (2 -4) ulnae and (21-52) flat and mixture bones of mandibular, teeth etc. which could not be determined more precisely had also been used (Kerdy and Schibler in prep.). Most of the artefacts that could be identified only as made of a long bone are probably also made from metapodial bones. Other bones that could be identified more frequently were connected with a certain type of artefacts for which they were most suitable. For instance, pig fibulae were used to make pins and points, pig, but also sheep/goat tibiae were used to make scrapers. From flat bones, ribs were most frequently used (usually split longitudinally into two flat halves) for making artefacts with the pointed head as sort of a comb.

4.4.2.1 Projectile points

This category includes pieces of bone and antler that have been shaped with at least one end formed into a tapering tip that may be pointed, blunt or tanged. There are several projectile points of varied typology in all Sutz-Lattrigen assemblages (Tab. 16):

- Awls with articulation,
- Spear points without articulation,
- Double points with the thin-smoothed base
- Arrow points
- Needles and Harpoons.

The pointed tools are the most represented tools in the assemblages of Sutz-Lattrigen Hafen US/OS with 38% and Sutz-Lattrigen Aussen with 56%. Pointed tools present very diverse features. Among the pointed tools, the medium sized point without articulation is dominate, followed by flat-smoothed base points, double points and small-sized points with articulation. There are also many points made from split ribs and fibula.

In Sutz-Lattrigen Lattrigen Hafen US/OS, over 50% of the pointed tools are from ovicaprine metapodial followed by long bones splinters from big mammal and ribs while in Lattrigen Aussen the pointed ribs from pig are the most presented which is explained to the domination of pig bones rest in the settlement (over 70% of the consumed meat come from pig).

The process of making bone points, awls or chisels goes normally throw two steps, the making of blanks and the shaping of the blanks into the aimed tool. The techniques of production applied to produce the pointed tools are mostly similar on all points with an articulation. They were made by double associate technique “Sawing and Splitting” where all of the metapodials were abraded before they were cut in two longitudinal same-sized pieces.

Scraping, which is found on over 85% of the specimens, is a very common technique applied to the metapodial of both Lattrigen assemblages. Scraping is implemented by moving a blade in a direction perpendicular to the tool's long axis. This technique is obvious by long, sweeping striations often covering the total length of the diaphysis.

Silex flakes or graver made from bone, antler or silex could be used in the process of metapodials splitting as abrasive tools. Polishing and rubbing were applied afterwards in order to remove the cancellous bone and to get it ground. Traces of sawing mostly with a flint tool are visible on a lot of the Lattrigen's points.

4.4.2.2 Needles

This typology is represented by 6 small size needles. The shape and technique of preparation are similar in all needles. They were shaped from small split ribs or from a segment of a long bone. One needle was recorded in the assemblage of Lattrigen Hafen and five needles were observed in the assemblage of Lattrigen Aussen. The raw material used in making every needle is bone. The manufacturing technique employed on all needles is similar by using a flint tool, splinters of bones were extracted and shaved toughly to a thin pointed shape, and were shaped and polished afterwards by sandy or soft stone rubber.

4.4.2.3 Ornaments

The five tools in Sutz-Lattrigen Aussen and one piece in Sutz-Lattrigen Hafen OS examined were made from the lower canine of pig, dog, fox, and metapodial of Sheep/goat and one from red deer antler. The lower canines are thin flakes with one enamel side and another dentine one. Both the objects have one end with convergent edges, drilled in one side forming a hole. The wall of the hole has circular marks, which would suggest that a rounded perforator had been used. A lot of marks can also be seen on the dentine face.

4.4.2.4 Chisels

These artefacts with a sharp transverse edge were found in large number and represent the second most important bone tool in both Lattrigen assemblages. It consists mainly of big sized chisels (over 7cm long) made from long bone with a heavily used cutting edge and small-sized chisels made from ovicaprinae various bone. Some antler pieces and mostly from the tine were used to produce some chisels. Most of them show traces of hammering on the rear side which can clearly interpret their function as chisels.

The chisels could be defined into two groups

- The small chisels can be clearly distinguished from the other axes and chisels by raw material choice and thus represented by its massiveness and weight, as well as by the ratio of length to width. For these chisels mostly bones from ovicaprinae or from pig are used. Only two tools with a joint from pig fibula were found in the assemblages.

- Axe-shape and massive chisels without a joint. This form of cutting tools is identified through the absence of the joint and the raw material used for production and its transversal cutting edge. In the assemblages of Sutz-Lattrigen Hafen they are with the small chisels the most represented chisels type among the carving tools group. They were mostly fabricated from long bones splinters of large ruminants, rarely from the pig. Commonly for these tools is the use of the long bones of a skeleton, mostly tibia and femur due to its decisive and robustness which explains clearly why caprinae metapodials were not selected. Characteristically for the axes-shape tools the intensive use of the outer and inner bone surface where the medullary cavity is absence and the tool looks like an axe blade with an extreme polish on the working edge.

4.4.3 Antler tools

Antler tools have been found from various lakeshore archaeological sites in Switzerland (Suter 1981; Schibler 2013; Deschler-Erb *et al* 2002). In the assemblages of Sutz-Lattrigen Hafen only red deer (*Cervus elaphus*) antler was used for the production of the antler tools, while in the Sutz-Lattrigen Aussen 2 pieces of roe deer (*Capreolus capreolus*) and one of Elk (*Alces alces*) were found.

Several authors have developed a typological system to classify the antler tools into groups (Schwab 1971; Suter 1981; Schibler 1997; Winiger 1992). By applying this system, the antler tools of both Lattrigen assemblages have been identified into sleeve, sockets, weapon, pendants and wasted raw materials. Only sleeves and sockets will be described here.

4.4.3.1 Sleeves/sockets

In Switzerland, they are the most typical antler tool from lakeshore sites in the 4th Millennium generally and are well presented especially in Sutz-Lattrigen Aussen assemblage. They were made to fit stone axes into the wooden handle (Schibler 2013) to protect the stone blade and the wooden handle. Several shapes of sleeves/sockets were developed mostly during the 4th Millennium and were gradually used instead of the stone axes which more often fit directly into the wooden arm in the period before 4000 BC (Schibler 2013; Wyss 1994). It was necessary to produce lighter tools and to save broken stone blades from losing, that's why lighter stone axes were made and antler sleeves/sockets were embedded between the wooden handle and the stone blade.

Sleeves and sockets made from red deer are the most characteristic antler tool type (s) from lakeshore sites in the fourth millennium. Such objects are especially well represented in the Sutz-Lattrigen Aussen assemblage. The categories of worked antler at Sutz-Lattrigen settlements include the common sleeves and sockets made from a tine and beam such as Tine sleeves, Tenon sleeves, Spur and Winged sleeves and sleeves with transverse perforation "bird-beak" style. Furthermore, there are numerous examples of half-finished objects and relatively large amounts of refuse in the form of cut-off tines showing that such tools were manufactured on- site. Several types can be distinguished among the sleeves/sockets in the assemblage from Sutz-Lattrigen Aussen and Sutz-Lattrigen Hafen US/OS.

In the assemblages of both Sutz-Lattrigen sites several types of sleeves/sockets were classified; socketed sleeves, tine sleeves, perforating sleeves, tenon sleeves and sleeves with transverse perforation.

4.4.3.2 Tine sleeves

Tine sleeves are the oldest type of sleeves and were made from antler tines, mostly from the brow or bez tines and fastened into a slightly curved wooden arm (Fig. 17, A-F). The distal mortise is mostly oval shaped and offer a place for a tiny stone blade and always has polish traces. The length of these sleeves varies between 90-160 mm. These sleeves are characteristic for the Pfyn and Cortaillod cultures (Suter 1981; Schibler *et al.* 1997), in particular, these sleeves are the only type of sleeves represented in the assemblage of Sutz-Lattrigen Hafen US, contrary, only two pieces were found in Lattrigen Aussen assemblage. This absence of the tine sleeves in the Horgen culture might be linked to the development of more strength sleeves types which were made from antler beam and offer more stability during wooden work and more space for a bigger stone piece to be embedded in the sleeve.

4.4.3.3 Tenon sleeves

A shift in the antler working had taken new dimension when the tendency of the artisans' preference was towards longer sleeves, mainly using the beam of the antler rack and to accommodate larger stone blades (Fig. 17, G-H; Fig 18). The sleeves transformed fundamentally during the fourth millennium within both Sutz-Lattrigen assemblages into more efficient and stable shapes that offered more room for larger stone axe blades to be embedded in the sleeve. This configuration, in turn, provided more stability during heavy work with wood (Maigrot 2011).

These sleeves were made from the upper or lower straight beam segment, the crown is normally short and swelled, the shift between the crown and tenon gives the shape of seating area on the handle to avoid the penetration of the sleeve into the wooden arm. The length of the sleeve could range between 70-75mm (29n) sleeves were found in the assemblage of Lattrigen Aussen and are the dominated type. This type with its oval section could have held bigger stone blade than the tine sleeve.

4.4.3.4 Spur and winged sleeves

A technical shift took over when tine sockets were fitted in the enlarged head of wooden handle and finally a much-advanced technique was used by producing the sockets from the antler beam. In the second half of the 4th millennium, sleeves and sockets were produced with sort of setting line to prevent them from gouging into the wooden handle (Fig. 19) (Schibler 2013). This advanced technique kept evolving, resulting in sleeves with "bird-beak" style that were fastened in the wooden handle (Fig. 20 C-D). These types make a good use of antler and there is a minimum loss of raw material as they were produced from the fork, the basic and middle junctions of the antler (Maigrot 2005). While spur sleeves have played a role in the middle Neolithic, they start decreasing in favour of the winged sleeves which are characteristic for the Horgen period and the final Neolithic (Suter 1981). The extended wing out of the crown helps the sleeve from invading and wrecking into the wooden handle. To produce these types, the antler could be exploited efficiently as the sleeves can be produced using antler segments from the beam and tine junctures, the base or the middle segment of the antler beam. These types require less raw material but remain stable when in use. While spur sleeves can also be found in the Cortaillod assemblages in the region, their proportion starts decreasing in favour of winged sleeves which are characteristic for the Horgen period and later (Suter 1981). The extended wing created from the antler rack crown keeps the sleeve from protruding and damaging the wooden handle during use. Most of the tools display traces of high polish which could be due the maintaining of the tools with specific plant oil. Molecular and isotopic analysis on artefacts from Park-Opera site at Lake Zurich provided evidence for the archaeological hypothesis that the bone and antler artefacts were specific tools which were deliberately fashioned, and pre-treated and maintained with a preservative material based on plant oil likely from seeds of *Linum usitatissimum* (flax) and *Papaver somniferum* (poppy), with probably some contribution from *Corylus avellana* (hazelnut) and *Brassica rapa* (turnip) (Spangenberg et al. 2014) (Fig. 21).

However, despite the typo-chronological development of sleeve and sockets, typologically observed between the first and the second half of the fourth millennium (Pfyn, Cortaillod, and Horgen cultures), the manufacturing processes themselves remain fairly similar. From a technical perspective, two features have changed indicating cultural differences; the management of the raw material (the antler) and the technical use of the wooden handle. The antler was exploited more precisely and efficiently especially by the intensification of using the middle and upper sections during the Horgen culture after most of the Pfyn and Cortaillod culture tools were made from the basal part or the lower and middle tines. The wooden handle was used also differently; in the eastern part of Switzerland cutting wood to fall tree was accomplished crossly while in the western part the technique was to work the wood in parallel shaft (Schibler 2013). This differences in woodworking have resulted in different shapes of sockets that fit with the applied technique.

Thus, in western Switzerland during classic Cortaillod, the sleeve and socket concept arrived from an outside culture group (Schüssenried) but was directly adjusted into a regional model (e.g. from socketed axe sleeves to perforating axe sleeves). This style appears to be better adapted to local traditions of direct hafting in the west of Switzerland showing that the artisanal tradition of direct hafting influenced technical choice (Pétrequin 1993). The working positions, the wooden handle, the technique for felling trees and woodworking (parallel/cross), the gestures and norms for sharpening the stone blades of the two tools are completely different.

The comparison between the parts of the antler rack is most efficiently used for producing tools clearly shows that the craftspeople focused on the more robust lower part of the antler closer to the burr. This raw material management may be linked to technical adaptation connected to innovation on the part of the manufacturers.

The local people living in both settlements of Sutz-Lattrigen improved the manufacture techniques of their tools based only on their need for certain kinds of tools to accomplish their tasks. There are two kinds of antler equipment. The first kind of antler tools comprises small tools used to manufacture objects like flint tools or butchering animal bodies (Maigrot 2011). The second, more numerous group of antler tools comprises heavy-duty tools such as sleeves or antler axes connected to environmental exploitation e.g. woodwork and construction of houses. Some of the antler axe/adzes in the eastern of Switzerland are decorated and their wooden handles are preserved. They are likely connected to some kind of ritual behaviour as well (Choyke per comm.) Inevitably, a balance had to be struck between the type and size of the axe/adze as well as the wooden handle, kinds of agriculture, woodworking, development in the local natural environment in the hinterland of a particular settlement that indicates a natural impact and cultural difference in doing the everyday jobs.

4.5 Use wear

The wear trace analyses of a small number of bone and antler specimens from late Neolithic site of Lattrigen Aussen showed that they were used in a variety of activities. Some of these activities are not detectable from actual artefacts gathered on site, but are only represented indirectly by micro-wear traces observed on the investigated specimens. Examples are bark and hide processing. One of the main features of this assemblage is the presence of a significant number of formally worked pointed implements (Wojtczak and Kerdy 2018). They seem to have been used for working with plant and animal material, but further use-wear studies should be undertaken to shed more light on their function. The results of the use-wear analyses of bones and antler implements could complement those of the functional, technological and typological analyses of the other artefact categories, particularly flint and stone as well as wood and vegetal fibre.

5. Syntheses

5.1 Subsistence's strategies and economic adaptions

5.1.1 The exploitation of wild resources

There are obviously several reasons why people have hunted wild animals in the Neolithic period, not all of which have would have concerned with the need for food (Serjeantson 2011). Hunting was practiced in the early phase of humanity in order to survive and obtain mainly meat. Obviously, the need for meat was not always the main hunting purpose; other needs such as antler and bone as raw material, fur, self-defence etc. were considered in the hunter mind. Red deer was hunted for the meat, skin, bone and, antler as raw materials even though it is possible to obtain it without killing the animal. Fox and beavers were hunted for their fur that can be used in textile production, wolves were hunted as they cause danger to house animals, deer and aurochs can also cause damage to cereal fields, therefore, they were also hunted and certainly hunting was kind of social practice to demonstrate the power over wild animals. In the Neolithic time, hunting was practised regularly beside husbandry and cultivation of plants but the importance of hunting was remarkably fluctuating. The hunting of wild animals is a means by which some farmers have counteracted food shortage. In some environments, during specific periods, farmers had to rely more on wild sources which have always been considered as "secondary" or "fall back" sources (Serjeantson 2011). Farmers, during poor harvest seasons, have partly turned back to their "hunter-gatherer" function in order to exploit urgently wild sources. In Sutz-Lattrigen settlements, a wide range of wild animals was found among the assemblages which can explain not only the nutrition system and hunting practices but also can offer many answers to the environment the hunters have to live in.

However, based on NISP, the ratio of domestic to wild animal gives, at first glance, an approximate idea of the importance of hunting over house animal keeping in the studied phases. However, the relative abundance of domestic and wild animals shows noticeable changes during the period of 4th Millennium BC in Sutz-Lattrigen. The first half of the Millennium show a much stronger intensification on hunting activities than later in the second half, especially in the 37th century BC. Red deer was the most important wild animal. This high proportion of wild animal (One-third of the eaten meat was consumed from wild animals) indicates primarily a steady intensification of hunting than the period later at the end of the Millennium. Red deer were the only wild animals that are present in the faunal assemblages of both Sutz-Lattrigen Hafen settlements in an enough high number to present a substantial percentage of the meat available to the inhabitants of Sutz-Lattrigen Hafen but not in the settlement of Sutz-Lattrigen Aussen. Why was more wild meat consumed in this phases? Why were domestic animal meats not enough to cover the daily demand for meat as it's the case in Horgen period? Were the tangible resources minor, so people needed to go out of their settlements to hunt wild animals and exploit wild plants?

The drastic economic change that happened in the 37th century where wild animal sources have been intensively hunted is observed not only in Lake Bienne sites (Twann, Sutz-Lattrigen etc.) but also in sites around Lake Zurich, Neuchatel, and other regions. The increased presentation of red deer is not witnessed only in one region but in all over the regions in Switzerland and abroad such as the French Jura (Arbogast 2010) which suggest that these regions have shared a common phenome that leads to this development.

A relation between short climatic fluctuations and intensive hunting, using the atmospheric 14C-content as a climatic proxy (Schibler 2006; Magny 1993) has shown strong correlations with climatic conditions. Low C14-concentrations being linked to warm and dry conditions and high C14-concentrations to wet and cold conditions. A comparison of the atmospheric C14-content between 4400 and 2700 and the proportions of hunted animals on the basis of bone fragments from Lake Zurich sites have confirmed this relationship. During short periods of climatic deterioration (cold/wet weather) the importance of hunting has increased: up to 80% of the consumed meat was game, mostly red deer. During periods of more favourable climatic conditions, hunting was not as important and therefore only up to 20% of the game was consumed (Schibler 2006; 2017).

However, in settlements that have a high frequency of wild animal bones, the number of species is significantly lower than in settlements where hunting played a less important role even when the sample size is large. This means that when Neolithic farmers were forced to hunt intensively wild animals, they determined their goals on hunting larger species to benefit as much as possible from their maximum amount of meat, therefore, red deer is the most dominant wild animal in most of the Neolithic assemblages in Switzerland (Schibler *et al.* 1997). The species diversity in Sutz-Lattrigen Hafen both layers can confirm this climatic fluctuation influences.

As stated above, the percentage of the wild animal in the 38th and 37th century in both Sutz-Lattrigen Hafen settlements is much higher than in the settlement of Sutz-Lattrigen Aussen dated to the 32nd century BC. The wild animal's diversity in both settlements of Sutz-Lattrigen Hafen is remarkably lower while the assemblage of Sutz-Lattrigen Aussen includes a wider range of species than earlier.

The importance of red deer proportion in both Sutz-Lattrigen Hafen settlements is greatly higher than later in the assemblage of the 32nd century BC. The proportion of red deer among wild animals reaches 82% in Sutz-Lattrigen Hafen while in Sutz-Lattrigen Aussen, only 33% of red deer proportion have been identified among wild animals. This means that, in the 38th and 37th century, almost only red deer have been hunted. This specific target of species refers to an economically stimulated hunting of large-sized mammals, focusing on species that offer the highest possible yield of meat. Interestingly, when hunting did take place, it targeted those "rich in meat" animals making the strategy sound very economically.

Furthermore, this tendency becomes evident, during periods of climatic deterioration in other regions, for example, during the food crisis of the 37th century BC, when wild animal bones constitute up to

80% of fauna in the Zurich area sites (Schibler and Jacomet 2010). During the 60-year period between 3660 and 3600 BC, intensive hunting of red deer in the Zurich region led to overexploitation of these animals and induced a strong negative selection: the size of adult red deer diminished (Schibler and Steppan 1999). Thus, the intensification of red deer exploitation during food crisis periods influenced the size variability of the red deer population. According to osteometric data from Lake Zurich, the intensification of red deer hunting led to a decrease in red deer size (Schibler and Steppan 1999). Do we have similar results in Sutz-Lattrigen? Or the witnessed phenomenon in Zurich is affected by the age at death or the sex ratio of red deer? Based on available osteometric results from both sites of Sutz-Lattrigen Hafen and Sutz-Lattrigen Aussen, the results are identical with Lake Zurich sites. Measurements on the breadth of the phalanx 1 proximal have shown that the red deer was much smaller in the settlement of the 37th century compared to those of the 32nd century where hunting was practised inconsiderably (Tab. 15; Fig. 10). Therefore, the climatic condition has in one hand forced the farmers to exploit their wild resources intensively and on the other hand led to a negative selection of wild species e.g. red deer causing a reduction in body size.

However, not only one but a number of climatic deterioration have been observed in the Alps and Alpine foreland during the Holocene (Jacomet *et al.* 1995; Schibler 2006). These weather fluctuations which can cause chilly and rainy summers resulting in a crop failure that can lead to starvations. The cereals are usually the most important calorie sources of the domestic plants and the most found plant remains in sites around Lake Bienne especially Barley (*Hordeum volgare*), Emmer (*Tritcum dicoccon*) and Nacked wheat (*T. aestivum turgidum*) (Gross *et al.* 1990; Brombacher and Marti-Grädel 1999; Brombacher 1997). Among wild plants, the plant rich in seeds and fruits are the most important and were systemically collected such as the hazelnuts (*Corylus avellana*), wild apples (*Malus sylvestris*) and different sorts of berries. Practically, it is difficult to determine if there was a decrease in cereal cultivation since the presence of plant remains is very influenced by the taphonomic and preservation conditions of the settlement and the plant itself e.g. pea has poor resistance to bad preservation condition when compared with wheat (Brombacher and Marti-Grädel 1999). Furthermore, events that lead to good preservation, like village fire, did not occur always when grain store was fully loaded (Schibler *et al.* 1997). Nevertheless, the cultural layers of the 37th century BC around Lake Bienne show a much less density of remains, especially the Linum (*L. usitatissimum*) than later on in the 32nd century BC even though the preservation conditions were very good. Unfortunately, we don't have a systematic botanical analysis of the site Sutz-Lattrigen Hafen but nevertheless, this phenome of a low density of domestic plant remains during the period where hunting was more intensified and was observed in other lakeshore sites around Lake Zurich. Additional sources must have used to cover the daily demand of needed nutrition for the people, and also because wild animal meat is not rich enough in calories, therefore, several wild plants, which are very rich in calories, protein and fat were intensively collected. In sites around Lake Bienne, the hazelnuts were the most important wild plant (100g=ca.600 Kcal, 15g protein) (Jacomet *et al.* 1989).

Summarising these findings, it becomes evident here that crop failures seem to be - during unfavourable climatic and weather conditions - very probable, considering both the zoological and botanical evidence. People obviously tried to compensate the lost calories by intensifying their hunting activities and surely also by collecting more fruits and wild plants rich in calories.

The increased red deer hunting in the villages of Sutz-Lattrigen Hafen during the period of occupation shows that there may have been some economic problems. Also there, hunting selection obviously led to a reduction in the size of red deer (Fig. 10; Tab. 15). In the somewhat later villages of the Sutz-Lattrigen region, where hunting was not so important, the values of red deer body size are clearly higher. Following this interpretation, the higher red deer LSI values at 3200 BC would be the sign of less hunting pressure during a favourable climatic period for farming.

5.1.2 Farming and food

The Neolithic farmers of Sutz-Lattrigen have farmed, managed their animals and lived their life. For a long time, it was taken for granted that people in lakeshore sites have practised a mix of farming, growing cereals as well as keeping animals. But what was more important in providing calories? The plant or the animal food. Several investigations at the shore sites of Lake Zurich have shown that the vegetable food component was more important in providing food gods to the people than the animal resources (Schibler *et al.* 1997). Model calculations have shown that about two-thirds of the calories were supplied by plant food resources and one third by animal resources. Cereals were dominant among the plant remains due to its high calorific contents delivering almost half of the needed calories (Gross *et al.* 1990). The archaeobotanical investigations in the late Neolithic period of Lake Bienne lakeshore sites (Nidau, Lüscherz, Sutz-Lattrigen VI, and Sutz-Lattrigen Hauptstation) have shown that cereals, especially naked wheat, barley, and emmer are dominant among the cultivated plants. Cereal weeds, flax, and opium poppy were also detected (Brombacher 1997).

Beside plant economy, the exploitation of domestic animals represents, after farming and hunting, the other important source of food supply. The animal keeping have played a significant role in the food system. The five major domestic animals (cattle, pig, sheep, goat and dog) have been all identified among the animals remains at all settlements of Sutz-Lattrigen. But, over time, and especially in the 4th Millennium, an economic change has taken place generally in the Neolithic period in Switzerland and it's very perceptible in Sutz-Lattrigen assemblages (Kerdy et. al. 2018; Schibler 2017; Schibler 2006). Several fluctuations have occurred mainly in the 37th century BC and the 34th century BC. An increase of the wild animal's proportion in the 37th century BC is witnessed. No increase of the domestic animals during crisis periods is noticed and later on, beginning in the 34th century BC the proportions of the individual domestic species has fluctuated. Cattle number are greater than those for other species in the first half of the Millennium in Sutz-Lattrigen Hafen, while pig's remains are dominant in the second half of the Millennia in the Horgen settlement of Sutz-Lattrigen Aussen. Sheep and Goat weren't abundant;

their representation is always less than 10%, but they were present in all phases of occupation at Sutz-Lattrigen settlements. Next to cattle, pig, and caprinae, the dog was represented in a minor rule.

If we look at the phenomes of these results, at the changes in the frequencies of different animal species over the 4th Millennium, several questions arise; why the Neolithic farmers didn't increase during crisis periods their herding size but rather hunted more wild animals.

On the basis of the archaeobiological remains (plant and animal species) and after taking into account several factors e.g. taphonomic problems, methodological problems etc. it is remarkable that the exploitation of wild sources had occurred only when the food procurement from cultural plants and domestic animals was not enough; therefore, people were forced to hunt and collect wild resources. The wild plant and animals made a significant contribution to the subsistence economy of the population when problems with domestic resources appear not to be providing the needed food for the people. In this cases, people have returned back to their ancestor's habits by collecting and gathering wild resources. the inhabitants did not maximise their herd size because, doing so, several factors have to be taken into account, for example, a favourable climatic condition which was not the case during the 37th century and available population that can provide the required labour with domestic animals. Increasing the herd size to its maximum to cover the daily demand of food also require fodder supply during winter for the house animals especially, for cattle, which can offer the biggest amount of meat (Schibler 2006). An increase in cattle herd size will involve more individuals in order to maximise the work of collecting leaf hay from the woods in the surroundings of the settlement to ensure the fodder for cattle for the winter months. The mass of branches and twig fragments, which make up the biggest part of organic cultural layers in the shore side, provide unequivocal evidence for the importance of lopping in the Neolithic cattle economy (Schibler *et al.* 1997). Based on labour calculations, one person would need 5 days to provide one cow with winter fodder (Rasmussen 1990). Therefore, maximising the herd size from, for example, 40 animals to 80 animals, the amount of work to provide fodder would be immense. Not only the fodder was the biggest problem but also an available grassland that could be used as a gesture for animals. Short-time climatic deterioration (dry seasons) might be responsible for agricultural catastrophes which could not only cause crop failures but also shrink in grassland size. Therefore, an intensification in cattle herding was not the ideal solution to offer the needed amount of meat. Consequently, people were forced to go out of their settlement to look for wild resources.

However, an additional solution has been introduced to cover the needed food. The proportion of pigs has been slightly increased during the 37th century (Kerdy *et al.* 2018) which provide the first sign of pigs breeding intensifications. The increase of pig's herd size may have led to partly reduce two extraordinary labours; to hunt more wild animals and to offer fodder for more cattle individuals. The keeping of pigs does not require the same labour as the one for cattle and obviously is much less hard to hunt wild animals, such as the red deer or roe deer. The phenome of pigs as "backup" plan didn't stop here, but rather continued to be used tremendously in the Horgen period.

The increase in pig's herd size during the 37th century BC and mainly from the 34th century BC (in Sutz-Lattrigen Aussen 90% of the domestic remains are pigs) suggest that a profound change took place in the relationship between humans and their herds at that time. Thought people continued to keep cattle, sheep and goat, gradually they raised pigs which usually produce only meat. Pigs are often seen as woodland animals, but in fact, have a broad dietary and environmental niche and are adaptable to a variety of management systems. They can exploit parts of the ecosystem that the ruminants do not generally use (invertebrates, carrion, tubers, fungi, fruits and seeds), indirectly processing these resources to provide meat and manure (Hamilton *et al.* 2009). Furthermore, pigs being very reproductive and having large litters are perfect animals for the production of meat; larger quantities of meat can be produced in a relatively shorter time than with cattle (Serjeantson 2011). The fast and high reproduction that characterises this breeding confers the pigs as an undeniable source which enables the population to respond quickly to the variability of needs. This flexibility seems to have been widely used and could explain the wide fluctuations in the representation of this animal. On the other hand, the decision to exploit more pigs among the domestic animals may have also resulted from the discovery that rearing pigs is the only form of farming that does not necessarily require more farmland and additional fodder which is the case for cattle. Additionally, in contrast to the ruminants, pigs can use parts of the ecosystem and exploit several biological remains (invertebrates, carrion, tubers, fruits and seeds etc.) enabling households to have a 'trash compactor' which converted domestic waste, forest products and field remains into meat (Bogucki 1993, Hamilton *et al.* 2009). Therefore, the high importance of pig keeping might have been the only practical solution for producing more meat without demanding big efforts.

Evidently, intense pig keeping was a possibility to replace the hunting of large wild ungulates (red deer, wild boar and aurochs). This shift from hunting wild ungulates to pig husbandry was developed in the eastern part of Switzerland between 3'800 und 3'400 BC and has been adopted in the western part of Switzerland in a very short time (34th century) as the settlements at Lake Bienne and in Concise at lake Neuchâtel demonstrates (Chiquet 2012; Kerdy *et al.* 2018).

To conclude this phenome, we see that cattle production appears to be less developed than pig, although its contribution to meat supply is greater than any other species. Several investigations using find density (number of bones in sq. m) which is a different method than NISP in the site around Lake Zurich haven't shown any decreases of cattle bones during this period. Therefore, the increase of pig remains obviously has reduced the percentages of cattle when using NISP calculation method (Schibler 2017).

The rearing of small ruminants such as sheep, and goat, which seem to represent in balanced proportions in all the assemblages have confirmed that the exploitation of domestic herds is primarily based on cattle and pig which provide the essential resources. This distribution, in which the small ruminants still occupy a marginal place, translates a form of association between cattle and pig each of which corresponds to different ways of demand. Cattle keeping is based on the availability of pasture and sufficient resources to ensure the feeding of animals during the winter season. Pig farming is much less restrictive in needed space and can be quickly stepped up without necessary components of the used land.

6. Conclusions

Thanks to several thousands of great preserved bone, antler and teeth as well as other biological and non-biological remains, it was possible to investigate different aspects, mainly in the economy of the Neolithic period in the 4th Millennium in the western part of Switzerland and to compare the results with other lakeshore sites. The research has not only focussed on the exploitation of available fauna and its meat resources but also on the production of food during shortage times. Many facets of life in the Neolithic period in which animals were involved have been discussed. These include ways in which animals were kept, the reasons on herd size intensification and the amount of meat they provided, the role of wild animals and also the way animal bodies were used as raw material sources.

This review has confirmed some of the long-held results about animal use in the Neolithic pile dwellings of Sutz-Lattrigen and generally around Lake Bienne and has also answered several questions about the economy in the Neolithic. When the results of Sutz-Lattrigen are viewed, we now have better and clear picture than before on the development of the pile dwellings economy in the 4th Millennium especially on the husbandry and hunting of animals in the region of Lake Bienne.

The high density of data allows interpreting the fluctuations which took place during the 37th century and to investigate the reasons for these fluctuations. During short periods of climatic deterioration, the proportion of wild animals was very high. The meat supply relied mainly on the exploitation of wild resources combined with a hunting game especially red deer and gathering wild plants. The hunting of games has focussed on the animal that has the biggest amount of meat (red deer) and the wild plants that are rich in protein indicating an economical specialised hunting and gathering strategies. During periods of more favourable climatic conditions, hunting was not as important and therefore only up to 20% or less of the game was consumed. Furthermore, the periods of climatic deterioration have not only forced people to hunt more game but also affect certain animal species. The intensive hunting of red deer in Sutz-Lattrigen region led to overexploitation of these animals and induced a strong negative selection: the size of adult red deer reduced (Fig. 10, Tab. 15). This phenome is also witnessed in Lake Zurich region.

It is evident that the people in Sutz-Lattrigen primarily in stable climatic conditions wanted to cover their need for meat by keeping domestic animals. The frequencies of domestic animals show strong fluctuations in the settlement assemblages both in Sutz-Lattrigen and other western lakeshore sites in Switzerland in the 4th Millennium. By the end of the 4^{th} Millennium in the Horgen culture, we see very high proportions of domestic animals. This indicates that the Neolithic lakeshore dwellers aimed for the most intensive use of domestic animals possible.

The amount of consumed meat from domestic animals was stable over the century but changes have taken place in the animal species and their herd sizes. In the first half of the Millennium cattle was the dominant animal. People have consumed cattle meat more than any other domestic animals. In the second half, the calculation has shown different results. The proportion of pig has increased strongly making the animal dominant among other domestic animals.

The keeping of herds involved many tasks; looking after the animals, providing food during winter time when grassland is no more suitable and guarding and protecting the animals. People, for several reasons, have developed new herding management strategies by keeping more domestic pigs in the settlement. Pigs, with their fertile reproduction and rapid growth, are even better as a 'foodstuff bank'. Pigs converted domestic garbage and barely-edible forest harvests and field leftover into meat. Apparently, cattle simply did not make logic anymore as a stock for meat alone or only as insurance against agricultural shortages during climatic deteriorations. Individual households in Sutz-Lattrigen pile dwelling probably kept small cattle herds. Limitations on grazing land and on everyday labour would have been understandable reasons to keep herds small.

To sum up, the importance of hunting and the development of pig farming can be considered as an indication of the availability of forest areas and woodland, between game resources and the potential of terrors bordering the settlement. A large number of domestic pigs could have been a reflection of an increase in the woodland which is the favoured place for pigs to forage food.

On the other hand, concerning the bone and antler tools, the results have shown that the bone and antler analyses of assemblages from lakeshore sites in the bay of Sutz-Lattrigen indicate skilful toolkit production and development of innovative ways of using available raw materials, especially red deer antler, to cover the raw material and functional demands of the tools they needed. Choice of which animals and skeletal elements should be selected for making tools must have depended on several circumstances; e.g. a shifting combination of physical properties, availability, appropriateness of the shape of the skeletal element, its fracturing properties and beliefs in the qualities of certain bones and animal species.

Available raw material sources around the settlement greatly influenced the technical choices people could choose from. The increase in the numbers of pigs raised on Horgen settlements directly influenced the proportion of bone tools made from pig suggesting that raw material availability had a significant impact on which duty was chosen for the production of the toolkits of daily life. This choice is all the more remarkable since pig bone, with the subtle twist in most of the long pig bones, is a less easily worked material.

Nevertheless, in the matter of antler exploitation for tools, changes in the character and quality of red deer antler forced adaptations in the form which can be recognised in the way the raw material was managed as well as in the morphology and quality of objects. Antler has been shown to be and more resistant to shock, more elastic than bone.

The manufacturing trends in traditions of bone tool production which continues from the Early Neolithic into the Middle and Late Neolithic periods is markedly similar throughout all lakeshore sites in Switzerland reflecting a long-term continuity. Very likely, bone tool production was a widespread tradition and represents a technical continuum over broad regions as parts of stable technological horizons. The technical style connected with antler tool production, however, is much more variable and associated with innovative approaches that responded to new subsistence needs in everyday life at these lakeside settlements.

Finally, animal husbandry has for many years now been discussed and researched. The economic basis of life cannot be overlooked: people have settled at lakeshores, people have to eat, so the food they ate - and hence, the ways the animals were managed - are basic to human life. This review is a substantive examination of the animals from Neolithic period in Switzerland. It answers questions about the animals themselves and the roles they participated in the nutrition system for every day and every individual in the settlement. However, this review has also highlighted the facts that there are many areas concerned with human life, human interactions with their herds, the climatic change and animals themselves for which we still know a few. Some questions have been answered in this study, and some will be answered in the coming research decades. Many questions will remain open.

7. Bibliography

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8. Figures, tables and raw datas

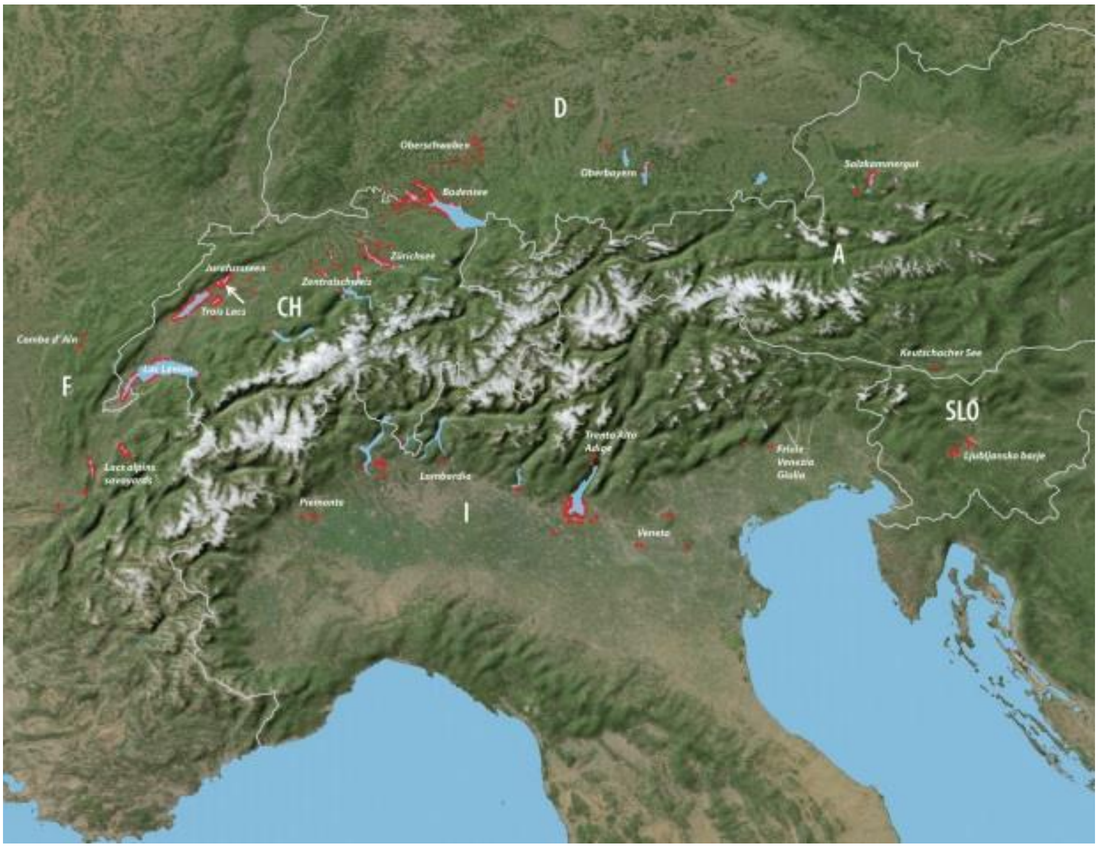

Fig. 1: Pic of coloured all pile dwelling. Distribution of Prehistoric Pile-dwellings around the Alps. In the framework of the UNESCO world heritage candidature "Prehistoric Pile-dwellings around the Alps", a completely new and international inventory of all sites has been undertaken for the first time since the 1930s (Hafner 2009). As a result, the mapping of nearly 1000 sites for the whole alpine region is now possible. Arrow: Lake Biel. (Hafner 2012).

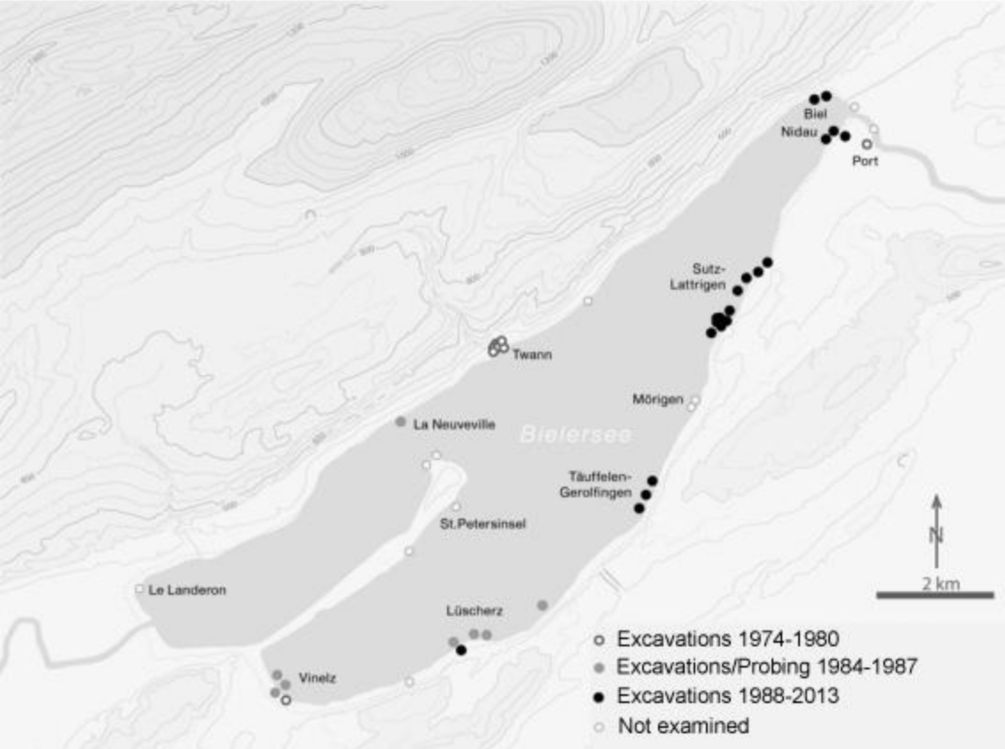

Fig. 2: Lake Biel with those in the last 40 years from the Archaeological service of canton of Berne investigated sites. The flat south bank has much higher numerous of settlements.

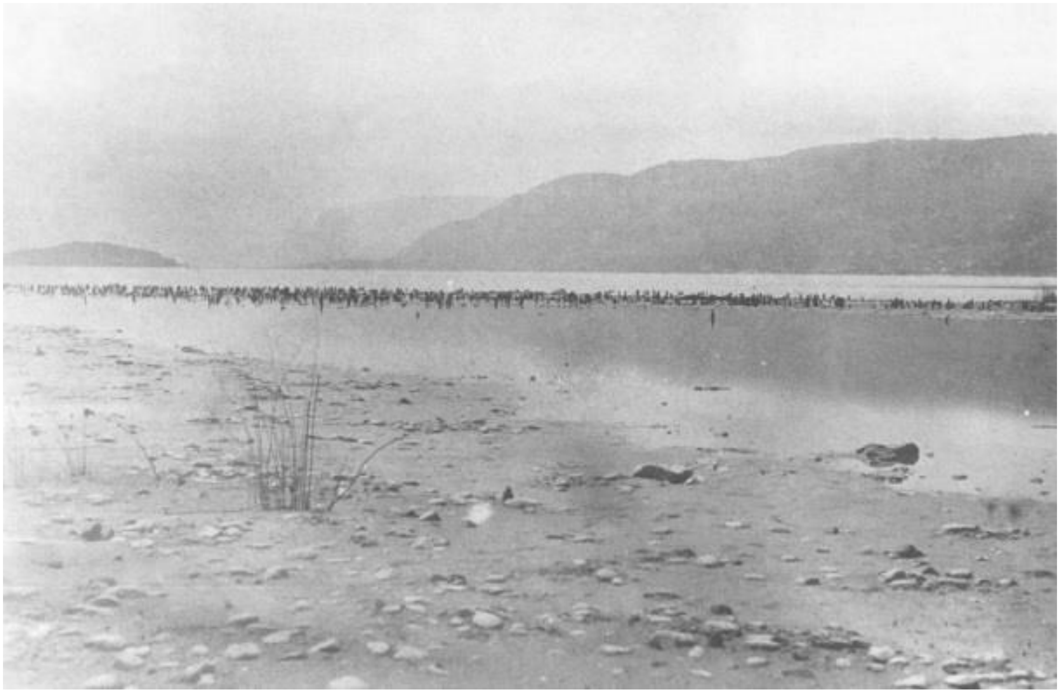

Fig. 3: Lakeshore sites remains: Condition of the field after the lake level sinking for the first Jura water correction. Bürki 1874. In (Hafner 2005b).

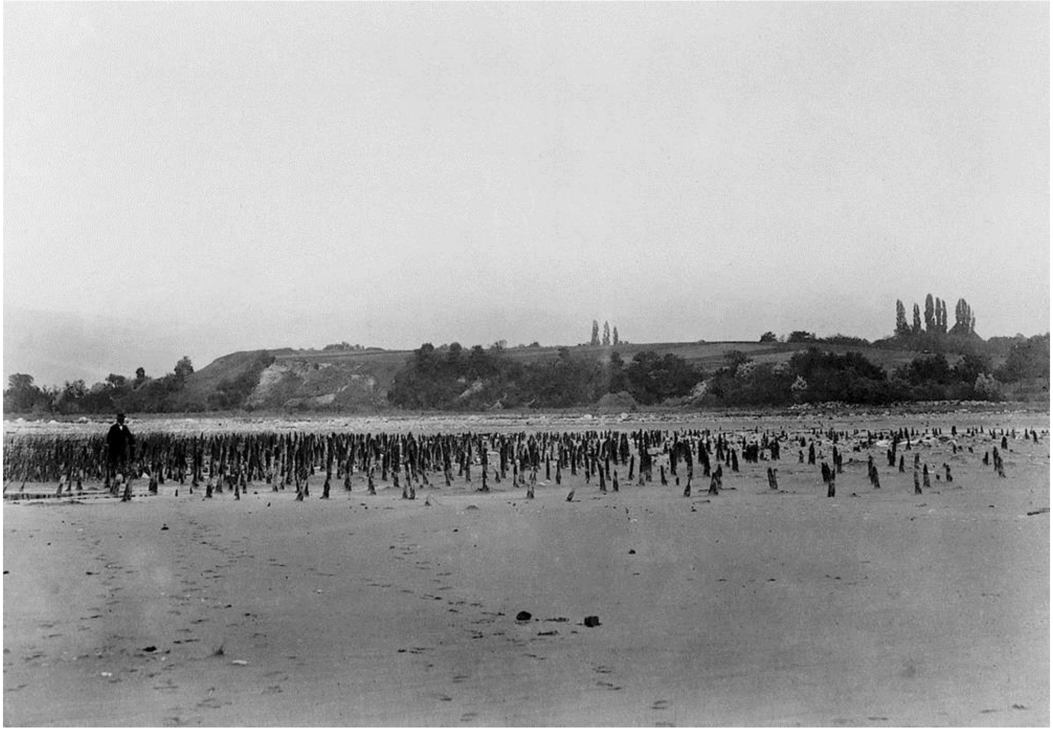

Fig. 4: Lakeshore sites remains: Condition of the field after the lake level sinking for the first Jura a water correction. Photographed near Mörigen in October 1874 (Bernisches Historisches Museum) © Photo Stefan Rebsamen.

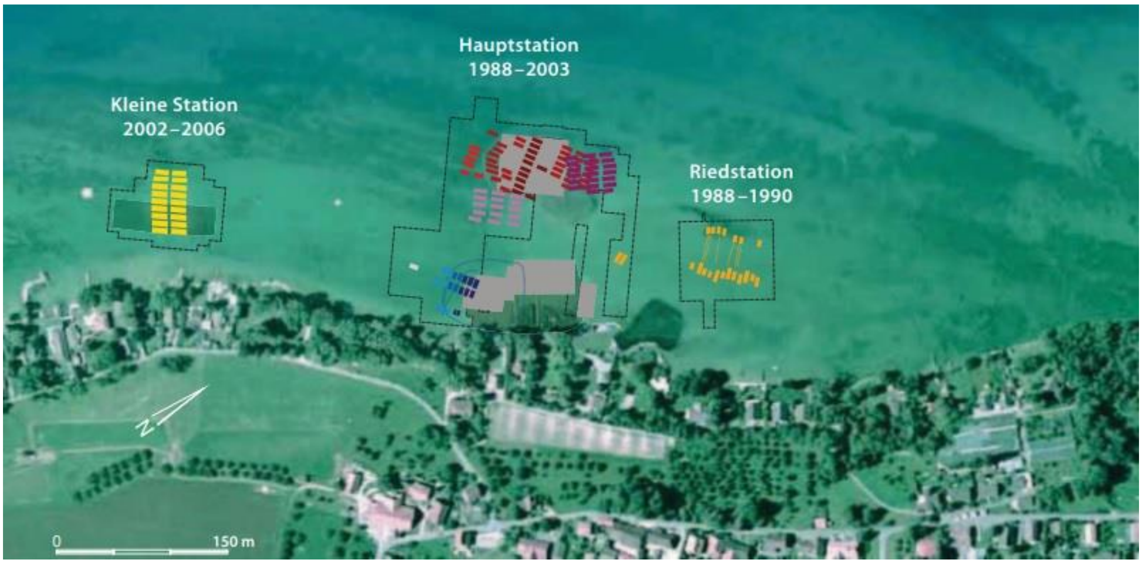

Fig. 5: Lakeshore sites in Lake Bienne. Situation of Sutz-Lattrigen Hauptstation with the surrounding “Kleinstation” and the site of “Riedstation”. The gray areas were archaeologically examined between 1988 and 2003. The late Neolithic Settlement area "outside" is seaward in the north-western part of Hauptstation site (Hafner 2005b).

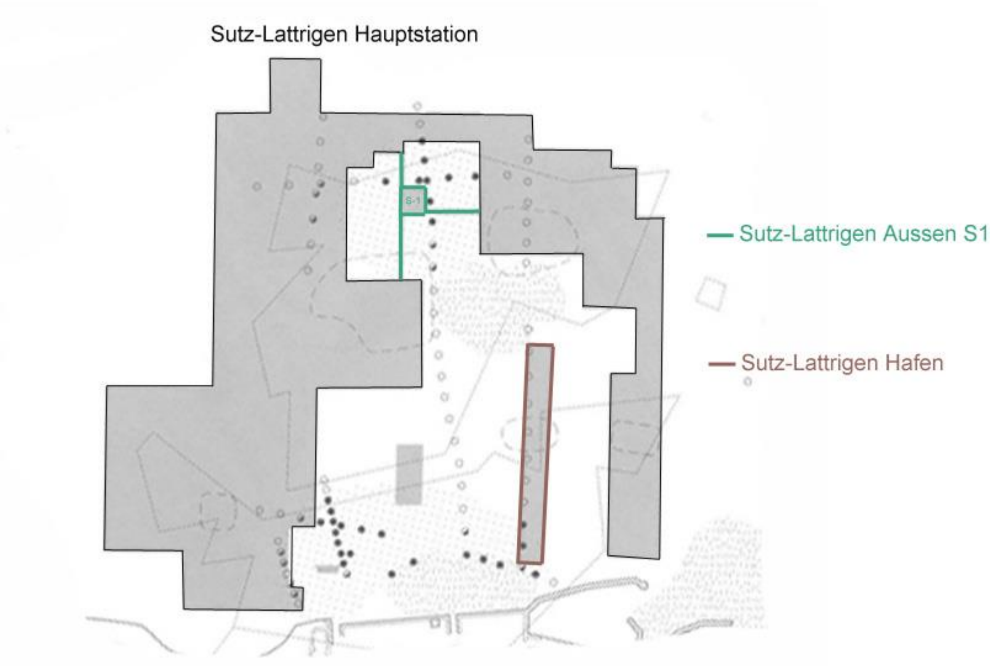

Fig. 6: Sutz-Lattrigen Hauptstation and the included settlements of Sutz-Lattrigen Aussen S1 and Sutz-Lattrigen Hafen.

Fig. 7: Pile dwellings in the bay of Sutz-Lattrigen: Currently, the research areas cover more than 43.000 m2 of lake bottom. The oldest structures go back to 4600-4000 BC, dated by C14, whereas the earliest dendrochronological date is 3856 BC. The sites cover the whole time span from the Neolithic to Early Bronze Age (Hafner 2012).

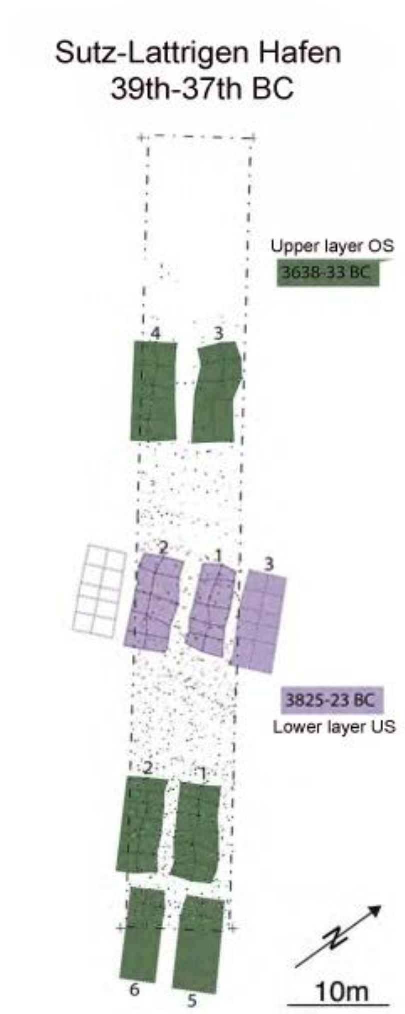

Fig. 8: Sutz-Lattrigen Hafen both layers (Stapfer *et al.* 2014).

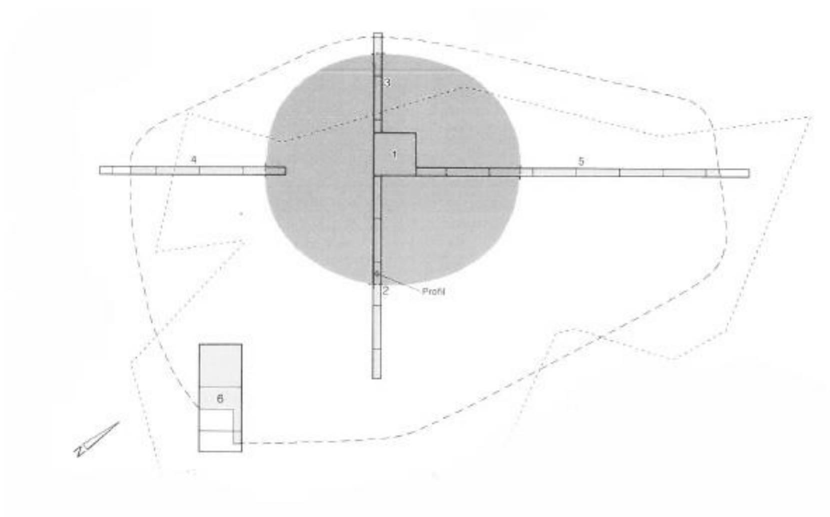

Fig. 9: Sutz-Lattrigen Aussen. Excavation's sections (1-6). The materials of the present study are the central section-1 from the year 1988 (Hafner 1994).

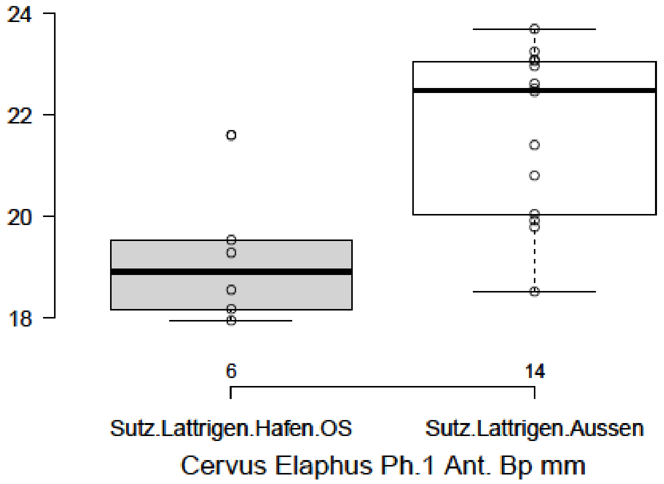

Fig. 10: Red deer Box-plots of the Phalanx 1 Ant. Proximal width showing different in red deer body size between Sutz-Lattrigen Hafen OS and Sutz-Lattrigen Aussen.

Fig. 11: Lower jaw of domestic pig (upper: Female, lower: Male) showing the technique to extract bone marrow and canine tooth in the case of male.

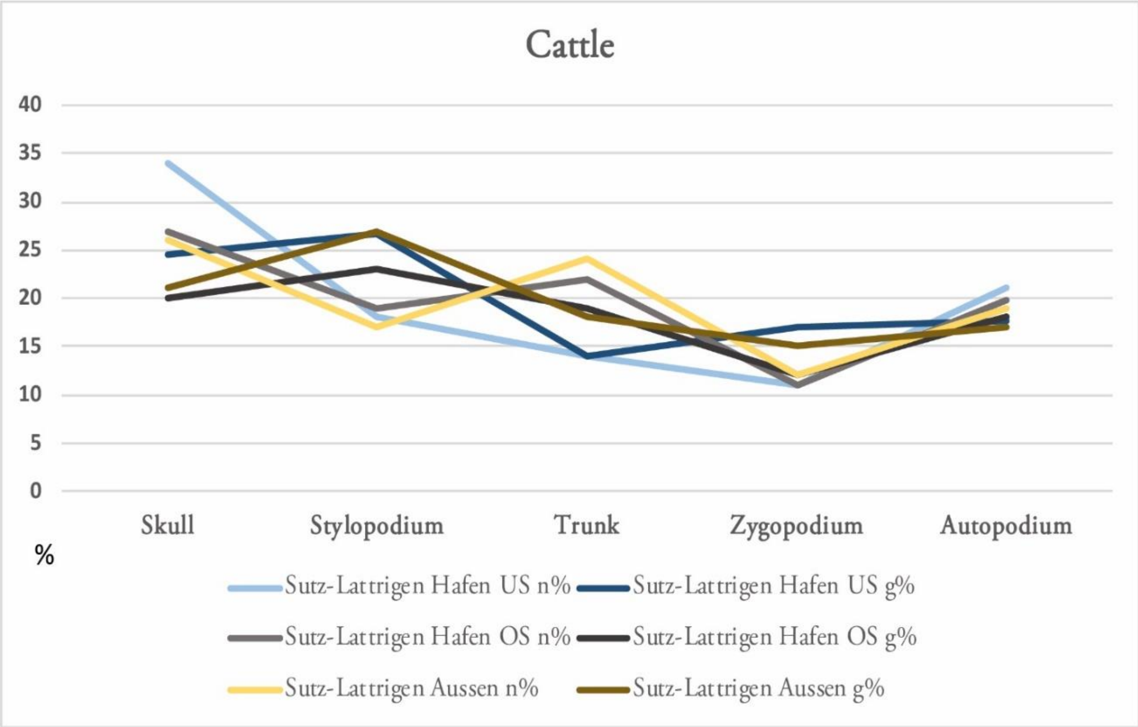

Fig. 12: Comparison of cattle body part proportions from Sutz-Lattrigen Hafen US, OS and Sutz-Lattrigen Aussen (% of bone number and g% of the weight).

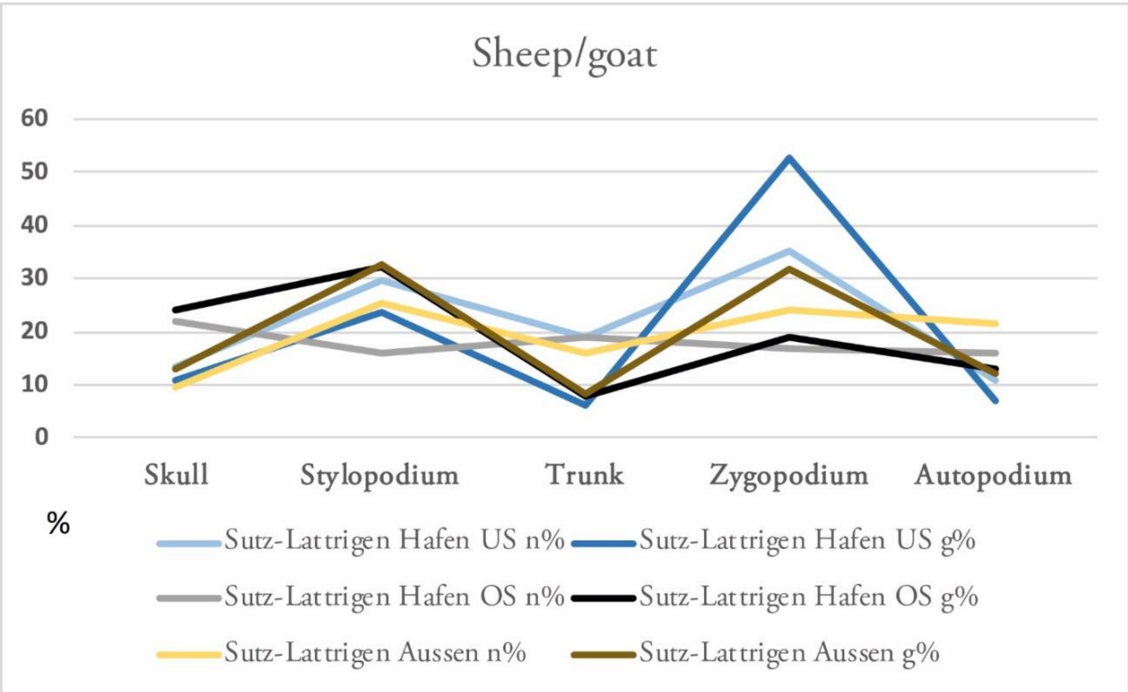

Fig. 13: Comparison of sheep/goat body part proportions from Sutz-Lattrigen Hafen US, OS and Sutz-Lattrigen Aussen (% of bone number and g% of the weight).

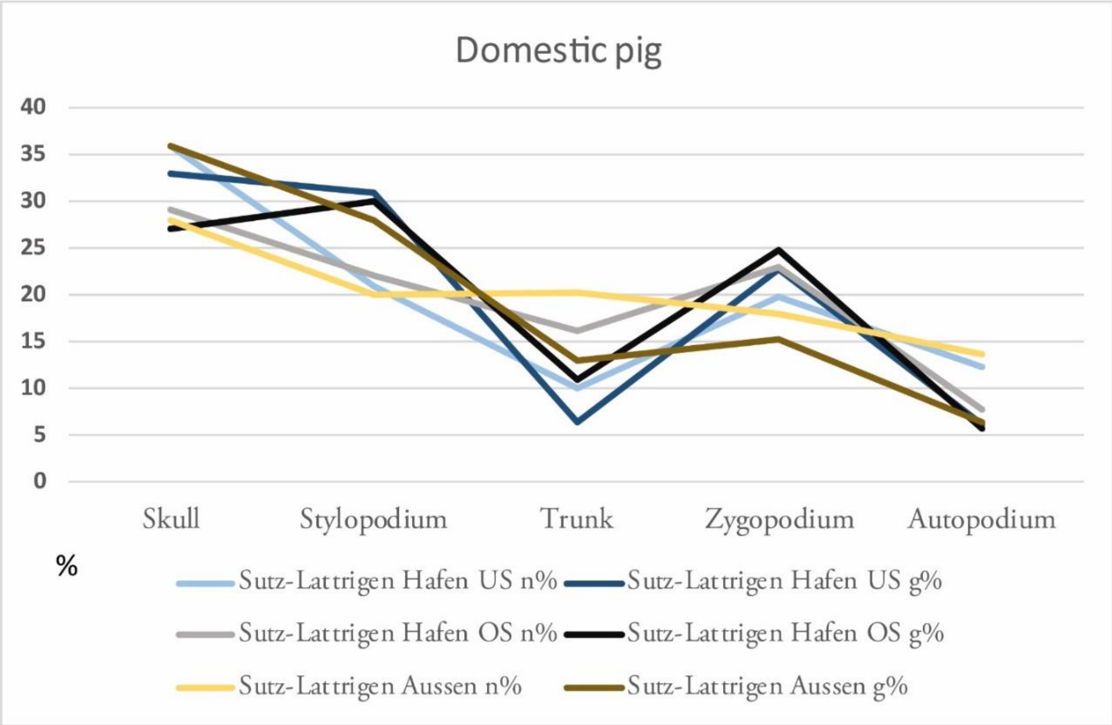

Fig. 14: Comparison of domestic pig body part proportions from Sutz-Lattrigen Hafen US, OS and Sutz-Lattrigen Aussen (% of bone number and g% of the weight).

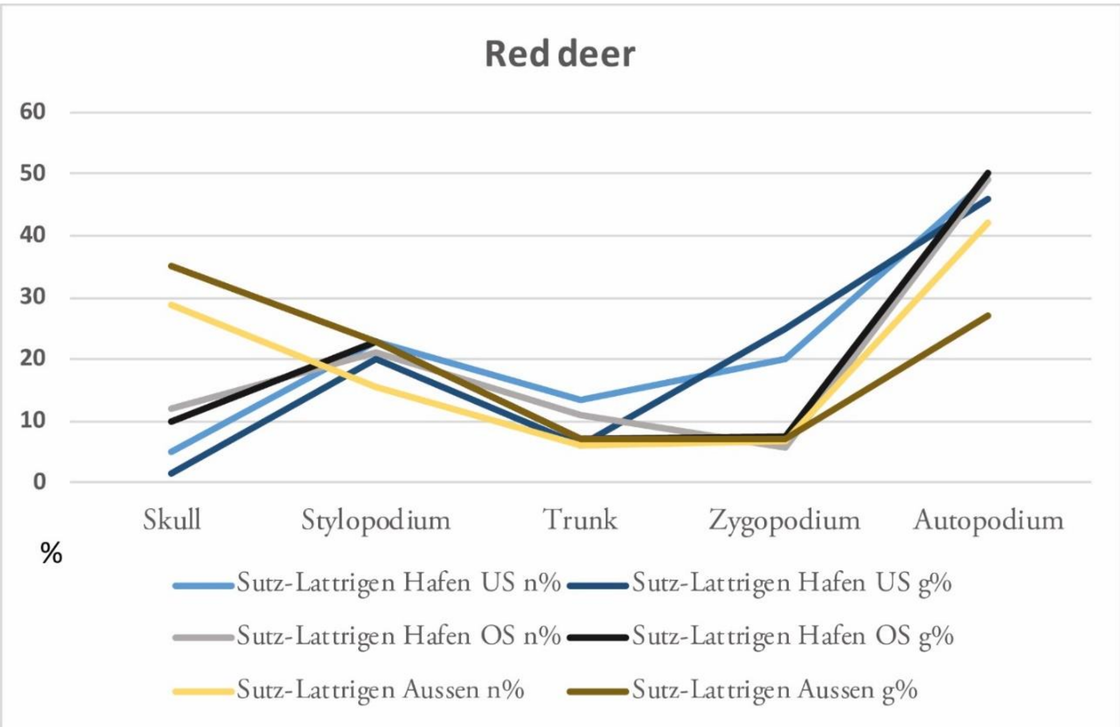

Fig. 15: Comparison of red deer body part proportions from Sutz-Lattrigen Hafen US, OS and Sutz-Lattrigen Aussen (% of bone number and g% of the weight).

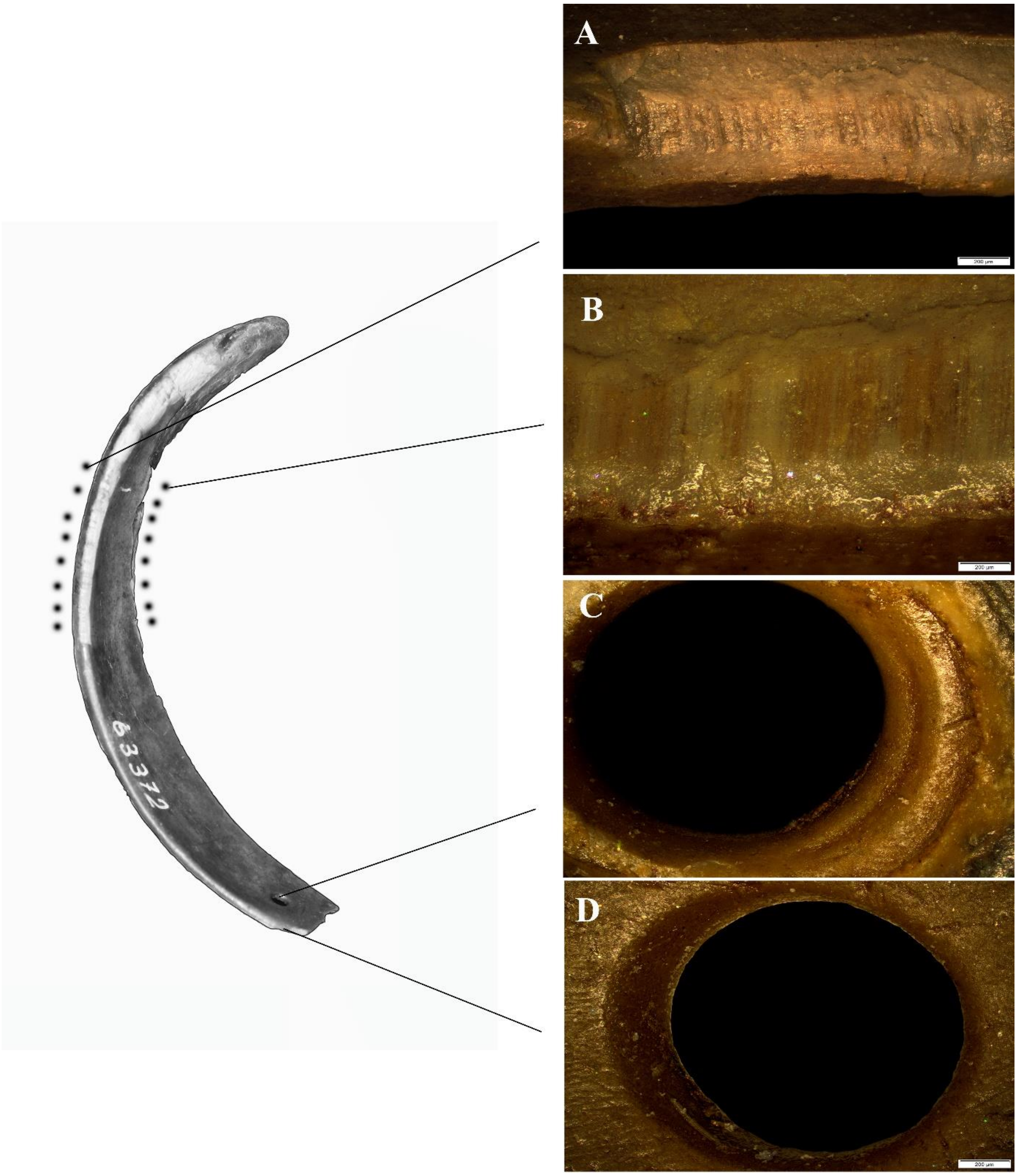

Fig. 16: Pig tooth lamella with a hole on the distal side.

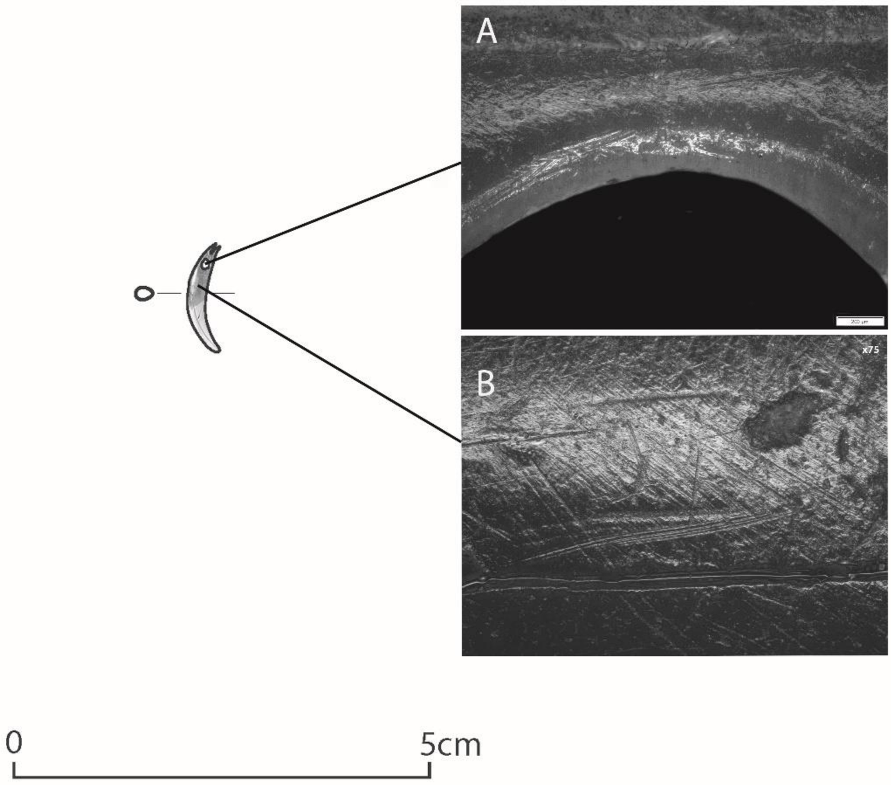

Fig. 17: Canine of a fox with perforated hole.

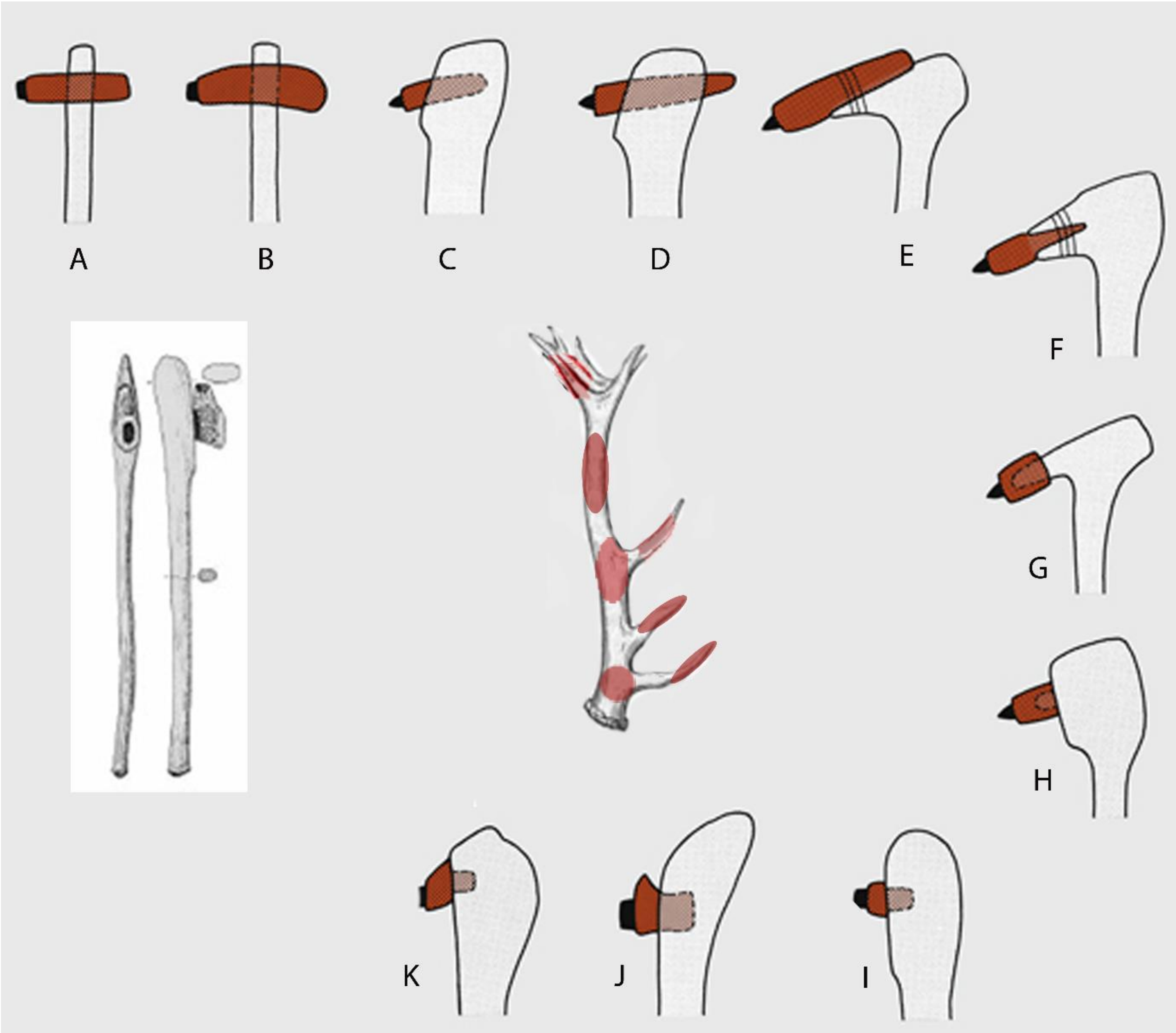

Fig. 18: Antler sleeve/sockets and the different ways to fit in the wooden handle (modified after Schibler 1997).

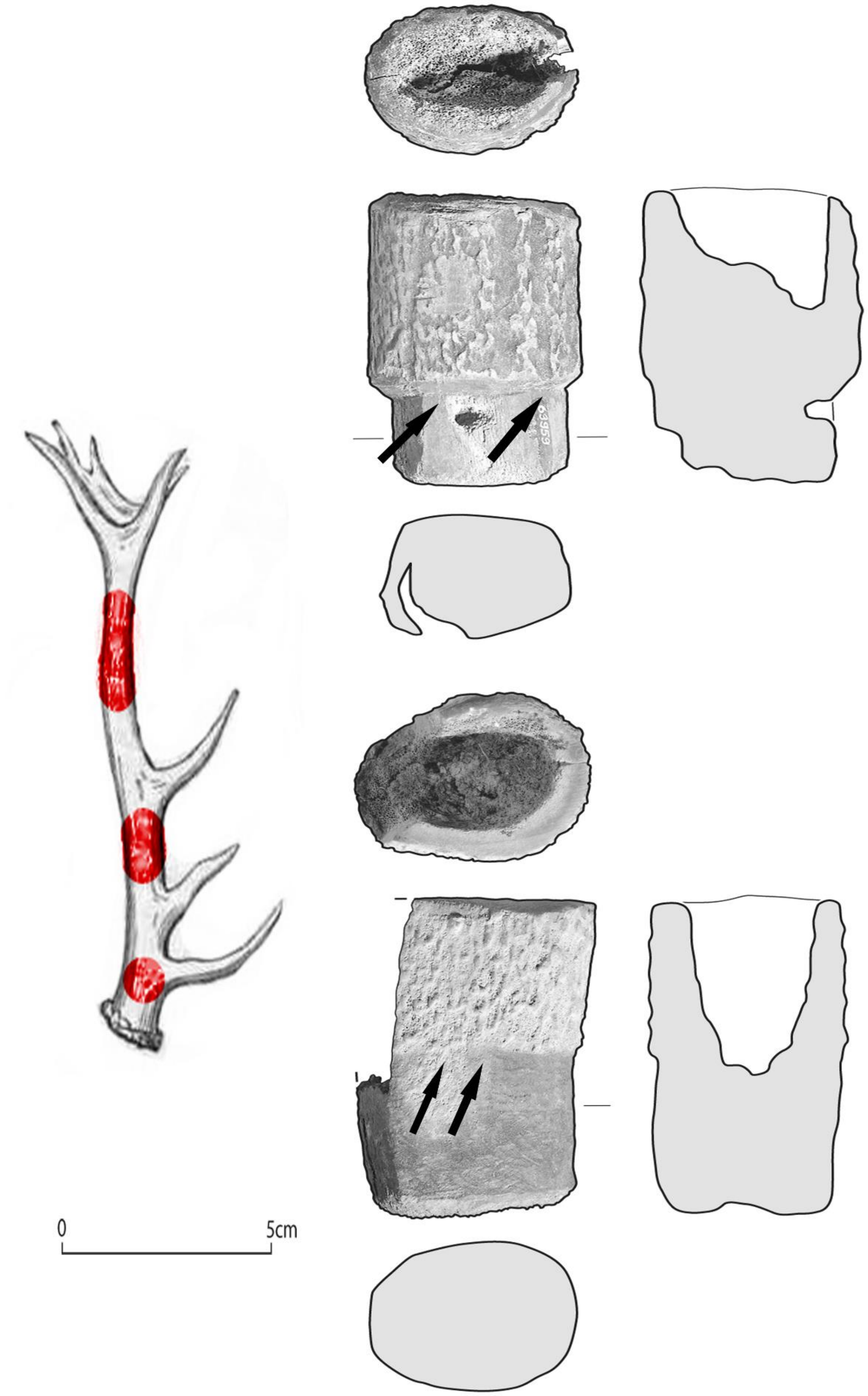

Fig. 19: Tenon sleeves showing setting line to prevent them from gouging into the wooden handle.

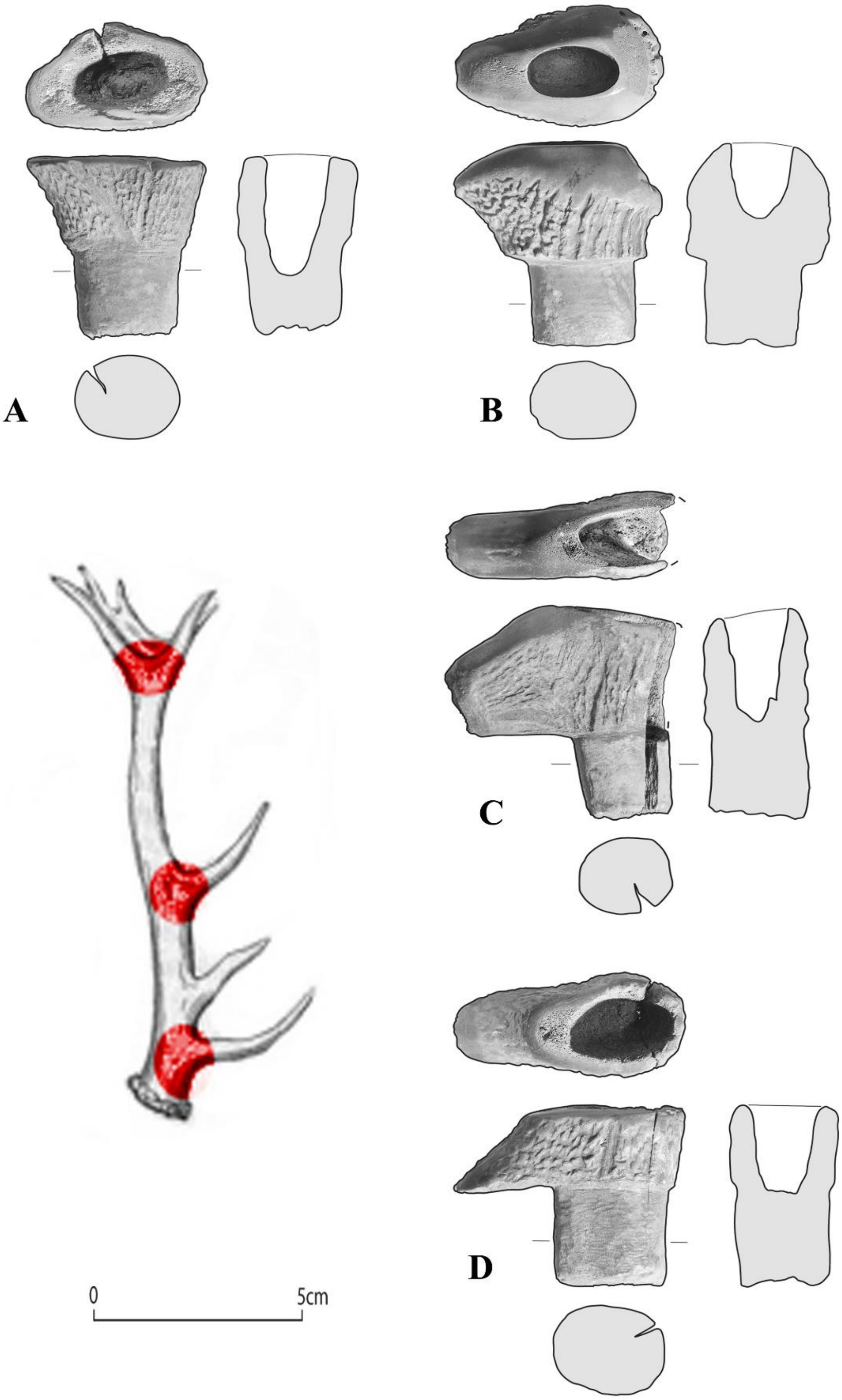

Fig. 20: "Bird-nose" style antler tools.

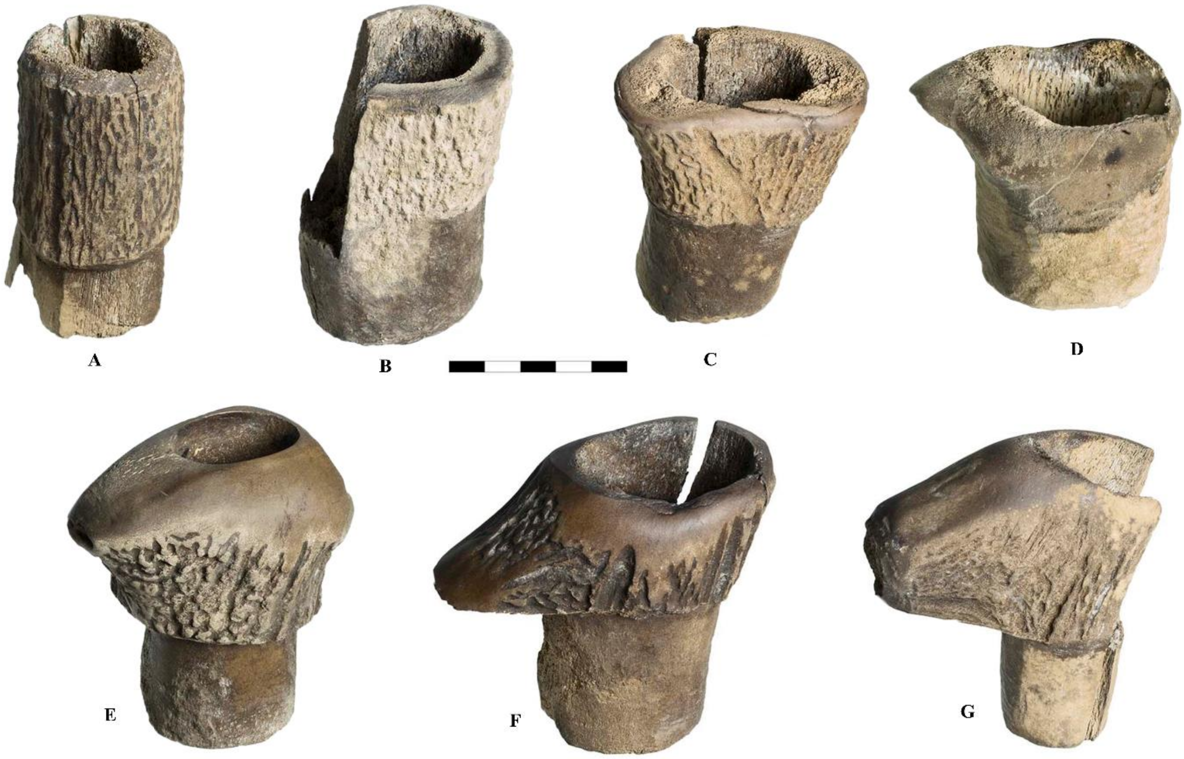

Fig. 21: Antler sleeves display traces of high polish connected to contact with wooden materials.

Species	**N**	**%**	**Weight g.**	**g%**
Cattle (*Bos taurus*)	306	45	6911	51.9
Sheep/goat	37	5.4	208.4	1.6
Sheep (*Ovis aries*)	7	1	99.6	0.7
Goat (*Capra hircus*)	4	0.6	58	0.4
Domestic pig (*Sus domesticus*)	178	26.2	1376	10.3
Dog (*Canis familiaries*)	8	1.2	49.6	0.4
Total domestic	**525**	**77.2**	**8702.6**	**65.3**
Red deer (*Cervus elaphos*)	132	19.4	3875.2	29.1
Aurochs (*Bos primigenius*)	5	0.7	191.1	1.4
Wild pig (*Sus scrofa*)	14	2.1	236.7	1.8
Bear (*Ursus arctos*)	1	0.1	263.9	2
Beaver (*Castor fiber*)	3	0.4	34.3	0.3
Mallard (*Anas platyrhynchos*)	1	0.1	3.2	0.1
Total wild	**155**	**22.8**	**4604.4**	**34.7**
Total domestic/wild	**680**	**100**	**13307**	**100**
Large ruminant	111		698.8	
Small ruminant	24		58	
Indet large ruminant	60		291.8	
Indet size pig	45		97.8	
Indet size sheep	11		11.9	
Domestic/wild cattle	1		3.3	
Domestic/wild pig	23		78	
Dog/fox	3		9	
Indet	288		564	
Total	**1246**		**15119.3**	

Tab. 1: Sutz-Lattrigen Hafen US animal remains taxa, fragment numbers and weight in gramm.

Species	**N**	**%**	**Weight g.**	**g%**
Cattle (*Bos taurus*)	828	40.9	17440.6	54.5
Sheep/goat	174	8.6	597.6	1.9
Sheep (*Ovis aries*)	10	0.5	154.3	0.5
Goat (*Capra hircus*)	6	0.3	89.9	0.3
Domestic pig (*Sus domesticus*)	497	24.6	3378.2	10.6
Dog (*Canis familiaries*)	19	0.9	140	0.4
Total domestic	**1534**	**75.8**	**21800.6**	**68.1**
Red deer (*Cervus elaphos*)	391	19.3	8031.3	25.1
Aurochs (*Bos primigenius*)	5	0.2	343.1	1.1
Wild pig (*Sus scrofa*)	49	2.4	1158	3.6
Roe deer (*Capreolus cap.*)	7	0.3	79.1	0.2
Red fox (*Vulpes vulpes*)	6	0.3	18	0.1
Brown bear (*Ursus arctos*)	3	0.1	299	0.9
Beaver (*Castor fiber*)	17	0.8	189.3	0.6
Wolf (*Canis lupus*)	1	0.1	54.9	0.2
Hedgehog (*Erinacaeus europaeus*)	3	0.1	0.7	0.1
Wildcat (*Felis silvestris*)	2	0.1	6.7	0.1
Mallard (*Anas platyrhynchos*)	2	0.1	1.7	0.1
Swan (*Cygnus columbianus*)	1	0.1	8.9	0.1
Red junglefowl (*Gallus gallus*)	2	0.1	0.9	0.1
Total wild	**489**	**24.2**	**10191.6**	**31.9**
Total domestic/wild	**2023**	**100**	**31992.2**	
Large ruminant	268		2073.7	
Small ruminant	51		123.1	
Indet large ruminant	273		1410.8	
Indet small ruminant	127		266.3	
Indet size sheep	49		70	
Indet size hare	2		8.8	
Domestic/wild cattle	5		398.3	
Domestic/wild pig	67		269.3	
Dog/fox	4		13.8	
Anas sp.	2		4.4	
Aves sp.	1		0.1	
Anatidae	1		1.2	
Indet	906		1705	
Total	**3779**		**38337**	

Tab. 2: Sutz-Lattrigen Hafen OS animal remains taxa, fragment numbers and weight in gramm.

Species	**N**	**%**	**Weight g.**	**g%**
Cattle (*Bos taurus*)	1088	18.2	15959	24.6
Sheep/goat	240	4	1501	2.3
Sheep (*Ovis aries*)	8	0.1	166.2	0.3
Goat (*Capra hircus*)	149	2.5	1029.5	1.6
Domestic pig (*Sus domesticus*)	3813	64.4	36871.2	56.8
Dog (*Canis familiaries*)	84	1.4	792	1.2
Total domestic	**5382**	**90.9**	**56318.9**	**86.8**
Red deer (*Cervus elaphus*)	163	2.8	4336.3	6.7
Aurochs (*Bos primigenius*)	4	0.1	107.7	0.2
Wild pig (*Sus scrofa*)	132	2.2	2973	4.6
Roe deer (*Capreolus cap.*)	6	0.1	18.4	0.1
Red fox (*Vulpes vulpes*)	82	1.4	247.2	0.4
Brown bear (*Ursus arctos*)	12	0.2	548	0.8
Beaver (*Castor fiber*)	25	0.4	256	0.4
Red squirrel (*Sciurus vulgaris*)	7	0.1	1.9	0.1
Tawny owl (*Strix aluco*)	1	0.1	1	0.1
Frog (*Rana temporaria*)	19	0.3	7.7	0.1
European perch (*Perca fluviatilis*)	16	0.3	4.9	0.1
Hedgehog (*Erinacaeus europaeus*)	9	0.2	4.7	0.1
Buzzard (*Buteo buteo*)	5	0.1	7	0.1
Pike (*Esox lucius*)	32	0.5	42.3	0.1
Wildcat (*Felis silvestris*)	12	0.2	12.4	0.1
Pochard (*Netta rufina*)	3	0.1	8.7	0.1
Mallard (*Anas platyrhynchos*)	4	0.1	0.6	0.1
Goshawk (*Accipiter gentilis*)	1	0.1	4.1	0.1
Pine Marten (*Martes martes*)	2	0.1	0.3	0.1
Chamois (*Rupicapra rupicapra*)	1	0.1	14.2	0.1
Total wild	**536**	**9.1**	**8596.4**	**13.2**
Total domestic/wild	**5918**	**100**	**64915.3**	
Large ruminant	324		2552	
Small ruminant	117		337	
Indet large ruminant	16		76.7	
Indet carnivore	8		5.6	
Domestic/wild cattle	1		133.5	
Domestic/wild pig	49		769	
Dog/fox	4		15.2	
Anas sp.	4		1.4	
Aves sp.	4		0.6	
Cyprinidae	8		6	
Amphibian	5		0.6	
Indet.	2991		6943	
Total	**9449**		71858.3	

Tab. 3: Sutz-Lattrigen Aussen animal remains taxa, fragment numbers and weight in gramm.

	S2		S3		S4		S5	
Species	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Cattle (*Bos taurus*)	197	17.8	19	3.8	28	9.6	281	9.7
Sheep/goat	65	5.8	3	0.6	3	1	61	2.1
Goat (*Capra hircus*)							1	0.1
Sheep (*Ovis aries*)	1	0.1	2	0.4			1	0.1
Domestic pig (*Sus domesticus)*	221	20	78	15.4	120	41.2	1312	45.2
Dog (*Canis familiaries*)	15	1.3			1	0.3	13	0.4
Total domestic	**499**	**87.2**	**102**	**68**	**152**	**85.8**	**1669**	**91**
Red deer (*Cervus elaphus*)	27	2.4	3	0.6	14	4.8	36	1.2
Aurochs (*Bos primigenius*)							2	0.1
Roe deer (*Capreolus cap.)*	18	1.6	1	0.2	5	1.7	15	0.5
Chamois (*Rupicapra*	1	0.1						
Wolf (*Canis lupus*)					1	0.3		
Wildcat (*Felis silvestris*)	3	0.2						
Wild pig (*Sus scrofa*)	6	0.5	29	5.7	2	0.7	34	1.2
Red fox (*Vulpes vulpes*)	8	0.7					41	1.4
Beaver (*Castor fiber*)	1	0.1					11	0.4
Brown bear (*Ursus arctos*)	2	0.1			1	0.3		
Badger (*Meles meles*)							4	0.1
Hedgehog (*Erinacaeus*	3	0.2	1	0.2	1	0.3	2	0.1
Northern pike (*Esox lucius*)	1	0.1	10	2			12	0.4
Pochard (*Netta rufina*)	1	0.1						
Frog (*Rana temporaria*)	1	0.1						
European perch (*Perca*			1	0.2			6	0.2
Red squirrel (*Sciurus vulgaris*)					1	0.3		
Common crane (*Grus grus*)	1	0.1	1	0.2			2	0.1
Total wild animals	**73**	**12.8**	**46**	**32**	**25**	**14.2**	**165**	**9**
Dog/fox	2	0.1	6	1.2	1	0.3	1	0.1
Domestic/wild pig			2	0.4	4	1.4	26	0.9
Large ruminant	77	6	26	5.1	18	6.2	133	4.6
Small ruminant	15	1.3			2	0.7	10	0.3
Indet large ruminant	62	5.6					1	0.1
Aves sp.	1	0.1	1	0.2			8	0.3
Rana sp.			3	0.6				
Percidae			1	0.2				
Indet	375	33.9	318	63	89	30.6	890	30.7
Total	**1104**		**505**		**291**		**2903**	

Tab. 4: Sutz-Lattrigen Aussen Sections 2-5 animal remains taxa, fragment numbers and weight in gramm.

Bone	Fusion times (after Silver 1969)	Number of bone		
		Sutz-Lattrigen Hafen US	Sutz-Lattrigen Hafen OS	Sutz-Lattrigen Aussen
Scapula tuberosity	7-14 months	f (2) , uf (1)	f (2) , pf (1)	f (4) , pf (4) , uf (2)
Distal humerus	12-18 months	f (5) , pf (2) , uf (1)	f (4) , pf (2), uf (3)	f (6) , pf (3) , uf (3)
Proximal radius	12-18 months	f (2)	f (8)	f (6) , pf (3) , uf (3)
Proximal ph1	19-24 months	f (5) , pf (1)	f (9) , pf (2)	f (17) , uf (4)
Proximal ph2	15-18 months	f (7) , pf (1)	f (12) , pf (1)	f (16) , pf (2) , uf (2)
Distal metacarpus	2-2.5 years	f (3) , uf (1)	f (10) , pf (1) , uf (1)	f (8) , pf (3) , uf (1)
Distal tibia	2-2.5 years	f (3) , pf (1) , uf (1)	f (5) , pf (3) , uf (2)	f (7) , pf (5) , uf (3)
Distal metatarsal	2-3 years	f (1) , pf (2)	f (6) , pf (3) , uf (1)	f (6) , pf (6) , uf (1)
Distal calcaneum	3-3.5 years			f (3) , pf (1)
Proximal femur	3.5 years	f (1) , pf (2)	f (2) , pf (4) , uf (1)	f (2) , pf (3) , uf (5)
proximal humerus	3.5-4 years	f (1) , pf (2) , uf (1)	f (2) , pf (2)	f (4) , pf (4)
Distal radius	3.5-4 years		pf (2)	f (3) , pf (3) , uf (1)
Proximal ulna	3.5-4 years	f (1) , uf (1)	f (2) , pf (2) , uf (1)	f (5) , pf (3) , uf (2)
Proximal tibia	3.5-4 years	pf (1)	f (6) , pf (6) , uf (2)	f (2) , pf (2)

Tab. 5: Epiphyseal fusion in the limb bones of domestic cattle (*Bos taurus*) from the settlements of Sutz-Lattrigen Hafen and Aussen. Note: F- fused, pf- part fused, uf- unfused.

Stage of tooth eruption	Number of teeth		
	Sutz-Lattrigen Hafen US	Sutz-Lattrigen Hafen OS	Sutz-Lattrigen Aussen
Premolars unerupted < 3 weeks			1
Premolars erupted < 3 months	1	6	1
M1 part erupted 7-14 months	1	10	
M1 part erupted 15-24 months	5	7	4
M2 part erupted 19-24 months	6	7	14
M2 erupted > 3 years	7	6	3
M3 part erupted > 3 years	8	5	11
M3 erupted, over 3 years	7	21	10

Tab. 6: Ageing of the teeth of cattle (*Bos taurus*) from Sutz-Lattrigen assemblages. The ageing sequence follow that of Becker and Johansson 1981 and Habermehl 1975 resp. (Ossobook codes).

Bone	Fusion times (Silver 1969)	Number of bone		
		Sutz-Lattrigen Hafen US	Sutz-Lattrigen Hafen OS	Sutz-Lattrigen Aussen
Distal metacarpal	18-24 months	f (1) , uf (1)	f (7) , pf (1) , uf (3)	f (1) , pf (1)
Distal tibia	18-24 months	f (1)	f (2)	f (5) , pf (5) , uf (1)
Distal metatarsal	20-28 months			f (2) , pf (4)
Proximal ulna	2.5 years	pf (1)	uf (1)	f (6) , pf (3) , uf (1)
Proximal calcaneum	2.5-3 years		f (1) , pf (1)	f (2) , pf (5)
Distal radius	3 years	f (1) , pf (1)	f (2) , pf (2)	f (6)
Proximal humerus	3-3.5 years			f (1) , pf (2)
Proximal tibia	3-3.5 years		f (1) , uf (1)	f (1) , pf (5) , uf (1)

Tab. 7: Epiphyseal fusion in the limb bones of domestic sheep/goat from the settlements of Sutz-Lattrigen Hafen and Aussen. Note: F- fused, pf- part fused, uf- unfused.

Bone	Fusion times (Silver 1969)	Number of bone		
		Sutz-Lattrigen Hafen US	Sutz-Lattrigen Hafen OS	Sutz-Lattrigen Aussen
Scapula tuberosity	12 months	f (1) , pf (4) , uf (1)	f (3) , pf (4) , uf (2)	f (10) , pf (26) , uf (14)
Distal humerus	12 months	f (2) , pf (2) , uf (1)	f (5) , pf (9) , uf (5)	f (24) , pf (15) , uf (12)
Proximal radius	12 months	pf (5) , uf (2)	f (6) , pf (4)	f (7) , pf (16) , uf (3)
Proximal ph2	12 months	f (1) , pf (1) , uf (1)	f (1) , pf (1)	f (30) , pf (15) , uf (4)
Distal metacarpus	2 years		f (5) , pf (2)	pf (1)
Distal tibia	2 years	pf (2) , uf (2)	f (2) , pf (5) , uf (1)	f (1) , pf (17) , uf (8)
Proximal ph1	2 years	pf (1) , uf (1)	f (2) , pf (1)	f (30) , pf (15) , uf (4)
Proximal calcaneum	2-2.5 years	pf (2)	pf (3)	f (35) , pf (42) , uf (15)
Proximal femur	3.5 years	uf (1)	f (1) , pf (4) , uf (1)	f (2) , pf (14) , uf (6)
Distal metatarsal	2.5 years	pf (1)	f (1)	f (2) , pf (2)
Distal fibula	2.5 years			f (2) , pf (6) , uf (5)
Proximal ulna	3- 3.5 years	f (1) , pf (1) , uf (1)	pf (5) , uf (3)	f (6) , pf (52) , uf (11)
Distal ulna	3-3.5 years		pf (1)	f (1) , pf (8) , uf (1)
Proximal humerus	3.5 years	pf (1)	f (1) , pf (1)	f (1) , pf (12) , uf (6)
Distal radius	3.5 years	pf (1) , uf (1)	pf (4)	f (1) , pf (16) , uf (8)

Distal femur	3.5 years	pf (2) , uf (1)	f (1) , pf (1)	f (4) , pf (19) , uf (2)
Proximal tibia	3.5 years		pf (6) , uf (1)	pf (22) , uf (6)

Tab. 8: Epiphyseal fusion in the limb bones of domestic pig from the settlements of Sutz-Lattrigen Hafen and Aussen. Note: F- fused, pf- part fused, uf- unfused.

Stage of tooth eruption	**Number of teeth**		
	Sutz-Lattrigen Hafen US	**Sutz-Lattrigen Hafen OS**	**Sutz-Lattrigen Aussen**
Pre molars erupted < 4 months			
M1 part erupted 6-10 months		2	
M1 erupted, M2 unerupted 10-12 months		1	
M2 part erupted 12-16		1	
M2 erupted, M3 unerupted < 18 months			4
M3 part erupted >20months	5	2	8
M3 worn >3 years	2	7	2

Tab. 9: Ageing of the teeth of domestic pig from Sutz-Lattrigen Hafen and Aussen. The agein sequence follows that of Becker and Johansson 1981 and Bull and Payne 1982 resp (Ossobook age codes).

Bone	**Fusion times (after Zietzschmann and Krölling, 1955)**	**Number of bone**		
		Sutz-Lattrigen Hafen US	**Sutz-Lattrigen Hafen OS**	**Sutz-Lattrigen Aussen**
Distal ph1	ca. 1.5-2 years	f (7) , pf (1)	f (10) , pf (1)	f (4)
Scapula	ca. 12 months	pf (1)	f (1) , pf (4)	pf (2)
Distal humerus	ca. 12 months	f (1) , pf (1)	f (2) , pf (1)	
Proximal radius	ca. 10 months	f (1) , pf (2)	f (3)	f (2)
Diestal radius	ca. 2.5 years	f (1) , pf (1)	pf (1)	f (1)
Proximal ulna	ca. 2.5-3 years	pf (5)	f (2) , pf (1)	f (1)
Distal metacarpus	ca. 1.5 years		f (5) , uf (1)	f (2)
Proximal femur	ca. 3 years	pf (1)		pf (1)
Proximal tibia	ca. 3 years		f (2) , pf (2)	
Distal tibia	ca. 1.5-2 years	f (4)	f (5)	
Distal metatarsal	ca. 1.5-2 years		f (1) , pf (1)	
Proximal ph1	ca. 1.5 years	f (7) , pf (1)	f (10) , pf (1)	f (11) , pf (1)
Proximal ph2	ca. 1.5 years	f (3)	f (8) , pf (3)	f (3)

Tab. 10: Epiphyseal fusion in the limb bones of red deer from the settlements of Sutz-Lattrigen Hafen and Aussen. Note: F- fused, pf- part fused, uf- unfused.

	Sutz-Lattrigen Hafen US				Sutz-Lattrigen Hafen OS				Sutz-Lattrigen Aussen			
Body part	**n**	**n%**	**g**	**g%**	**n**	**n%**	**g**	**g%**	**n**	**n%**	**g**	**g%**
Cranium	12	3.9	109	1.6	23	2.8	289	1.7	67	6.2	981.3	2.9
Mandibula	22	7.2	553	8	67	8.1	1450.8	8.3	89	8.2	3824	11.4
Maxilla					2	0.2	137.5	0.8	20	1.8	717.5	2.1
Dens inferior	41	13.4	616	8.9	81	9.8	1005.2	5.8	30	2.8	315.4	0.9
Dens superior	23	7.5	412	6	47	5.7	714.2	4.1	66	6.1	1207	3.6
Os hyoideum									9	0.8	29.5	0.1
Processus cornualis	1	0.3	2.5	0.8	3	0.4	90.5	0.5	3	0.3	169.4	0.5
Skull	**99**	**32.4**	**1692**	**24.5**	**223**	**26.9**	**3687.2**	**21.1**	**284**	**26.1**	**7244**	**21.6**
Humerus	26	8.5	882	12.8	68	8.2	1728.3	9.9	48	4.4	2913	8.7
Femur	18	5.9	530	7.7	60	7.2	1468.9	8.4	57	5.2	2131	6.4
Scapula	4	1.3	290	4.2	14	1.7	541.4	3.1	29	2.7	1830	5.5
Coxa	5	1.6	145	2.1	17	2.1	434.7	2.5	52	4.8	2151	6.4
Stylopodium	**53**	**17.3**	**1846**	**26.7**	**159**	**19.2**	**4173.3**	**23.9**	**186**	**17.1**	**9026**	**27.0**
Atlas					7	0.8	166.6	1	12	1.1	357.4	1.1
Axis (Epistropheus)					3	0.4	79.9	0.5	4	0.4	192.4	0.6
Vertebra					3	0.4	20.4	0.1	2	0.2	24.1	0.1
Vertebra caudalis	2	0.7	16.2	0.2	3	0.4	16.3	0.1	3	0.3	19	0.1
Vertebra cervicalis	3	1	68.4	1	9	1.1	156.9	0.9	30	2.8	722.9	2.2
Vertebra lumbalis	2	0.7	46.8	0.7	15	1.8	276.2	1.6	24	2.2	817.4	2.4
Vertebra thoracicus	4	1.3	76.7	1.1	10	1.2	215.9	1.2	51	4.7	1244	3.7
Sacrum/Synsacrum	2	0.7	98.3	1.4	4	0.5	112.1	0.6	7	0.6	186.9	0.6
Costa	32	10.5	768	11.1	128	15.5	2433	14	143	13.1	2506	7.5
Trunk	**43**	**14.1**	**977**	**14.1**	**182**	**21.9**	**3477.3**	**19.9**	**269**	**24.7**	**6070**	**18.1**
Radius	17	5.6	414	6	20	2.4	701.4	4	42	3.9	1846	5.5
Radius+Ulna (verwachsen)					1	0.1	17.5	0.1	3	0.3	61.3	0.2
Tibia/Tibiotarsus	13	4.6	48.7	0.7	63	7.6	1845	10.6	58	5.3	2450	7.3
Ulna	4	1.3	719	10.4	11	1.3	262.5	1.5	30	2.8	814.7	2.4
Zygopodium	**34**	**11.1**	**1182**	**17.1**	**95**	**11.5**	**2826.4**	**16.2**	**133**	**12.2**	**5173**	**15.5**

Calcaneus									8	0.7	454.2	1.4
Carpale II+III	3	1	22	0.3	3	0.4	29.9	0.2	7	0.6	72.9	0.2
Carpale IV	2	0.7	11.5	0.2	2	0.2	20.1	0.1	2	0.2	14.8	0.1
Centroquartale	2	0.7	49.7	0.7	4	0.5	144.1	0.8	10	0.9	273	0.8
Metacarpus III+IV	4	1.3	213	3.1	40	4.8	1043.1	6	37	3.4	1987	5.9
Metacarpus Nebenstrahl									1	0.1	2.1	0.1
Metapodium	20	6.5	31.1	0.5	3	0.4	27	0.2	4	0.4	58.2	0.2
Metatarsus III+IV	17	5.6	434	6.3	57	6.9	1360.4	7.8	43	4	1449	4.3
Os carpi accessorium									3	0.3	6.7	0.1
Os carpi intermedium	1	0.3	6.3	0.1	3	0.4	29	0.2	2	0.2	25.9	0.1
Os carpi radiale	1	0.3	7.3	0.1	3	0.4	29.8	0.2	6	0.6	86.2	0.3
Os carpi ulnare					3	0.4	30.1	0.2	4	0.4	40.9	0.1
Patella	4	1.3	99	1.4	2	0.2	42.3	0.2	2	0.2	47.4	0.1
Phalanx 1 ant.	2	0.7	32.1	0.5	6	0.7	106.9	0.6	7	0.6	160.9	0.5
Phalanx 1 ant./post.	2	0.7	36.5	0.5	8	1	70	0.4	14	1.3	122.3	0.4
Phalanx 1 post.	2	0.7	33.1	0.5	2	0.2	40.3	0.2	6	0.6	126.6	0.4
Phalanx 2 post.	4	1.3	32.6	0.5	7	0.8	77.5	0.4				
Phalanx 2 ant.	3	1	31.8	0.5	5	0.6	80.8	0.5				
Phalanx 2 ant./post.	1	0.3	6.9	0.1	4	0.5	20.8	0.1	21	1.9	231.3	0.7
Phalanx 3 ant./post.	6	2	57	0.8	8	1	93.2	0.5	18	1.7	202.7	0.6
Sesamoid	3	1	13	0.2	9	1.1	31.1	0.2	1	0.1	2.8	0.1
Talus (Astragalus)									13	1.2	599.1	1.8
Autopodium	**77**	**25.2**	**1215**	**17.6**	**169**	**19.8**	**3276.4**	**18.8**	**216**	**19.9**	**5964**	**17.8**
Total	306		6911		828		17440.6		1088		33477	

Tab. 11: The frequency of cattle body parts from Sutz-Lattrigen Hafen US/OS and Sutz-Lattrigen Aussen after fragment numbers and weight (g). (Total with the groups).

	Sutz-Lattrigen Hafen US				Sutz-Lattrigen Hafen OS				Sutz-Lattrigen Aussen			
Body part	n	n%	g	g%	n	n%	g	g%	n	n%	g	g%
Cranium					4	2.3	41	6.7	1	0.4	46.2	3.1
Mandibula	1	2.7	7.8	3.7	5	2.9	27.1	4.4	4	1.7	49	3.3
Dens inferior	2	5.4	3.6	1.7	20	11.5	53.3	8.6	3	1.3	4.1	0.3
Dens superior	2	5.4	11.1	5.3	5	2.9	17.8	2.9	14	5.8	89.7	6
Processus cornualis					2	1.1	8.3	1.3	1	0.4	2.8	0.2
Os hyoideum					3	1.7	2.7	0.4				
Skull	**5**	**13.5**	**22.5**	**10.8**	**39**	**22.4**	**150.2**	**24.4**	**23**	**9.6**	**191.8**	**12.8**
Humerus	6	16.2	23.2	11.1	1	0.6	62	10.1	20	8.3	109.4	7.3
Femur	3	8.1	10.9	5.2	20	11.5	80	13	12	5	123.3	8.2
Scapula	1	2.7	3.8	1.8	6	3.4	52.6	8.5	15	6.3	159.6	10.6
Coxa	1	2.7	11	5.3	1	0.6	6.9	1.1	14	5.8	97.6	6.5
Stylopodium	**11**	**29.7**	**48.9**	**23.5**	**28**	**16.1**	**201.5**	**32.7**	**61**	**25.4**	**489.9**	**32.6**
Atlas									1	0.4	8.4	0.6
Axis (Epistropheus)					1	0.6	6.1	1	1	0.4	5.1	0.3
Vertebra					1	0.6	1.2	0.2				
Vertebra cervicalis					1	0.6	5.6	0.9	2	0.8	20.7	1.4
Vertebra lumbalis	1	2.7	7	3.4	1	0.6	12.2	2	6	2.5	33.4	2.2
Vertebra thoracicus					2	1.1	1.6	0.3				
Sacrum/Synsacrum									1	0.4	8.5	0.6
Costa	3	8.1	5.6	2.7	28	16.1	23.2	3.8	28	11.7	56.7	3.8
Trunk	**4**	**10.8**	**12.6**	**6**	**34**	**19.5**	**49.9**	**8.1**	**38**	**15.8**	**124.4**	**8.3**
Radius	4	10.8	38.6	18.5	10	5.7	24.6	4	24	10	152.8	10.2
Tibia/Tibiotarsus	8	21.6	62.1	29.8	20	11.5	90.8	14.7	22	9.2	290.6	19.4
Ulna	1	2.7	8.8	4.2	1	0.6	7.2	1.2	12	5	33.1	2.2
Zygopodium	**13**	**35.1**	**109.5**	**52.5**	**31**	**17.8**	**122.6**	**19.9**	**58**	**24.2**	**476.5**	**31.7**
Carpale II+III									1	0.4	1.3	0.1
Metacarpus III					4	2.3	24.1	3.9				
Metacarpus III+IV					4	2.3	8.9	1.4	5	2.1	18.7	1.2
Metapodium					2	1.1	5.3	0.9	2	0.8	3.2	0.2
Metatarsus III	2	5.4	9.3	4.5	2	1.1	17.1	2.8				
Metatarsus III+IV					3	1.7	13.9	2.3	26	10.8	134.3	8.9
Os carpi intermedium									1	0.4	1	0.1
Patella					1	0.6	5.7	0.9	1	0.4	2.4	0.2

Phalanx 1 ant./post.					1	0.6	3.5	0.6	8	3.3	14.1	0.9
Phalanx 2 ant./post.	1	2.7	2	1	2	1.1	3.3	0.5	2	0.8	1.3	0.1
Phalanx 3 ant./post.									6	2.5	4.9	0.3
Talus (Astragalus)	1	2.7	3.6	1.7								
Autopodium	**4**	**10.8**	**14.9**	**7.1**	**19**	**10.9**	**81.8**	**13.3**	**52**	**21.7**	**181.2**	**12.1**
Total	37		208.4		174		616.5		240		1501.8	

Tab. 12: The frequency of sheep/goat body parts from Sutz-Lattrigen Hafen US/OS and Sutz-Lattrigen Aussen after fragment numbers and weight (g). (Total with the groups).

	Sutz-Lattrigen Hafen US				**Sutz-Lattrigen Hafen OS**				**Sutz-Lattrigen Aussen**			
Body part	**n**	**n%**	**g**	**g%**	**n**	**n%**	**g**	**g%**	**n**	**n%**	**g**	**g%**
Cranium	13	7.3	62.9	4.6	25	5.0	163.2	4.8	362	9.5	2314.6	6.3
Mandibula	20	11.2	201.5	14.6	32	6.4	279.6	8.3	270	7.1	7672.7	20.8
Maxilla	1	0.6	42.6	3.1	9	1.8	193.5	5.7	178	4.7	2535.9	6.9
Dens inferior	21	11.8	94.8	6.9	55	11.1	182.9	5.4	134	3.5	371.01	1.0
Dens superior	9	5.1	56.3	4.1	24	4.8	100.3	3.0	120	3.1	567.9	1.5
Dens superior/inferior	1	0.6	3	0.2	3	0.6	5.7	0.2	2	0.1	0.3	0.1
Os hyoideum									1	0.1	0.2	0.1
Skull	**65**	**36.5**	**461.1**	**33.5**	**148**	**29.8**	**925.2**	**27.4**	**1067**	**28**	**13462.61**	**36.5**
Humerus	12	6.7	152.3	11.1	50	10.1	469.5	13.9	245	6.4	3524.7	9.6
Femur	14	7.9	97.5	7.1	41	8.2	244.7	7.2	228	6	1852.3	5
Scapula	10	5.6	155.8	11.3	15	3.0	193.8	5.7	173	4.5	2576.5	7
Coxa	2	1.1	20.5	1.5	7	1.4	133.5	4.0	126	3.3	2566.3	7
Stylopodium	**38**	**21.3**	**426.1**	**31.0**	**113**	**22.7**	**1041.5**	**30.8**	**772**	**20.2**	**10519.8**	**28.5**
Atlas					1	0.2	30.4	0.9	28	0.7	416.3	1.1
Axis (Epistropheus)					2	0.4	13.3	0.4	4	0.1	55	0.1
Vertebra									10	0.3	62	0.2
Vertebra caudalis									9	0.2	19.6	0.1
Vertebra cervicalis					1	0.2	4.7	0.1	38	1	270.9	0.7

Vertebra lumbalis	1	0.6	11	0.8	7	1.4	47.6	1.4	108	2.8	872.4	2.4
Vertebra thoracicus					8	1.6	54.4	1.6	136	3.6	814.4	2.2
Costa	16	9	69.4	5.0	61	12.3	209.4	6.2	425	11.1	2247.1	6.1
Sacrum	1	0.6	9.6	0.7	2	0.4	15.7	0.5	12	0.3	123.2	0.3
Trunk	**18**	**10.1**	**90**	**6.5**	**82**	**16.5**	**375.5**	**11.1**	**770**	**20.2**	**4880.9**	**13.2**
Radius	9	5.1	92.8	6.7	28	5.6	200.8	5.9	136	3.6	1009.6	2.7
Tibia/Tibiotarsus	19	10.7	138.7	10.1	66	13.3	403.1	11.9	295	7.7	2669.3	7.2
Ulna	6	3.4	69.7	5.1	14	2.8	220.1	6.5	144	3.8	1750.6	4.7
Fibula	1	0.6	11.9	0.9	6	1.2	12.4	0.4	107	2.8	215.5	0.6
Zygopodium	**35**	**19.7**	**313.1**	**22.8**	**114**	**22.9**	**836.4**	**24.8**	**682**	**17.9**	**5645**	**15.3**
Calcaneus	2	1.1	16.9	1.2	3	0.6	11.6	0.3	47	1.2	544.9	1.5
Carpale									2	0.1	4	0.1
Carpale IV					1	0.2	3.5	0.1	2	0.1	4.1	0.1
Metacarpus II	1	0.6	1	0.1	1	0.2	0.7		17	0.4	38.5	0.1
Metacarpus III	2	1.1	14	1.0	2	0.4	6.5	0.2	28	0.7	143.2	0.4
Metacarpus IV	4	2.2	19	1.4	4	0.8	24.9	0.7	26	0.7	119.7	0.3
Metacarpus V	1	0.6	1	0.1	1	0.2	1.2		18	0.5	50.1	0.1
Metapodium									111	2.9	301.9	0.8
Metatarsus II					1	0.2	3.6	0.1	12	0.3	25	0.1
Metatarsus III					3	0.6	10.9	0.3	55	1.4	218.4	0.6
Metatarsus IV					4	0.8	17.7	0.5	22	0.6	50.6	0.1
Talus (Astragalus)	3	1.7	17	1.2	4	0.8	35.8	1.1	29	0.8	362.3	1
Tarsale IV (Os cuboideum)	1	0.6	2.3	0.2					3	0.1	7.6	0.1
Os intermedioradiale									1	0.1	3.2	0.1
tarsi centrale									5	0.1	8.4	0.1
Patella					7	1.4	63.7	1.9	9	0.2	55.8	0.2
Phalanx 1 ant./post.	3	1.7	7.7	0.6	3	0.6	8.3	0.2	62	1.6	290.3	0.8
Phalanx 2 ant./post.	4	2.2	5.7	0.4	3	0.6	5.1	0.2	43	1.1	85.2	0.2
Phalanx 3 ant./post.	1	0.6	1.1	0.1	2	0.4	2.4	0.1	30	0.8	49.6	0.1
Autopodium	**22**	**12.4**	**85.7**	**6.2**	**39**	**7.8**	**195.9**	**5.8**	**522**	**13.7**	**2362.8**	**6.4**

Total	178		1376		497		3378.2		3813		36871.11	

Tab. 13: The frequency of domestic pig body parts from Sutz-Lattrigen Hafen US/OS and Sutz-Lattrigen Aussen after fragment numbers and weight (g). (Total with the groups).

	n	n%	g	g%	n%	n%	g	g%	n	n%	g	g%
Cranium	1	0.8	4.7	0.1	9	2.3	70.2	0.9	14	8.6	522.4	12
Dens inferior	4	3	35.5	0.9	15	3.8	161.3	2	2	1.2	9.5	0.2
Dens superior									13	8	92.2	2.1
Dens superior/inferior									1	0.6	4	0.1
Mandibula	2	1.5	14.4	0.4	10	2.6	108.6	1.4	10	6.1	733.3	16.9
Maxilla					2	0.5	106.9	1.3	6	3.7	155	3.6
Cranium with antler					12	3.1	408.1	5.1				
Os hyoideum									1	0.6	2.8	0.1
Skull	**7**	**5.3**	**54.6**	**1.4**	**48**	**12.3**	**855.1**	**10.6**	**47**	**28.8**	**1519.2**	**35**
Humerus	13	9.8	525.3	13.6	24	6.1	637.9	7.9	2	1.2	28.6	0.7
Femur	14	10.6	190	4.9	50	12.8	653.1	8.1	5	3.1	229.5	5.3
Scapula	1	0.8	7.9	0.2	2	0.5	504.3	6.3	4	2.5	206.1	4.8
Coxa	3	2.3	63.1	1.6	6	1.5	119.7	1.5	14	8.6	531.2	12.2
Stylopodium	**31**	**23.5**	**786.3**	**20.3**	**82**	**21**	**1915**	**23.8**	**25**	**15.3**	**995.4**	**23**
Atlas									2	1.2	76.1	1.8
Axis (Epistropheus)	1	0.8	9.8	0.3	1	0.3	11.7	0.1	1	0.6	72	1.7
Vertebra									1	0.6	17.3	0.4
Vertebra cervicalis	3	2.3	32.7	0.8	3	0.8	93	1.2	1	0.6	48	1.1
Vertebra lumbalis	1	0.8	24	0.6	17	4.3	189.3	2.4	2	1.2	42.6	1
Vertebra thoracicus	3	2.3	46.3	1.2					1	0.6	17.4	0.4
Costa	10	7.6	127.9	3.3	24	6.1	294.9	3.7	2	1.2	32.2	0.7
Trunk	**18**	**13.6**	**240.7**	**6.2**	**45**	**11.5**	**588.9**	**7.3**	**10**	**6.1**	**305.6**	**7**
Radius	7	5.3	418.2	10.8	1	0.3	15.2	0.2	4	2.5	166.7	3.8
Radius+Ulna (verwachsen)					12	3.1	253.2	3.2				
Ulna	6	4.5	187.6	4.8	4	1	197.3	2.5	2	1.2	97.3	2.2

Tibia/Tibiotarsus	14	10.6	398.7	10.3	6	1.5	136.2	1.7	5	3.1	48	1.1
Zygopodium	**27**	**20.5**	**1004.5**	**25.9**	**23**	**5.9**	**601.9**	**7.5**	**11**	**6.7**	**312**	**7.2**
Metacarpus III+IV	3	2.3	35.7	0.9	21	5.4	609.7	7.6	12	7.4	284.4	6.6
Metapodium	3	2.3	25	0.6	14	3.6	113.7	1.4	2	1.2	29.7	0.7
Metapodium III+IV	4	3.0	22	0.6	5	1.3	44.6	0.6	11	6.7	104.6	2.4
Metatarsus III+IV	11	8.3	582.5	15.0	24	6.1	627.1	7.8				
Os carpi accessorium					1	0.3	2.5	0.1				
Os carpi intermedium					2	0.5	9.1	0.1	2	1.2	17.6	0.4
Os carpi radiale					6	1.5	62.8	0.8	2	1.2	19	0.4
Os carpi ulnare					2	0.5	12.3	0.2				
Os intermedioradiale					2	0.5	16.4	0.2				
Os tarsi centrale (Os naviculare)	2	1.5	61.2	1.6	6	1.5	146.6	1.8				
Patella	1	0.8	15.1	0.4	4	1.0	79.2	1				
Phalanx 1 ant.	2	1.5	38.4	1.0	10	2.6	50	0.6				
Phalanx 1 ant./post.	3	2.3	18.8	0.5	2	0.5	35.2	0.4	24	14.7	326.1	7.5
Phalanx 1 post.	5	3.8	62.3	1.6	11	2.8	102.9	1.3				
Phalanx 2 ant./post.	4	3.0	35.5	0.9	5	1.3	24.3	0.3	5	3.1	60.7	1.4
Phalanx 3 ant./post.	5	3.8	26.3	0.7	20	5.1	309.1	3.8	2	1.2	21.6	0.5
Carpale IV									1	0.6	6.2	0.1
Centroquartale									3	1.8	93.1	2.1
Talus (Astragalus)	3	2.3	140.9	3.6	38	9.7	1204.3	15.0				
Calcaneus	3	2.3	725.4	18.7	14	3.6	560.6	7	3	1.8	210.5	4.9
Carpale II+III					6	1.5	60.1	0.7	3	1.8	30.6	0.7
Autopodium	**49**	**37.1**	**1789.1**	**46.2**	**193**	**49.4**	**4070.5**	**50.7**	**70**	**42.9**	**1204.1**	**27.8**
Total	132		3875		391		8031		163		4336.9	

Tab. 14: The frequency of red deer body parts from Sutz-Lattrigen Hafen US/OS and Sutz-Lattrigen Aussen after fragment numbers and weight (g). (Total with the groups).

Sutz-Lattrigen Hafen OS	Sutz-Lattrigen Aussen
18.55	22.97
17.95	22.6
19.28	22.46
21.6	19.8
19.53	20.03
18.17	23.25
	23.09
	19.92
	22.51
	23.06
	20.81
	18.51
	21.42
	23.69

Tab. 15: Red deer Phalanx 1 Ant. measurements in mm.

			Sutz-Lattrigen Aussen		Sutz-Lattrigen Hafen US/OS	
Main type	**Sub type**	**Type designation**	**n**	**n%**	**n**	**n%**
1	1	Caprinae metapodium point	2	0.3	12	4.6
1	2	Caprinae metapodium point with smoothed basis			2	0.8
1	4	Small point with joint	9	1.5	4	1.5
1	5	Large ulna point	1	0.2		
1	6	Massive point with joint	22	3.7	8	3.1
1	7	Small point without joint	69	11.5	6	2.3
1	8	Middle-Size point with joint	29	4.8	24	9.2
1	9	Massive point without joint	13	2.2	5	1.9
1	10	Point with smoothed basis	19	3.2	21	8
1	11	Rib point, comb form	74	12.3	1	0.4

1	12	Rib point, comb form, unfinished	3	0.5	1	0.4
1	13	Rib point	16	2.7	6	2.3
2	1	Bone double point			1	0.4
2	2	Rib double point	1	0.2	6	2.3
3	1	Arrow point			5	1.9
Points			258	42.9	102	38.9
4	1	Axe	2	0.3	2	0.8
4	2	Chisel in axe form	15	2.5	13	5.0
4	3	Massive chisel	22	3.7	52	19.8
5	1	Double axe	1	0.2		
5	3	Massive double chisel	7	1.2	3	1.1
4	4	Axe/chisel	2	0.3	1	0.4
4	5	Small chisel	59	9.8	34	13.0
5	5	Small double chisel	23	3.8	1	0.4
4	7	Massive ad-hoc chisel	1	0.2		
4	9	Thin chisel	1	0.2		
4	10	Rib chisel	1	0.2	6	2.3
5	10	Rib double chisel	1	0.2	1	0.4
4	12	Large ulna chisel	1	0.2	1	0.4
4	13	Massive chisel with joint	1	0.2	3	1.1
Chisels			137	22.8	117	44.7
6		Long bone chisel			2	0.8
8		Retoucher	5	0.8		
9		Double retoucher	5	0.8		
12		Spatula	2	0.3	1	0.4
13		Chisel/point	1	0.2		
17		Pig tooth lamella	32	5.3	14	5.3
21		Bone with hole	3	0.5		

22		Worked bone	49	8.2		
23.2		Tooth pendant	3	0.5		
23.3		Metapodium pendant	2	0.3		
26		Polished jaw	2	0.3	1	0.4
Worked bones			189	31.4	29	11.1
Indet			17	2.8	14	5.3
Total			601	100	262	100

Tab. 16: The categories of Projectile points (Fragment numbers of type and subtype) in Sutz-Lattrigen Hafen OS/US and Sutz-Lattrigen Aussen.

Sutz-Lattrigen Hafen US	**Body part**	**Male**	**Female**
Red deer	Skull	10	1
Domestic pig	Canine teeth	2	2
Cattle	Horn core		1
	Coxa		1
Sutz-Lattrigen Hafen OS			
Red deer	Skull	9	1
Wild pig	Canine teeth	1	
Domestic pig	Canine teeth	2	2
Cattle	Coxa		1
Sutz-Lattrigen Aussen			
Red deer	Skull	1	2
Sheep	Horn core	1	
Domestic pig	Cannine teeth	4	1
Wild pig	Cannine teeth	2	1
Domestic/wild pig	Cannine teeth	1	
Dog	Penis bone	2	
Beaver	Penis bone	1	

Tab. 17: Fragment number of bones with possible sex determination.

List of measurement abbreviations (according to Von den Driesch, 1976).

Bd: Breadth of distal end.

BFd: Greatest breadth of the facies articularis distalis.

BFp: Breadth of the facies articularis proximalis.

Bp: Breadth of proximal end.

BPC: Greatest breadth across the coronoid process.

BT: Greatest length of the trochlea.

DC: Depth of the caput femoris.

Dd: Depth of distal end.

Dp: Depth of the proximal epiphysis.

DPA: Depth across the processus anconaeus.

DLS: Diagonal length of the sole.

GB: Greatest breadth.

GL: Greatest length.

GLl: Greatest length of the lateral half.

GLm: Greatest length of the medial half.

GLP: Greatest length of the processus articularis

H: Height.

L: Length.

LA: Length of acetabulum (including lip).

LAR: Length of the acetabulum on the Rim.

Ld: Length of dorsal surface.

LFo: Inner length of the foramen obturatum.

MBS: Middle breadth of the sole.

SB: Smallest breadth (for pelvis: of illium).

SD: Smallest breadth of the diaphysis.

SDO: Smallest depth of the olecranon.

SH: Smallest height (for pelvis: of the illium).

SLC: Smallest length of the collum.