Middle Neolithic subsistence strategies in southwest Germany: the site Reichenau-B33 at Lake Constance in regional context

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Abstract

The archaeological sequence at western Lake Constance, located between Germany and Switzerland, is famous for the high density of Late Neolithic lakeshore settlements. Recent excavations uncovered several Middle Neolithic (MN) sites near the prehistoric lakeshore, with the site Reichenau-B33 providing a bioarchaeological assemblage. Here we present the anthracological, carpological, and archaeozoological results from Reichenau-B33, embedded in the analysis of a large bioarchaeological dataset, which covers Early Neolithic (Linearbandkeramik) and MN (Hinkelstein, Grossgartach, Rössen) assemblages from southwest Germany and helps elucidating subsistence adaptations of these first farmers at Lake Constance. Wood exploitation predominantly took place in the site's hinterland, with oak, beech and ash being the dominant woodland taxa. The charred carpological assemblage reveals a typical MN crop spectrum with naked barley, emmer, and einkorn, while pulses and oil crops are very rare. Two concentrations of fat hen (*Chenopodium album*) seeds reflect its use, along with additional wild species. This routine exploitation of wild plants is mirrored at several other MN sites. The faunal assemblage of Reichenau-B33 is dominated by red deer (>70%) and includes only low proportions of domestic pig and sheep/goat. From these data a picture emerges where the first farmers at Lake Constance adapted to a forested landscape, in which first clearings for settlements and fields likely attracted local wild herbivores that were routinely hunted. This focus on red deer hunting may have been an opportunistic response, allowing to obtain valuable animal resources while conserving the small herds of livestock and protecting crop fields at the same time.

Keywords

Archaeobotany, archaeozoology, anthracology, hunting, plant gathering, Lake Constance

Introduction

The Middle Neolithic (MN) in Central Europe covers the early to mid-5th millennium BCE (4,900–4,300 cal BCE) and reflects profound changes to the population structure and economic adaptations of farming communities. The period can broadly be divided into an earlier and a later phase, corresponding to various regional groups including Hinkelstein and Grossgartach, and Rössen, respectively (Müller 2000). The pottery decorations and house architecture of these groups show modifications but also continuities to early Neolithic Linearbandkeramik (LBK) traditions (Friederich 2012). While MN settlement areas broadly overlap with the LBK distribution on loess soils (Zimmermann et al. 2009), settlement density declined, indicative of lower population levels (Shennan 2018). Regionally, however, MN settlements appeared in landscapes formerly not inhabited by Neolithic farmers, offering the opportunity to study the economic strategies and adaptations of pioneering communities in new environments (cf. Ivanova et al. 2018).

One such landscape is western Lake Constance at the border between southwest Germany and northeast Switzerland. The shores of Lake Constance were densely settled during the Late Neolithic (LN; 4,300–2,200 cal. BCE), with the first settlements appearing around 4,000 cal. BCE (Schlichterle 2018). Lake Constance is part of a wider landscape across the valleys and plains north of the Alps – often referred to as the northern Alpine Foreland – where a high density of lakeshore sites developed since the second half of the 5th millennium BCE (Jacomet 2007; Ebersbach et al. 2024). A striking aspect of these new adaptations is the complex subsistence system that involved large-scale forest clearances and landscape management for resource acquisition, hunting, livestock herding, and crop cultivation in the settlement's hinterland (Jacomet et al. 2016; Bogaard et al. 2017; but see Rösch et al. 2017 for a different interpretation of palynological and archaeobotanical evidence). The LN deposits sporadically yield older artefacts, including stone axes and pottery, dating to the first half of the 5th millennium (Dieckmann 2011). These finds raise the questions of whether the research focus on the LN sites, with their rich waterlogged deposits, masked an earlier settlement phase at or near the lake, from which the LN adaptations and economic systems developed (Ebersbach et al. 2012).

Importantly, the levels of Lake Constance fluctuated throughout the Holocene, within the so-called 400 m a.s.l. line representing the highest levels of the lake since the last Glacial. Investigations of the remains of beach walls in the former shore zone show that at least in some phases of the second half of the 5th millennium BCE the lake reached up to the 400 m a.s.l. contour line (Vogt 2016). Therefore, potential MN lakeshore sites would likely not be located in the modern lake-edge zone but further away from the shore.

The first solid archaeological evidence of a MN settlement at Lake Constance, still limited to a few settlement features, was found in 2011 during a road construction northwest of Constance near Wollmatingen (Dieckmann et al. 2012). The site lies just above the 400 m a.s.l. line, meaning it was located in immediate proximity to the lake during the 5th millennium. In 2017, large-scale settlement traces were uncovered in Bodman with at least six MN house plans (Blobel et al. 2018). In the same year, a MN settlement was excavated on the extension of the federal road B33 near Allensbach-Hegne on mainland parcels of the municipality of Reichenau (Gutekunst and Hald 2018). This last site, Reichenau-B33, is located on the edge of the small northwestern basin of Lake Constance between the Island of Reichenau and Allensbach (Hald et al. 2020). Taken together, these recent excavations provide unique insights into the earliest lakeshore settlements at Lake Constance, while the systematic bioarchaeological sampling at Reichenau-B33 also offered the opportunity to reconstruct the economic strategies of these lakeshore pioneers.

The site of Reichenau-B33

The site Reichenau-B33 is situated between the Bodanrück hills and the marshy reed beds of Gnadensee (Figure 1), again at the so-called 400 m elevation line, marking the fluctuating lake edge during parts of the 5th millennium BCE. In the bay-like depression, about 300 m wide, a brown-black, strongly humic soil horizon was preserved, covering the features in the excavation area of about 4000

m² (Figure 2). In the underlying clay and gravel layers, about 400 discolorations of mostly shallowly preserved post holes as well as storage and waste pits were visible. Complete house plans were not preserved but concentrations of posts, together with the settlement pits, suggest a multi-phase settlement complex. The post buildings may have been oriented in a northwest-southeast direction, as indicated by individual rows of posts. Under the humus layer a shallow ditch, about 75 m long, was uncovered, which probably belonged to a fence or similar enclosure and delimited the settlement area from the lake. Decorated pottery fragments of various MN cultural groups including Hinkelstein, Grossgartach and presumably Rössen are present among the finds and indicate a longer settlement activity at this site in the first half of the 5th millennium BCE. Individual sherds also indicate more recent, so-called Epirössen, deposits from the second half of the 5th millennium.
Towards the edge of the excavated area a heavily disturbed grave of a presumably adult male and the inhumation of a probably 20–30 year old woman, about 1.6 m tall, were uncovered. The woman wore two flat stone bracelets on her upper left arm. Comparable pieces are known from MN settlement layers near Mühlhausen in the Hegau region (Dieckmann 1987). They suggest the woman was probably buried at the time of the Hinkelstein group (circa 4900–4700 cal. BCE) as also confirmed by radiocarbon dating of the skeletal remains, while all absolute dates together place the site's occupation into the first half of the 5th millennium (ca. 4,900–4,400 cal. BCE), with two dates indicating Late Neolithic activities (Figure 3; Supplementary Table 1).
The uncovered bioarchaeological assemblages of Reichenau-B33, including anthracological, carpological, and faunal remains, allow the reconstruction of wood exploitation, crop and livestock choices, plant gathering, and hunting strategies. By contextualizing our results within the LBK and MN bioarchaeological record of southwest Germany the study aims to use the Reichenau-B33 as a case study to reveal the MN subsistence strategies in relation to LBK traditions and adaptations to newly occupied environments outside the loess belt.

Materials and methods

Carpological and anthracological analysis

49 soil samples of up to 10 litres each were taken from 27 undisturbed features of Reichenau-B33, including individual pits and pit complexes, postholes, a grave, and a ditch. Sample processing via manual flotation involved mesh sizes of 2, 1, 0.5 and 0.3 mm. In 41 of these samples, seeds, fruits and cereal chaff remains were preserved by carbonisation (Supplementary Table 2). These remains were sorted from all fractions using a stereomicroscope (max. 40x magnification) and identified using the reference collections of the Institute for Archaeological Sciences at the University of Tübingen and the Archaeobotany Laboratory of the Baden-Württemberg State Office for Cultural Heritage, Hemmenhofen. Wood charcoal fragments were sorted from the 2mm fraction of 43 samples, using a stereomicroscope (max. 40x magnification; Supplementary Table 3). Charcoal fragments were taxonomically identified by observing wood anatomical characteristics on freshly broken surfaces using a stereomicroscope (up to x125 magnification) and a reflected-light microscope (x50-x500 magnifications). Identification is based on Schweingruber (1990) and the reference collection of the Dendrochronology Laboratory of the State Office for Cultural Heritage, Hemmenhofen. All data were entered into ArboDat (Kreuz and Schäfer 2022), allowing standardised formatting and data sharing.

Archaeozoological analysis

The find material from Reichenau-B33 includes 339 faunal remains, of which due to a high degree of fragmentation and poor surface preservation, only 24.5% have been identified to species level. Although with an NISP of 83 identified bones and teeth, this archaeofauna is comparably small (Supplementary Table 4), we can nevertheless expect reliable results concerning species distribution patterns, as shown by methodological studies on sample size requirements (Schmölcke 2013). Species identification was carried out based on comparative osteology (e.g. Nickel et al. 1986) and using archaeological and modern reference material of the Osteology department of Baden-Württemberg State Office for Cultural Heritage. For data recording, we used the archaeozoological database Ossobook (Kaltenthaler et al. 2022) including the criteria for documentation of bone and teeth measurements defined by von den Driesch (1976). The R software package ggplot2 served statistical analysis and its graphical implementation (Wickham 2016).

Interregional comparisons and data analysis

We compare the bioarchaeological data from Reichenau-B33 to a regional dataset of 13 MN sites, covering all available and quantified archaeobotanical and archaeozoological datasets from Baden-Württemberg that are securely attributed to a MN archaeological group (Figure 1, Table 1). We divided sites into earlier (MN I = Hinkelstein and Grossgartach) and later (MN II = Rössen) assemblages for detecting chronological developments within the MN and compare this dataset to Early Neolithic datasets, i.e. from the Linearbandkeramik (LBK) Culture in Baden-Württemberg (Figure 1; Table 1). LBK assemblages follow the general chronological phases of Meier-Arendt (1966); for the detailed LBK chronology of southwest Germany, see Strien (2011). The analysed archaeobotanical dataset only considers charred remains and includes 10 MN and 18 LBK sites, whereas the archaeozoological dataset includes 5 MN and 10 LBK sites. As the number of archaeozoological datasets available for the study region is limited, faunal data from areas in present-day Bavaria have been considered, increasing the number of datasets to 9 MN and 12 LBK sites. In some cases it was possible to subdivide faunal assemblages into different chronological units so that a total of 28 datasets was available for species distribution comparisons (see Supplementary Table 5).

Our comparison of LBK and MN crop proportions is based on all features that yielded more than 50 crop items (seeds and chaff) identified beyond genus level. High concentrations of more than 100 items per litre soil are interpreted as storage or processing (by-)products in primary contexts (following Kreuz et al. 2014). We did not exclude those storage samples from this analysis, because most MN sites would not yield meaningful numbers of crop remains and/or samples without them. Thus, for comparing crop and weed frequencies through time, we included all features yielding a minimum of 10 identified items (excluding wood). This low threshold was chosen to avoid excluding a high amount of MN features in the calculation of ubiquity values (presence of botanical remains across features, expressed as percentage).

We applied detrended correspondence analysis (DCA) using Canoco 5 (Šmilauer and Lepš 2014) to explore variation among crops, arable weeds, and other wild plants of all MN features (38 features from 9 sites) with a minimum of 10 identified macrobotanical items (excluding wood) and based on all taxa with a ubiquity of min. 5%.

Results

Anthracology of Reichenau-B33

206 charcoal fragments from 27 features (43 samples) were analysed (Supplementary Table 3). Overall, 41 % are *Quercus* (deciduous; present in 65 % of the samples), followed by *Fagus* (17% of fragments/37 % presence in samples), *Fraxinus* (12%/28%), Maloideae (8%/19%), *Corylus* (7%/16%), *Betula* (2%/7%), and with minor appearances (<1 % of the fragments) *Ulmus*, *Tilia*, *Acer*, *Alnus*, *Populus*, *Populus*/*Salix*, and one cf. *Abies*. Bark (unidentified) is present in 5 % of the samples. Some features show only *Quercus*, while others contained a mixture of up to 4 taxa, without a perceivable pattern.

Archaeobotany of Reichenau-B33 in regional context

The 41 analysed samples (27 features) yielded a total of 9,169 charred remains of fruits, seeds and vegetative parts (Supplementary Table 2). The material is dominated by cereal caryopses, cereal chaff, and seeds of fat hen (*Chenopodium album*). Naked barley (*Hordeum vulgare* subsp. *distichum* var. *nudum*) and emmer wheat (*Triticum turgidum* subsp. *dicoccum*) dominate the domesticated crop spectrum (Figure 4). Twisted barley grains are absent, suggesting two-rowed ears. One-grained einkorn wheat (*Triticum monococcum* subsp. *monococcum*) accompanies the cereals. Other crop species are absent from the assemblage except for a single potential pea seed (cf. *Pisum sativum*) and one flax seed (*Linum usitatissimum*).

Most of the cereal remains derive from one pit (feature 39), radiocarbon-dated to around 4,500 cal. BCE, that likely represents a storage context (Supplementary Table 1; Table 2). Barley rachises are absent from this context, while the mixture of emmer and einkorn grains together with the high proportion of fragmented, not further identifiable glume bases not identifiable to one of the two taxa makes it difficult to calculate grain:spikelet ratios for the hulled wheats. Taking into account the entire hulled wheat assemblage from feature 39, however, it seems likely that emmer and einkorn grains were stored in spikelets. Seeds of potential arable weeds are absent from this sample.

Two other pits, features 277 and 473, contained concentrations of charred *Chenopodium album* seeds, likely reflecting storage and/or accidental charring during food preparation. Feature 277 yielded some cereal remains alongside a concentration of more than 580 charred *C. album* seeds, while feature 473 contained about 2,000 charred *C. album* seeds alongside the highest diversity of wild taxa among all features from the site (n=14). These include moderate amounts of strawberry (*Fragaria* sp.) nutlets, alkekengi (*Physalis alkekengi*) seeds and some hazel (*Corylus avellana*) shell fragments. Seeds of *C. album* from this feature provided an AMS date of about 4,800 cal. BCE (Supplementary Table 1).

As seen in comparison with the other MN assemblages of southwest Germany, the principal MN crops in the study region are the hulled wheats emmer and einkorn, which occur together with naked barley and naked wheats in varying proportions (Figure 4; Supplementary Table 6). Emmer remains dominate the earlier MN sites Reichenau-B33, Kirchheim unter Teck-Kraichling, and Stuttgart-Mühlhausen "Viesenhäuser Hof", associated with artifact assemblages of the groups Hinkelstein and Grossgartach. In contrast, einkorn, naked barley and naked wheat characterise the later Rössen sites Weinstadt-Endersbach, Ditzingen, and Ilsfeld. However, as most MN sites yielded storage contexts, the presence and abundance of individual cereal species might be biased. Crops other than cereals are very rare and represented by individual seeds of pea, lentil (*Lens culinaris*), and flax (Supplementary Table 6).

Table 2 gives the contents of the MN samples representing seed or chaff concentrations, defined by more than 100 items per litre sediment. Alongside the features 39 and 473 from Reichenau-B33, such concentrations are present at four more sites and dominated by a diverse spectrum of crops and wild plant species, including *Lapsana communis, Fallopia convolvulus*, *Bromus arvensis*, and *Bromus secalinus*.

The correspondence analysis of 37 species from 38 MN features separates a group with cereals and arable weeds from clusters containing mostly wild plants (Figure 5). The first group includes cereal grains and chaff, and the segetals *Bromus arvensis*, *Galium aparine* and *spurium*, *Lapsana communis*, *Fallopia convolvulus*, and a *Bromus* spp. group including *sterilis* and *tectorum*. *Rumex acetosella* plots in this group too, possibly indicative of locally acidic soils near the sites of Ilsfeld and Creglingen-Frauental, where the species occurs. Axis 1 separates a cluster containing *C. album*, *P. alkekengi* and *Fragaria* sp. from this 'cereals plus segetals' group, driven mostly by samples from Reichenau-B33 (Supplementary Figure 1). Axis 2 separates forest and hedge species (*C. avellana*, *Prunus* sp.) and taxa of meadows and wetland habitats towards its negative end. The ruderals *Polygonum aviculare* agg., *Chenopodium glaucum* and P. *murale* plot here too, suggesting that these taxa are not primarily related to crop processing.
Naked barley and naked wheat characterise MN crop spectra (Figure 6) and occur only sporadically at LBK sites. These earlier records may include intrusive specimens wrongly assigned to the LBK (Kapcia et al. 2024), where cereal cultivation is typically dominated by emmer and einkorn. The ubiquity values of emmer and einkorn (Figure 7) do not show the same trends compared to their proportional data (cf. Figure 4). These discrepancies may indeed be explained by the dominance of storage deposits at most MN sites. Other crops, including pea, lentil, flax, and opium poppy (*Papaver somniferum*), also stand in a LBK tradition although the latter three disappear throughout the MN (Figure 7c). Gathered nuts and fruits reach the highest ubiquities in the early MN (Figure 7d) but we must note that these are mostly due to the high frequency of hazelnut, strawberry and *P. alkekengi* at Reichenau-B33. Among the most frequent weed species at LBK and MN sites, 8 out of 10 occur at LBK and MN sites (Figure 8). We include *C. album* here, as it is an arable weed, while its high ubiquity is also driven by its status as a food plant (Bogaard 2011).

Archaeozoology of Reichenau-B33 in regional context

The faunal assemblage is dominated by hunted game, reaching almost 82% of the total finds based on the NISP (Table 3, for the full dataset see Supplementary Table 4). Evidence for domestic mammals is limited to a few specimens of pig and sheep/goat (not further identifiable). Cattle, which play an essential role in Neolithic subsistence elsewhere, are completely absent. With 72.3%, red deer remains account for the majority of animal bones, while roe deer and wild boar occur in small numbers. If counting unidentified fragments of the cattle/deer category to red deer, wild animals would contribute almost 87% to the assemblage. Exploring specific hunting strategies, e.g. seasonality or a possible focus on a certain age group, is impossible since the small deer assemblage does not allow calculating a reliable slaughter age curve. At least the few cases in which we can evaluate the epiphyseal joint closure do not provide any evidence for hunting young animals at Reichenau-B33. Moreover, judging by the fact that food and slaughter waste are present, the deer carcasses were likely transported to the settlement for processing. This pattern is also found at other LBK and MN sites where systematic red deer hunting took place (e. g. Stephan 2006).
Comparisons with other sites are essential for interpreting local subsistence patterns. However, no statistically reliable MN faunal assemblages have been analysed so far from the region around Lake Constance. The only other local MN assemblage available so far, is located near Bodman-Ludwigshafen, 11 km northwest of Reichenau-B33. Besides seven pig and six cattle specimens of either the domesticated or the local wild form, a lower sheep or goat molar and an upper cattle molar provide the only definite evidence for domesticated animals. Despite this small material basis, it is nevertheless noteworthy that, in contrast to Reichenau-B33, domestic cattle appear in nearby

Bodman. The geographically closest LBK sites, located in the Hegau region, are dominated by domestic animals with game proportion of ca. 20% in Hilzingen "Forsterbahnried" and more than 40% in Singen "Scharmenseewadel" (Fritsch 1987).
By widening the comparison to sites in further parts of present-day Southwest-Germany, it becomes obvious that both in the Early Neolithic LBK as well as in MN groups such as the Grossgartach or Rössen, bone assemblages with differing proportions of wild game occur (Figure 9; Supplementary Table 5). For the LBK these values vary between 6.62% in Poltringen (Stork 1993) and 67.6% at Rottenburg "Fröbelweg" (Stephan 2006). In the MN, the range extends from 2% at Kraichtal-Gochsheim (Boessneck 1982) to 38.3% at Reusten "Grube 3" (Uerpmann 1977). These marked differences in the proportions of hunted game in MN faunal assemblages of the northern Alpine Foreland are confirmed when we consider the more extensive data sets from the neighbouring regions to the east. Here the percentage of wild animals varies between 1.6% and 55.7%. With 81.9%, the high proportion of game calculated for Reichenau-B33 is, however, unparalleled in both LBK and MN contexts north of the Alps (Figure 9). A similar situation occurs only in considerably younger contexts of the Cortaillod Culture site of Seeberg-Burgäschisee Süd, where domestic animals only contribute 5% to all NISP counts (Boessneck et al. 1963). However, assemblages from the circumalpine region dating to the second half of the 5th and early 4th millennium BCE do not show a uniform picture in this respect either (e.g. Ebersbach 2005, with further references).

Discussion

The environmental context of Reichenau-B33

The onset of the 5th Millenium BCE in western central Europe overlaps with a period of winter cooling (ca. 1.5°C) and a decrease in annual rainfall, which ended the ca. 600-year period of wet and relatively warm winters and cool summers, especially favourable for the spread and development of the LBK (Sánchez Goñi et al 2016). The location of Reichenau-B33 at the northwestern shore of Lake Constance, with its mild winters and southern exposure, could have compensated for at least some of this climatic development. The local vegetation surrounding the site, as inferred from the anthracological data, but also the pollen record at Gnadensee (Ryabogina et al. 2021), shows a dominance of oak forests with beech playing a sub-dominant role. From ca. 5000 cal. BCE onwards, the pollen record suggests that forests gradually developed a rather open character with increasing participation of light-demanding trees like birch and especially hazel. Such a pattern of increasing secondary forest is typical for the initial stages of the Neolithisation in the study region (Rösch et al 2014). Between 4900–4300 cal. BCE, a gradual decline of elm pollen, parallel to the increased influx of charred particles in the catchment area and a peak of *Plantago lanceolata* pollen, could be related to anthropogenic activities opening the landscape. This palynological signal matches the evidence for the MN occupation at Reichenau-B33 chronologically – as well as the broadly contemporaneous sites at Wollmatingen and Bodman – and their possible agency in modifying and opening the forested landscape via animal pasture, collecting fodder and other woodland resources, but also with forest clearings for settlement and crop cultivation.
The composition of the faunal assemblage equally suggests that the inhabitants of Reichenau-B33 were hunting fauna from a wooded landscape exposed to rather low human impacts. Species such as the European hare (*Lepus europaeus*) or the wild horse (*Equus ferus*), which are favoured by open landscapes, are missing in the assemblage. The environment supported a presumably dense red deer population – bearing in mind that the absence of individual species could also be due to the small

amount of identifiable faunal remains. In such forested landscapes, the use of leaf fodder was potentially crucial for animal husbandry. Leaf fodder of *Ulmus* and *Tilia* were preferred in central Europe, consistent with the high nutritive value of their twigs (Hejcman et al 2024). Thus, the reduction of elm observed in the pollen record from Gnadensee (Ryabogina et al 2021) during the initial MN could be related to such livestock and woodland management practices, which was already observed in the region and elsewhere in Europe (for a recent discussion see Grosvernor et al 2017).

Middle Neolithic agriculture and plant gathering

Middle Neolithic crop spectra in southwest Germany typically comprise the hulled wheats emmer and einkorn, naked barley, and – mostly hexaploid – naked wheat (Rösch 2014; Ebersbach et al. 2012). Most pulse and oil crops typical for LBK sites disappear throughout the early MN, except pea, which continues to be present at low frequencies throughout the MN. Reichenau-B33 provides evidence for the cultivation of naked barley and emmer, intermixed with some einkorn. Evidence for naked wheat is lacking from the site. This is somewhat surprising as hexaploid naked wheat, together with naked barley, is well attested at the contemporaneous waterlogged deposits at Singen-Offwiesen, located ca. 24 km northwest of Reichenau-B33 (Dieckmann et al. 1998; Ebersbach et al. 2012). These differences may hint at highly local crop choices possibly influenced by cultural preferences, as environmental conditions and local soils (luvisols) are comparable. On the other hand, Reichenau-B33 did not yield many features rich in plant remains. Only four out of 27 features contained more than 50 identifiable crop remains and only 13 features contained more than 50 identifiable plant remains in general. Therefore, the assemblage may not capture the full crop diversity. Alongside crop cultivation, the community at Reichenau-B33 engaged in collecting wild plants, including *Chenopodium album*, *Physalis alkekengi*, *Fragaria* sp., and *Corylus avellana*. As the assemblage is preserved by carbonisation only, this is likely only a small fraction of the wild plants collected around the site (Colledge and Conolly 2014).

The *C. album* seed concentrations from Reichenau-B33 are reminiscent of similar deposits at the later MN sites of Endersbach and Creglingen-Frauental, containing *Lapsana communis*, *Fallopia convolvulus*, *Bromus arvensis*, and *Bromus secalinus*. Such deposits raise the question, whether these species, which are all common arable weeds, were intentionally collected or represent discarded crop-processing by-products. It is well accepted that *C. album* seeds and/or leaves were valued as a nutritious food source by LBK and MN farmers (e.g. Knörzer 1967, 1971; Bakels 1992; Bieniek 2002; Stokes and Rowley-Conwy 2002; Bogaard 2004, 2011; Kreuz 2007; Mueller-Bieniek et al. 2019, 2020; Heidgen et al. 2020; Kapcia et al. 2024). The species grows in open, nutrient-rich habitats and could have been collected from ruderal or arable habitats, but also from riverbanks and shores of water bodies. Its status as a Neolithic cultivar must be considered, either as a weed systematically harvested from cereal fields (Bogaard 2011; Kapcia et al. 2024), or a cultivar in its own right (Mueller-Bieniek et al. 2019). Similar scenarios are likely for the other species, which equally occur in seed concentrations and are all attested as prehistoric wild foods (e.g. Behre 2008). The samples from Endersbach and Creglingen-Frauental also contain other weed species and relatively high proportions of cereal remains, suggesting they derive from crop processing activities (see Table 2). However, whether these concentrations of *L. communis*, *F. convolvulus*, *B. arvensis*, and *B. secalinus* indicate their sorting for later use, or their particular abundance in the cereal harvests, cannot be concluded from these deposits alone (Rösch 2014). Across the features from Rössen sites, *L. communis* and *F. convolvulus* have ubiquities of ca. 60%, which is comparable to *C. album* and much higher than the ubiquity values for all other weeds (Figure 8). Therefore, it is plausible that the seed accumulations in question

represent the sorting of valued wild seeds during crop processing, also considering the ample evidence for the use of wild forbs and weedy species in European Neolithic sites (e.g. Jacomet 2009; Bogaard 2011; College and Conolly 2014; Mueller-Bieniek et al. 2019; Kapcia et al. 2024).
Reichenau-B33 represents one of the earliest settlements at the shore of Lake Constance, and away from the typical environmental settings of other MN and virtually all LBK sites on fertile loess soils. Especially given the investment in hunting local game and the low proportions of livestock at Reichenau-B33, reconstructing crop growing conditions would give valuable insights into the agronomic adaptations of these lakeshore pioneers. However, the cereal storage deposit does not contain many weed seeds, which are rare throughout the assemblage. Besides *C. album*, *F. convolvulus* occurs in some samples and the presence of both species may hint at relatively productive growing conditions at Reichenau-B33. Moreover, the general MN weed assemblages of the study region are comparable to LBK weed floras (Figure 8; Rösch 2014), which characterise a rather intensive, small-scale arable system (Bogaard 2004; Bogaard et al. 2013, 2016). The pioneers at the shore of Lake Constance may well have operated in this arable tradition, although direct evidence for e.g. manuring is currently not available from MN sites.

Middle Neolithic hunting and animal husbandry

According to zooarchaeological results, the exploitation of animals at Reichenau-B33 was strongly focused on hunting, while domestic animals only slightly contributed to the meat supply. Comparing the local Reichenau-B33 data with assemblages from the Northern Alpine Foreland, confirms that this importance of wild resources is by no means the rule, but occurs in varying intensity in several Neolithic periods. The question of why some early farming communities of Central Europe still relied on hunting rather than on animal breeding has been controversially discussed (e.g. Stephan 2006; Uerpmann 1977; Schibler and Jacomet 2010). For the late Neolithic communities of the 37th/36th century BCE, Schibler and Jacomet (2010) demonstrated that increasing hunting activity in circum-alpine lakeshore settlements seems related to deteriorating climatic conditions for animal breeding. However, this model does not explain the development of Early and Middle Neolithic subsistence strategies, which are highly diverse and do not show any evidence for supra-regional patterns that could be linked to climatic fluctuations (e. g. Stephan 2006). Instead, it has been argued that, depending on the environmental setting, for early farmers who cleared forest for crop cultivation it was necessary to keep local game populations small in order to minimize crop losses caused by wild ruminant browsing activities (e.g. Boessneck et al. 1963; Uerpmann 1977). At the same time, hunting provided an important source of protein, which helped to conserve the relatively small herds of early Neolithic domestic animals that potentially also provided dairy and manure (e.g. Stephan 2006; Salque et al. 2012; Bogaard et al. 2013). For the MN site Reichenau-B33 and the still densely wooded surroundings of the Bodanrück landscape, which provided good conditions for large cervid populations, this model offers a plausible explanation for the high proportion of wild animals, and red deer in particular.

Conclusions

The bioarchaeological evidence from Reichenau-B33 provides evidence for subsistence adaptations during the settlement expansion to the shores of Lake Constance in the early 5th millennium BCE. This took place at least 800 years before the first Late Neolithic lakeshore dwellings were built and fits well with the earliest palynological signals of land use, including the onset of the elm decline, the continuous presence of microcharcoal peaks, and indicators for open habitats like *Plantago* *lanceolata*. Cultivated crops include naked barley, emmer, and einkorn, while hexaploid naked wheat – typical for many other regional MN sites - is missing from the assemblage. The general MN crop spectrum of southwest Germany stands in an LBK tradition but reflects new elements, including a declining importance of pulses and flax, and lacking evidence for opium poppy cultivation. Collected wild species are well attested, which at Reichenau-B33 are dominated by fat hen, occurring in two seed concentrations, alongside hazel, strawberry and *Physalis alkekengi*. Considering the evidence for wild seed use from other MN sites, often involving weedy species potentially collected from crop fields, it is justified to assume that wild plant consumption was a common element of MN subsistence strategies. The dominance of hunted animals and particularly red deer in the faunal assemblage of Reichenau-B33 reflects a more holistic agro-economic strategy that made use of available game resources, which at the same time protected crop fields and preserved the small herds of pigs and caprines. The general archaeozoological evidence from the landscapes north of the Alps, however, shows a variable picture where communities relied on varying proportions of domesticated and wild animals during the LBK and MN. At Reichenau-B33 this can be seen as a rather opportunistic response to the local forested environment with a dense deer population, although this explanation may only consider some of the factors that led individual LBK and MN communities to focus on hunting game over keeping larger herds of domestic animals.

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No potential conflict of interest was reported by the author(s).

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Figures and Tables

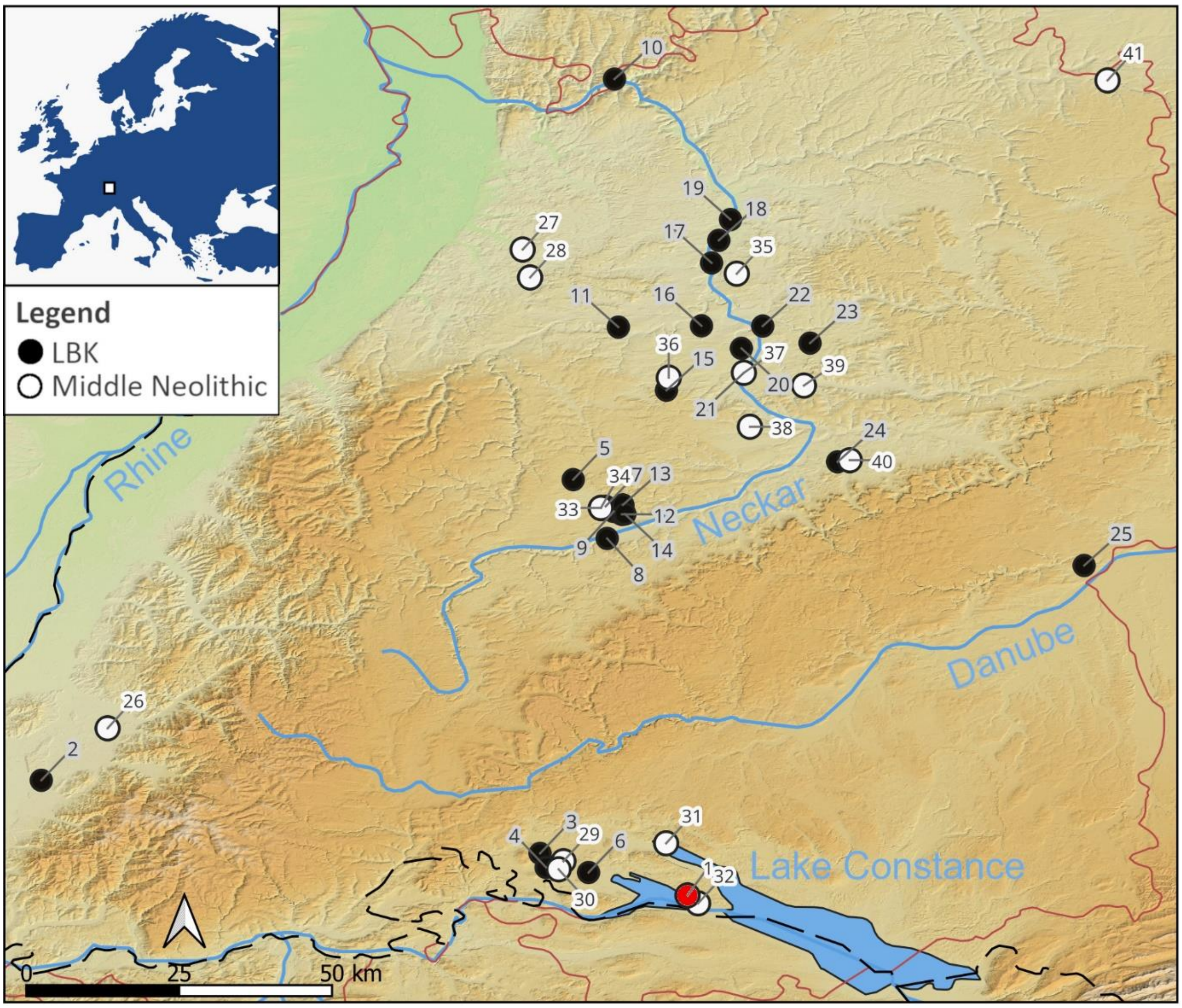


Figure 1. Map showing the study region of southwest Germany and Lake Constance with the location of Reichenau-B33 (red symbol) and the LBK and MN sites included in the interregional analysis. See Table 1 for key to sites.

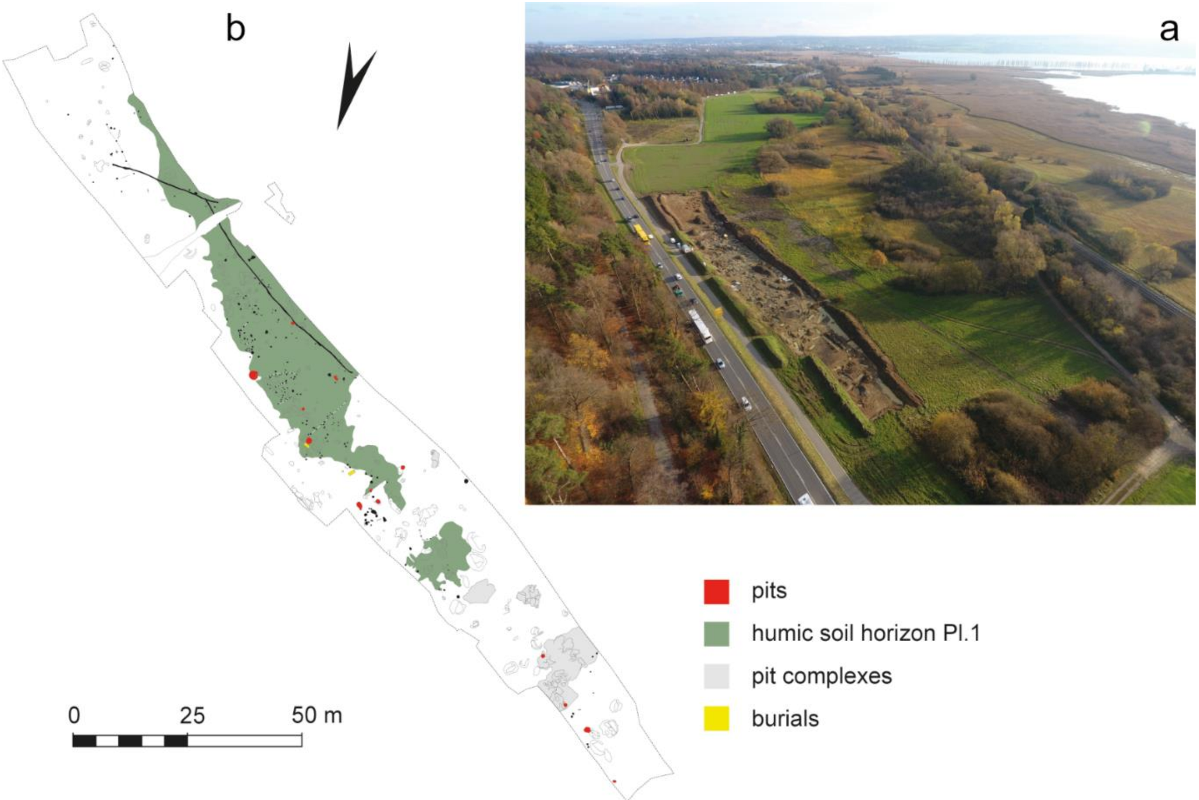


Figure 2. (a) Aerial photograph of Reichenau-B33 under excavation with Lake Constance in the background. (b) Plan of the site with legend of excavated features.

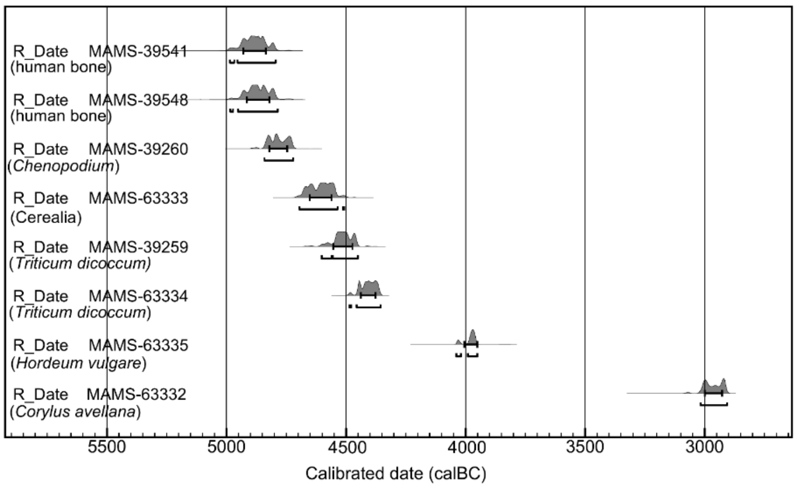


Figure 3. Calibrated radiocarbon dates from Reichenau-B33.

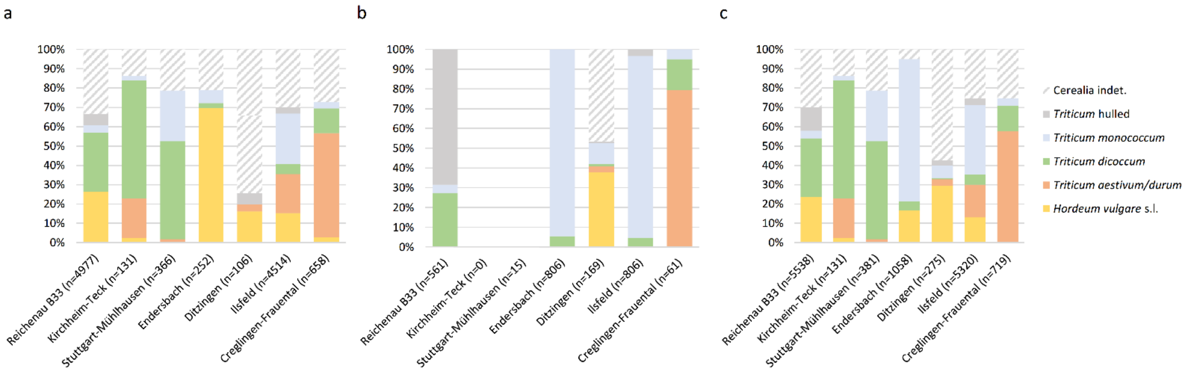


Figure 4. Composition of cereals across MN assemblages. (a) Grains, (b) chaff, (c) grains and chaff combined. Numbers in brackets gives amount of identified cereal remains (as MNI). Note that cereal composition is not displayed for sites where the total number of crop items is less than 50.

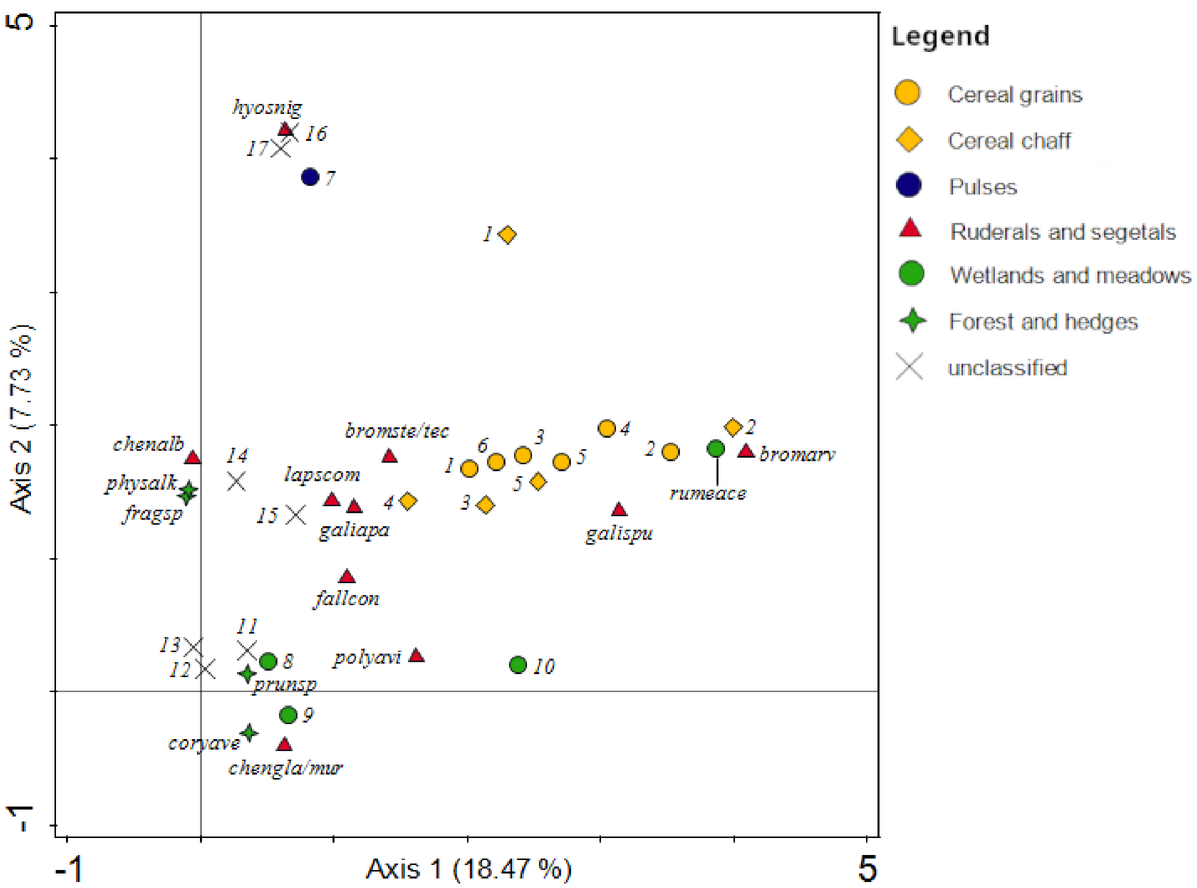


Figure 5. Ordination diagram of a DCA based on 37 species from 38 MN features. Percentages give the explained variation of the first two axes. Species key: 1) *Hordeum vulgare*, 2) *Triticum aestivum/durum*, 3) *Triticum dicoccum*, 4) *Triticum monococcum*, 5) *Triticum* hulled, 6) indet. cereals, 7) Pisum sativum, 8) *Polygonum* spp. wetlands (incl. *P. amphibium*, *lapathifolium*, *minus*), 9) *Trifolium* spp. meadows (incl. *T.* cf. *campestre/dubium* and cf. *medium*), 10) *Phleum pratense*, 11) *Galium* sp., 12) Polygonaceae, 13) Fabaceae, 14) *Carex* sp., 15) *Bromus* spp., 16) *Potentilla* sp., 17) Poaceae.

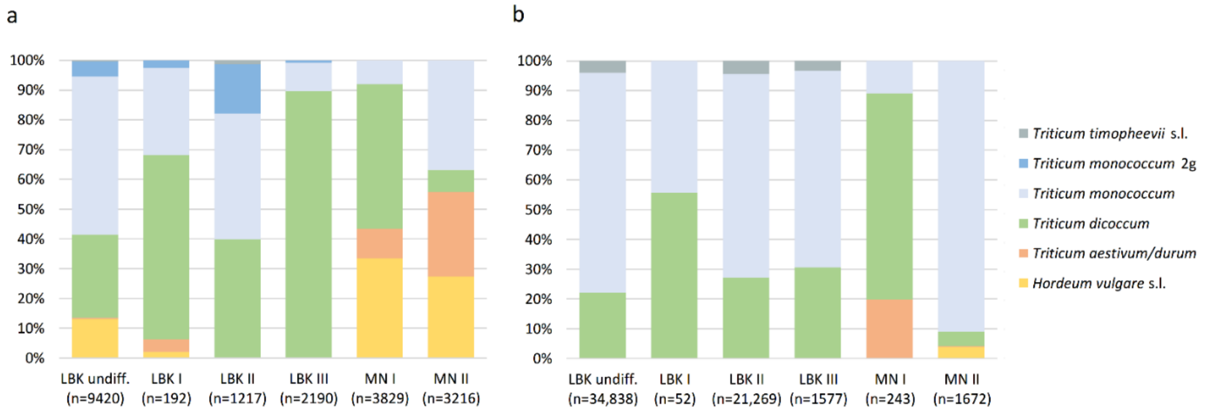


Figure 6. Development of cereal grains (a) and chaff (b) throughout LBK and MN phases. Numbers in brackets gives amount of identified cereal remains (as MNI).

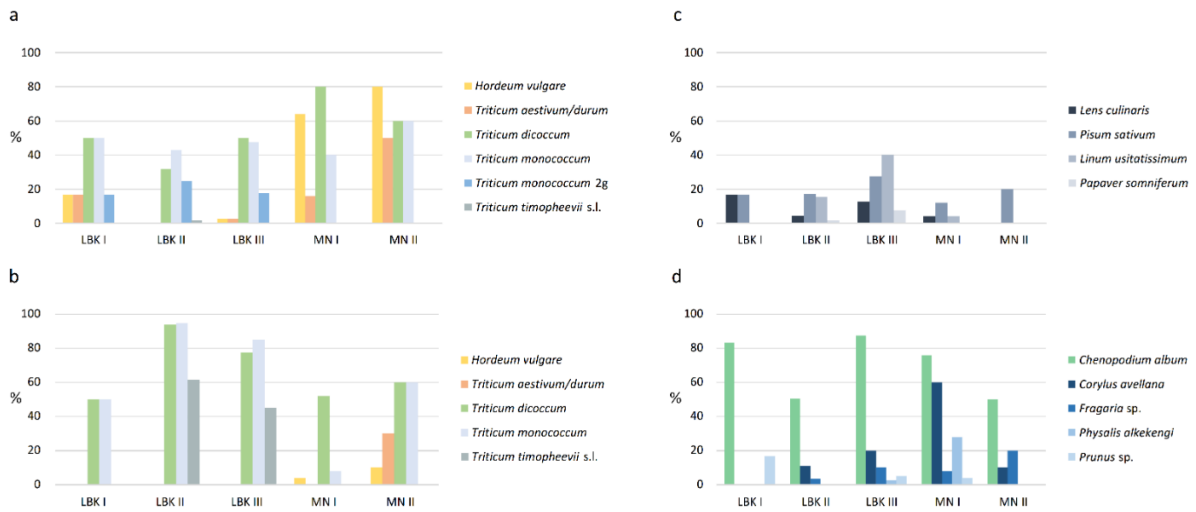


Figure 7. Ubiquity of crops and gathered plants across features with more than 10 identifiable items. a) Cereal grains, b) cereal chaff, c) legumes and oil crops, d) selection of gathered seeds, nuts and tree fruits common at MN sites; note that *C. album* also appears in Figure 8 as a segetal plant. Values for LBK phases II and III are heavily influenced by Vaihingen, which contributes 105/117 and 22/39 features to these phases, respectively. In particular, the high ubiquity for *T. timopheevii* s.l. is thus not generally representative for these phases.

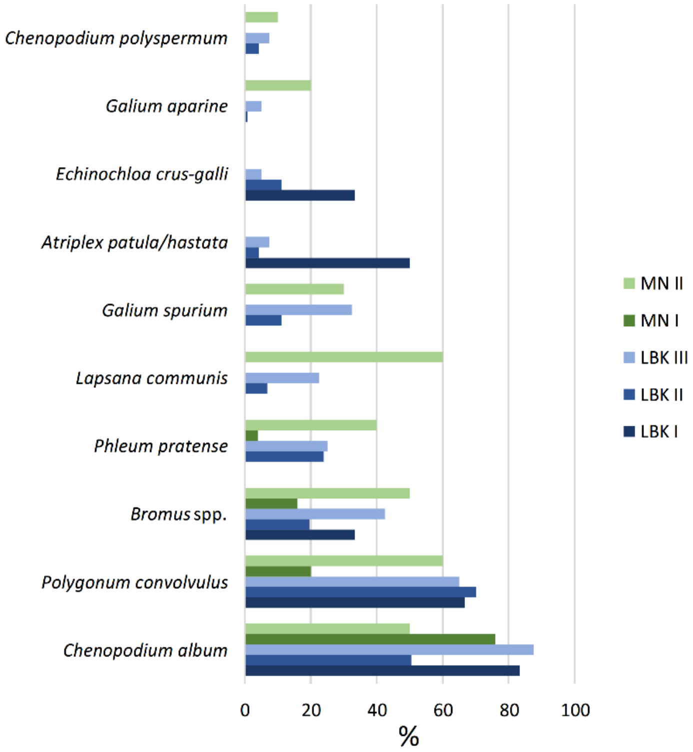


Figure 8. Ubiquity of the most common segetal taxa across LBK and MN features. Taxa that occur in three of the five chronological phases were considered. *Bromus* spp. represents an amalgamation of *arvensis*, *hordaceus*, *secalinus*, *sterilis*, and *tectorum* – as *Bromus* specimens are often identified to species groups rather than individual species. Note that the generally high ubiquities of *C. album* and *F. convolvulus* are likely driven by their status as collected food plants.

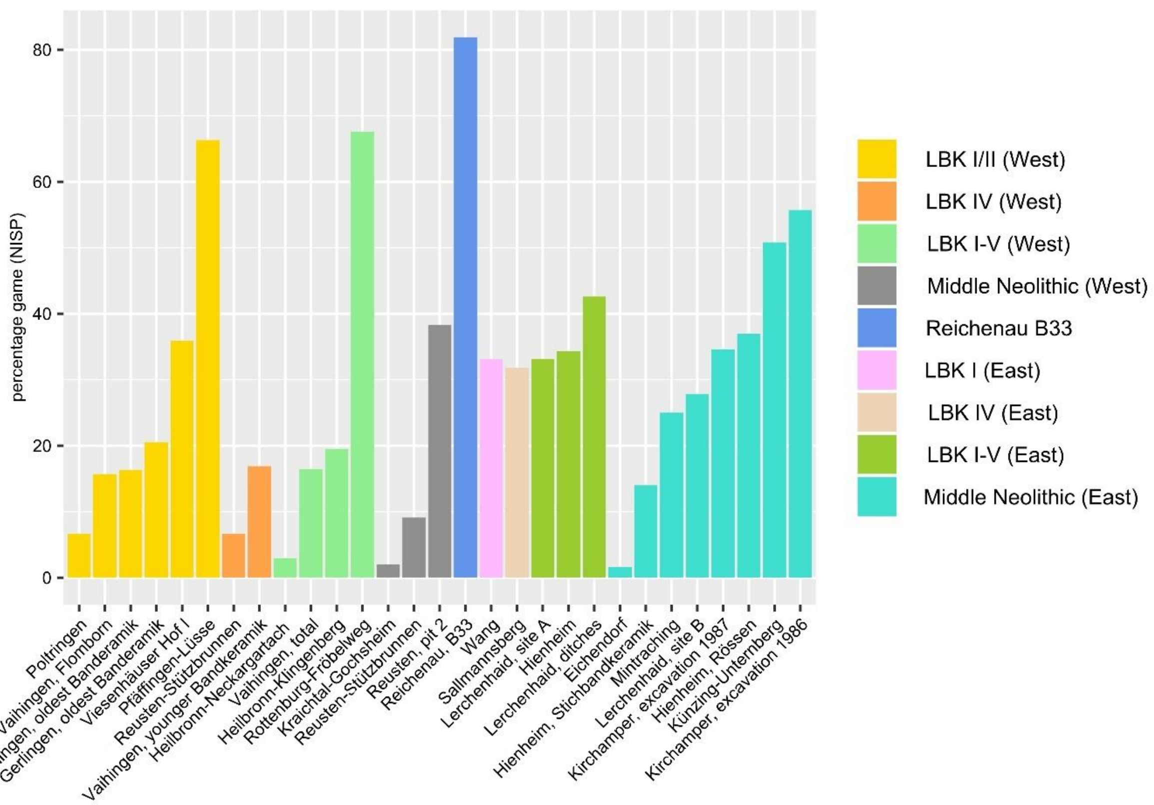


Figure 9. Percentage of wild game in LBK and MN faunal assemblages located in the western and eastern parts of the Northern Alpine Foreland.

Table 1. Sites in southwest Germany considered in the analyses and/or mentioned in the text. Site numbers correspond to Figure 1.

No.	Site	Period	Datasets considered		References
			botanical	faunal	
1	Reichenau-B33	MN	X	X	this paper
2	Schallstadt-Mengen	LBK	X		Rösch et al. 2008
3	Hilzingen	LBK	X		Stika 1991
4	Hilzingen-Forsterbahnried	LBK		X	Frisch 1987
5	Herrenberg-Affstaett	LBK	X		Stika 1991
6	Singen “Scharmenseewadel”	LBK		X	Fritsch 1987
7	Ammerbuch-Reusten	LBK	X	X	Märkle and Marinova (see Suppl. Tab. 6); Trixl unpubl.
8	Rottenburg-Fröbelweg	LBK		X	Stephan 2006
9	Poltringen	LBK		X	Stork 1993
10	Lauda-Koenigshofen	LBK	X		Rösch et al. 2008
11	Vaihingen an der Enz	LBK	X	X	Rösch 1995; Bogaard 2011; Schäfer 2017
12	Ammerbuch-Pfäffingen-Lüsse	LBK	X	X	Stork 1993; Heidgen et al. 2020; Trixl unpubl.
13	Ammerbuch-Entringen	LBK	X		Heidgen et al. 2020
14	Tuebingen-Unterjesingen	LBK	X		Märkle and Marinova (see Suppl. Tab. 6)
15	Gerlingen, Älteste BK	LBK		X	Stephan 2006
16	Bietigheim-Bissingen	LBK	X		Piening 1989
17	Lauffen am Neckar	LBK	X		Rösch 2014
18	Heilbronn-Klingenberg/Schlossberg	LBK	X	X	Stika 1996; Stephan 2008
19	Heilbronn-Neckargartach	LBK		X	Schmidgen-Hager 1992
20	Ludwigsburg	LBK	X		Piening 1982a
21	Stuttgart-Muehlhausen/Viesenhäuser Hof	LBK	X		Rösch 2014; Kokabi, unpubl.; selected faunal data in Stephan 2006, faunal data not considered as not fully published
22	Marbach	LBK	X		Piening 1982a
23	Weiler zum Stein	LBK	X		Piening 1982a
24	Kirchheim unter Teck	LBK	X		Gresiak 2018
25	Ulm-Egging	LBK	X		Gregg 1998
26	Voerstetten	MN	X		Rösch 2001
27	Kraichtal-Gochsheim, Fundstelle 3	MN		X	Boessneck 1982
28	Oberderdingen-Grossvillars	MN	X		Rösch 2005
29	Singen-Etzenfurth	MN	X		Märkle and Marinova (see Suppl. Tab. 6)
30	Singen-Offwiesen	MN			Dieckmann et al. 1998, not considered for analysis as data are not fully published

31	Bodman	MN		X	Trixl unpubl. and this paper
32	Wollmatingen	MN			n/a
33	Reusten-Stützbrunnen	MN		X	Stork 1993
34	Reusten, Grube 2	MN		X	Stork 1993
35	Ilsfeld	MN	X		Piening 1982b
36	Ditzingen	MN	X		Piening 1998
37	Stuttgart-Muehlhausen	MN	X		Rösch 2014
38	Ostfildern-Ruit	MN			Rösch 2014, too few plant remains for analysis
39	Endersbach-Weinstadt	MN	X		Pienig 1979
40	Kirchheim/Teck-Kraichling	MN	X		Rösch (see Suppl. Tab. 6)
41	Creglingen-Frauental	MN	X		Rösch 2014

Table 2. Middle Neolithic samples with more than 100 items/litre soil, indicating possible storage activities for individual species. Note that sample RBS-473 reaches only 96.7 items/litre but is included here, as *C. album* storage related to this feature is plausible. For references see Table 1.

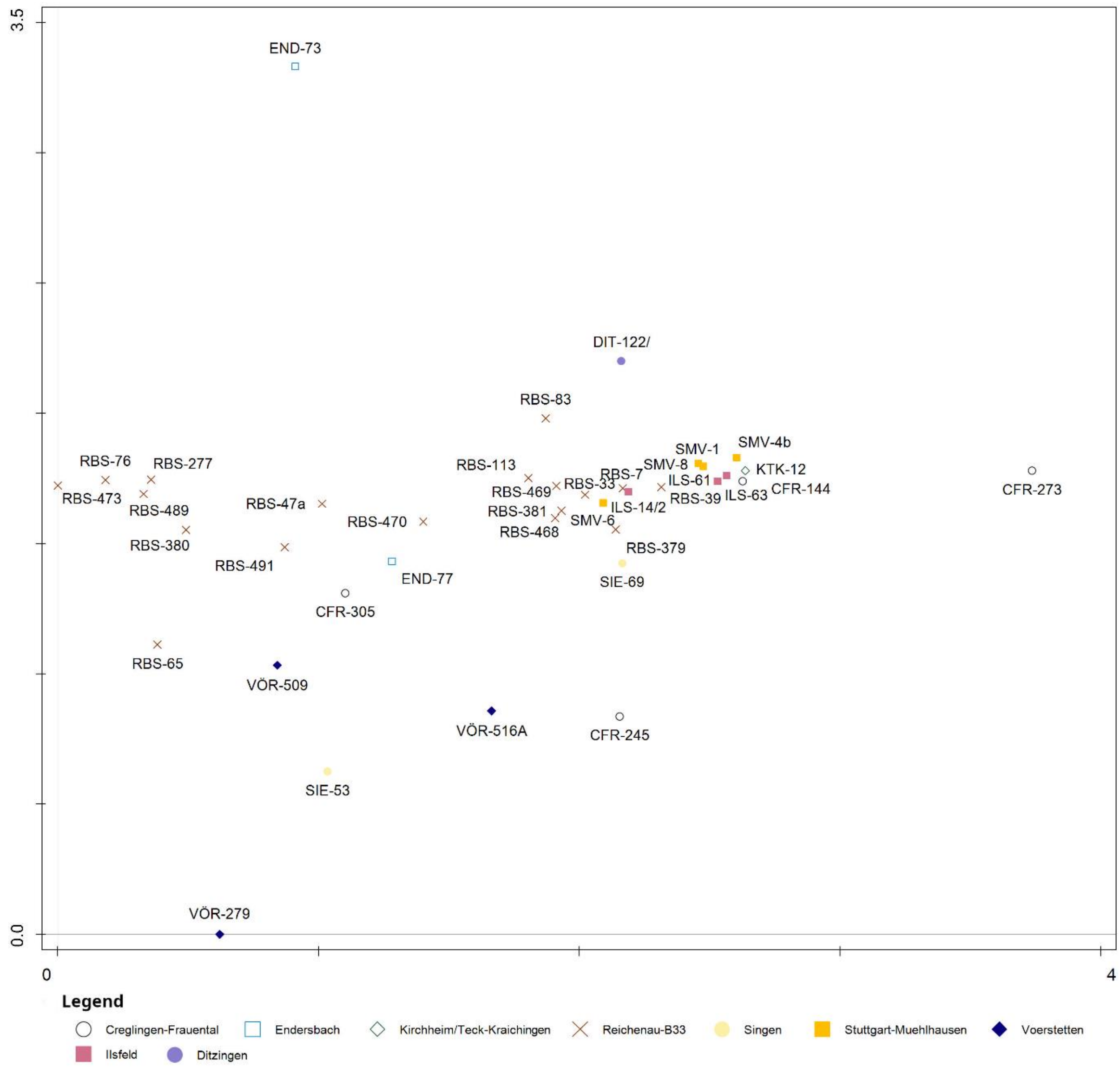
Site	Feature	Total *n*	Vol. (l)	Density (items/litre)	*Hordeum vulgare* s.l.	*Triticum aestivum/ durum*	*Triticum dicoccum*	*Triticum monococcum*	indet. cereal grains	cereal chaff combined*	*Bromus arvensis & secalinus*	*Chenopodium album*	*Fallopia convolvulus*	*Lapsana communis*	other wild species**
Reichenau-B33	RBS-473	2190	22.64	96.7	30	0	4	0	20	1	0	1953	1	0	181
Reichenau-B33	RBS-39	4857	7.43	653.7	1028	0	1436	184	1664	541	0	4	0	0	0
Kircheim/Teck-Kraichling	KTK-12	127	0.24	529.2	1	26	79	3	18	0	0	0	0	0	0
Endersbach	END-77	2314	5.12	452.0	175	0	2	5	53	806	11	130	202	816	114
Ilsfeld	ILS-6	5197	?	-	599	899	237	1177	1449	806	6	0	15	0	9
Creglingen-Frauental	CFR-273	2773	0.94	2950.0	4	315	72	21	114	59	1907	49	20	4	208

* Chaff at Reichenau B-33 is dominated by *T. dicoccum*; at Endersbach and Ilsfeld chaff is dominated by *T. monococcum*.
** RBS-473 includes 119 *Fragaria* sp. nutlets and 43 *Physalis alkekengi* seeds.

Table 3. The faunal assemblage from Reichenau-B33 (NISP only).

Species	NISP	%
Sheep/goat (*Ovis aries/Capra hircus*)	5	6
Domestic pig (*Sus domesticus*)	2	2.4
Domestic pig or wild boar (*Sus domesticus/scrofa*)	8	9.6
Wild boar (*Sus scrofa*)	6	7.2
Red deer (*Cervus elaphus*)	60	72.3
Roe deer (*Capreolus capreolus*)	2	2.4
Not identifiable	256	-
Total wild game among identifiable specimens*	**68**	**81.9**
Total identifiable	**83**	**100**

* Counting *S. domesticus/scrofa* as domestic pigs.



Supplementary Figure 1. Sample plot for (38 MN features, 37 species) of the DCA shown in Figure 5. Abbreviations correspond to feature codes in Supplementary Table 6.