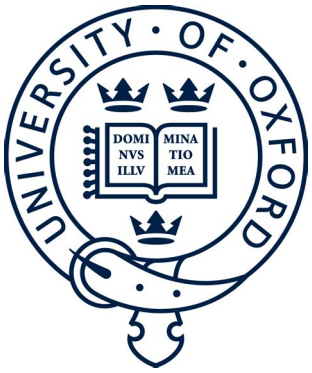
An archaeobotanical study of the prehistoric lakeshore settlement sequence at Ploča Mičov Grad, Lake Ohrid, North Macedonia



Amy Holguin

Hertford College

School of Archaeology

University of Oxford

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ABSTRACT

The southern Balkans is a pivotal area for understanding the spread of early farming from south-west Asia and its maturation in Europe. The southern Balkans is a climatically and ecologically diverse region. While the environmental conditions of some sub-regions, particularly parts of Greece, are similar to those of south-west Asia, the colder winters and wetter summers of upland and more northernly areas presented new contexts and affordances for early agricultural communities. This thesis explores how early agriculture was adapted to upland, wetland environments and new cultural preferences in the south-west Balkans.

Wetland sites preserve a greater range of plant parts and types than dryland sites, which typically underestimate the role of plant foods such as oilseed crops and foraged fruits and nuts. However, while numerous prehistoric wetland sites are known in the southern Balkans, few have been subject to systematic archaeobotanical investigation. This thesis aims to enrich our understanding of prehistoric wetland sites in the region, through the investigation of the prehistoric pile-dwelling settlement, Ploča Mičov Grad, Lake Ohrid, North Macedonia. An organic layer, rich with well-preserved waterlogged archaeobotanical remains, was present across four sediment cores extracted from the settlement's pile field. A range of plant foods from cultivated cereals and pulse to foraged fruits and nuts, as well as taxa relating to the wider biocultural landscape, was recovered, offering insights into cultivation practices, the interplay between human activity and local vegetation dynamics and activities such as crop processing and food preparation.

The first paper (Paper 1) of this thesis demonstrates the high level of preservation of the waterlogged archaeobotanical layer, with densities of plant remains comparable to those of

well-preserved pile-dwellings in the Alpine Foreland. New radiocarbon results confirm that the main cultural layer dates to the Late Neolithic (c. 4697-4500 to 4436-4257 cal BCE). A Middle Neolithic (c. 5790-5722 to 5755-5714 cal BCE) phase of occupation is among the oldest evidence for Neolithic activity in the Lake Ohrid basin, while a later Bronze Age (c. 1878-1688 cal BCE) phase relates to material culture recovered from the lakebed during the archaeological excavations and deriving from largely eroded cultural layers. Comparisons between the three phases chart long-term continuity in plant food systems, with some crop shifts. The broad spectrum of cultivated and foraged plant foods observed across the phases conferred resilience against crop failure and food shortage.

In the second paper of this thesis (Paper 2), the on-site Late Neolithic archaeobotanical results are synthesised with near-site palaeoecological data, offering evidence taken at different but complementary spatial and temporal scales. The integration of the palynological and archaeobotanical datasets provides a nuanced understanding of plant diversity within the Bay of Bones. This integrated approach enables assessment of the impact of foraging and cultivation on local vegetation by the Lake Neolithic community within the sheltered bay. Systematic collection of fruits and nuts coincides with increased pollination of rosaceous taxa, which flourished during the occupation phase. Together, the weed flora and the palynological evidence demonstrate that cultivation was small-scale and intensive, with arable plots located within a few hundred metres of the settlement.

The final paper of this thesis (Paper 3) considers the role of bitter vetch in Late Neolithic plant food systems. Bitter vetch is a minor component of archaeobotanical assemblages in the Balkans during the Early Neolithic but gains prominence in Late Neolithic assemblages, particularly in the northern Balkans. Evidence for the detoxification of the bitter vetch at Ploča

Mičov Grad suggests that this mildly toxic pulse was routinely processed and consumed, suggesting convergent cultural preferences across the region in the mid-5th millennium BCE.

Across the papers of this thesis, the diversity of plant food systems is evident. Land-use strategies that promoted diverse plant use protected against food shortages and resonate with present-day calls to diversify food systems in response to climate change. Due to preservation biases, this diversity would be underrepresented at typical dryland assemblages, highlighting the importance of wetland sites in the southern Balkans for understanding the breadth of early farming food systems in Europe.

CO-AUTHORSHIP STATEMENT

This thesis follows the article-based or 'integrated' thesis approach with three papers framed by a unifying introduction and conclusion. As part of a large and interdisciplinary project (ERC-synergy EXPLO project), the papers are co-authored by several colleagues to recognise their contributions to this work. My academic supervisors, Profs. Amy Bogaard and Mike Charles, provided the largest contribution through their teaching, direction and advice throughout my DPhil. Details of each author's contributions can be found in Appendix 3 of this thesis, as well as signed letters confirming that I conducted the vast majority of data collection, data analysis and writing of these papers.

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who I know are always there for me no matter what. Thank you for giving me every opportunity since being a child that led me to where I am today; for teaching me to love history and the environment and for encouraging and helping me to follow my dreams.

0.0 INTRODUCTION

0.1 OVERVIEW

As the climate and biodiversity crises faced by the Earth deepen, food systems must change, with crops adapting to new environments and diets diversifying (Gao et al. 2023). While thinking to the future, we can also look back to (pre-)history to inform present-day strategies, using archaeology as evidence for past resilience, adaptation or even failure of people and food systems experiencing environmental change (Bogaard et al. 2017; Fisher, 2020; Green et al. 2020; Cortinovis et al. 2020; Ebert et al. 2019).

Considering crop adaptation, a key period in human history was the spread of crops from south-west Asia to Europe: a defining feature of the onset of the Neolithic in Europe (Chapman and Souvatzi, 2020). These crops first entered Europe from south-west Asia through the southern Balkans, with crops appearing at sites from the mid-7th millennium BCE (Kotzamani and Livarda, 2018; Valamoti, 2023). The southern Balkans is a region with considerable climatic and eco-systemic diversity (Kryštufek and Reed, 2004; Hájek et al. 2008). Agricultural communities first encountered areas of the 'Mediterranean' biogeographic region (as classed by the European Environment Agency, 2017, Figure 1) with climatic conditions similar to that of western Anatolia. As such the crop spectrum was remarkably consistent between these regions (Colledge et al. 2005; Krauß et al. 2018). However, in order to spread further north into other parts of the Balkans and continental Europe, these introduced crops needed to adapt to new environmental conditions (Krauß et al. 2018; de Vareilles et al. 2022). Many crops did just that, gaining the ability to survive winter frosts alongside other adaptations, while others remained constrained to 'Mediterranean' climate zones (Krauß et al. 2018;

Ivanova et al. 2018; Ivanova, 2020; de Vareilles et al. 2022; Gutaker and Purugganan, 2023). As such, a narrowing of the crop spectrum can be, at least in part, linked to climatic and environmental changes and interpreted as an "adaptive strategy" (Sabanov et al. 2024, p.63) to such changes (Colledge et al. 2005; Krauß et al. 2018; de Vareilles et al. 2022). Archaeobotanical research centred upon Neolithic sites in the southern Balkans is pivotal for understanding how, why and when such biological and cultural adaptations took place, combining an understanding of plant physiology with a consideration of how ancient human activity and cultural choices supported such changes.

At present, the focus of archaeobotanical work in the southern Balkans has been centred upon drylands such as the Early Neolithic sites of Vrbjanska Čuka, central Republic of North Macedonia (Sabanov et al. 2024), Nea Nikomedeia, northern Greece (van Zeist and Bottema, 1971) and Vashtëmi on the Korça plain, southeastern Albania (Allen and Gjipali, 2014). Such sites have offered valuable insights into prehistoric agricultural practices (Valamoti, 2023) but typically have limited potential for exploring the role of *both* cultivated and collected plants in prehistoric food systems within their environmental setting, as their assemblages are biased towards plants that are stored year-round and processed in proximity to domestic fire installations (Jones, 2000; Bogaard and Halstead, 2015). As such, they can present a rich record for understanding cereal crops, which are often stored in bulk and processed throughout the year often with heat. Yet, they underrepresent the importance of many other plant foods which either often do not survive the charring event or are not routinely brought into contact with fire (Jacomet et al. 1989; Maier, 2001; Jacomet et al. 2004). In contrast, it is well-known in archaeobotany that waterlogged assemblages (often including both uncharred and charred components) preserve a more diverse plant spectrum (not just restricted to those

encountering or surviving heat) and a greater range of plant parts (including, for example, capsules, leaves and flowers; Jacomet et al. 2004; Jacomet, 2012; Colledge and Conolly, 2014). As such, these waterlogged assemblages can contextualise crop cultivation within a food system that includes elements such as the cultivation of oilseed crops and the collection of tree fruits and nuts, and is situated within the broader environment, through the presence of arboreal, wild and wetland plant types (Behre and Jacomet, 1991; Jacomet, 2012).

The most well-known waterlogged prehistoric sites in Europe are the circum-Alpine pile-dwellings, 111 of which were collectively granted UNESCO World Heritage protection (Hafner, 2014; Hafner et al. 2014; UNESCO World Heritage Centre, 2024). These prehistoric sites are constructed above or on the edges of lakes, rivers and other wetlands upon wooden stakes known as 'piles.' Thanks to over a century of archaeological interest, these pile-dwellings have been extensively researched by interdisciplinary teams offering nuanced insights into prehistoric lifeways and food systems from the late-6th to the mid-1st millennia BCE (Hafner et al. 2014). While less well-known, many pile-dwellings are situated on wetland areas within the southern Balkans, particularly from the Lake Ohrid region, which links Albania to the south and to the west and the Republic of North Macedonia to the north and to the east (Hafner et al. 2021; Reich et al. *in press*). With at least ten prehistoric wetland sites identified on the lake shore of Ohrid alone (Naumov, 2020; Hafner et al. 2021) and resting at the Alpine interface between 'Mediterranean' and 'Continental' biogeographic regions (European Environment Agency, 2017), this area presents an ideal opportunity to explore how crops were introduced to new environments and to consider whether crops could transcend this 'climatic barrier.' Key to this is the investigation of how agricultural practices were adapted to upland settings such as the Lake Ohrid basin, with colder winters and wetter summers, including the

integration of agricultural systems of Mediterranean origin with locally available wild plant foods.

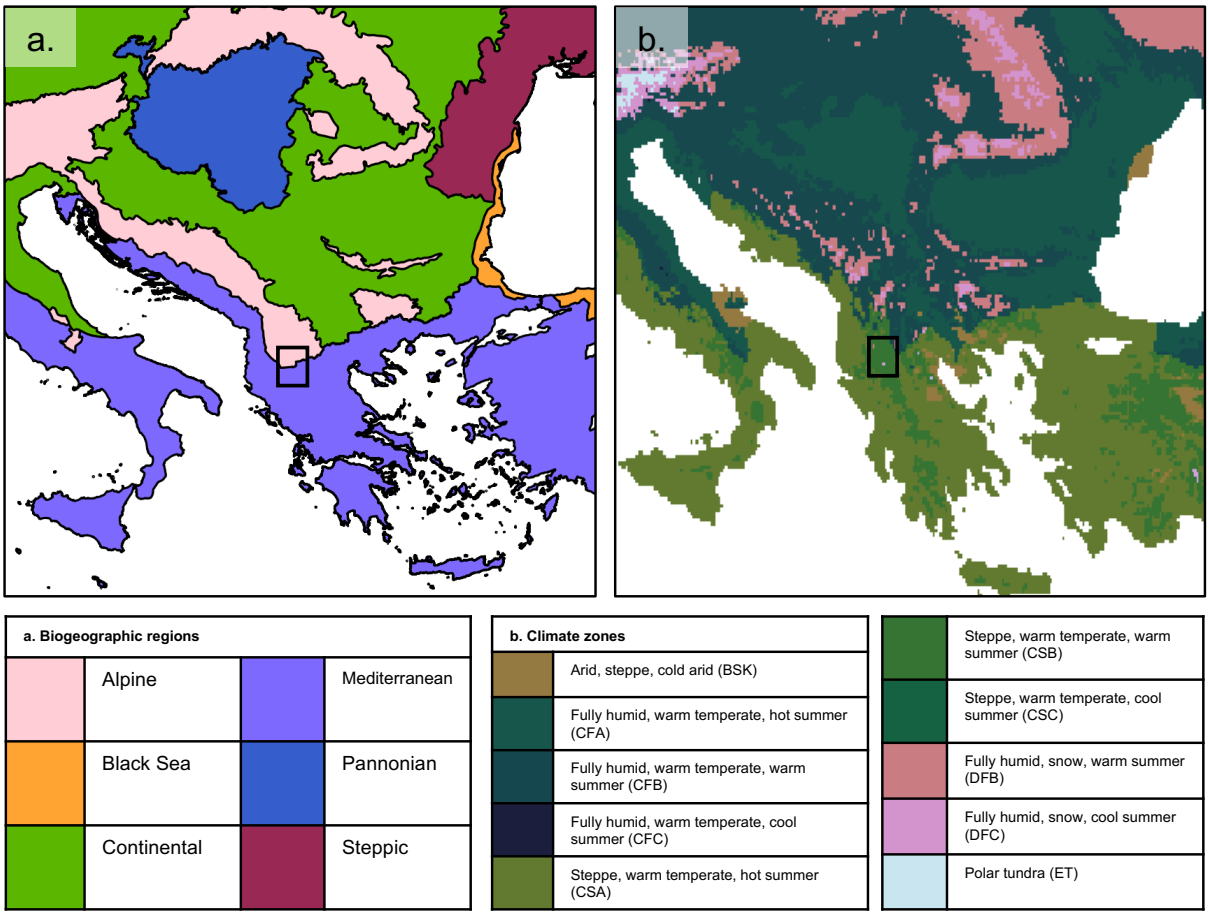


Figure 1: The bioarchaeological focus area of the EXPLO project (indicated by a black rectangle) is situated in at the interface of different biogeographic regions (a) and climate zones (CSb, b). Data for biogeographic regions from the European Environment Agency (© Council of Europe (CoE), Directorate-General for Environment (DG ENV), European Environment Agency (2017). Köppen-Geiger climate classification after Kottek et al. (2006) downscaling after Rubel et al. (2017) © Climate Change & Infectious Diseases Group, Institute for Veterinary Public Health, Vetmeduni Vienna, Austria.

A collaboration between the Universities of Bern, Oxford, and the Aristotle University of Thessaloniki, the ERC synergy EXPLO project (2019-2025) was designed to explore the spread

and establishment of agriculture in the south-west Balkans (Hafner et al. 2021; Bolliger et al. 2023; Brechbühl et al. 2023; Maczkowski et al. 2023; Holguin et al. *in press* - Appendix 3). This project concentrates upon the relatively temperate and mountainous lake-systems of northern Greece, eastern Albania and southern North Macedonia (Figure 1). Archaeobotanically focusing on three prehistoric pile-dwelling sites, Ploča Mičov Grad (eastern shore of Lake Ohrid, North Macedonia), Lin 3 (western shore of Lake Ohrid, Albania) and Dispilio (southern shore of Lake Kastoria/Orestiada, Greece), the project is pioneering the investigation of Neolithic wetland sites in this region, focusing on the nature of agricultural activity and the role of introduced crops with the maturation of agriculture (Hafner et al. 2021; Holguin et al. *in press*). As part of the EXPLO project, this thesis contributes to efforts to further our understanding of the spread of introduced crops in the southern Balkans, identifying plant use and management practices at the waterlogged pile-dwelling site of Ploča Mičov Grad. The focus on introduced crops and agroecology is grounded within an exploration of the whole plant food system from annual cultivars to gathered fruits and nuts, and within its cultural landscape.

0.2 THE NEOLITHIC CROP SPECTRUM OF THE SOUTHERN BALKANS

In order to discuss agricultural practices in the Middle and Late Neolithic, it is first necessary to review the beginnings of agriculture in the region to contextualise later practices. Following this, each crop will be briefly discussed with consideration given to its relative importance in the study region (Greece, Albania and North Macedonia) during the Neolithic. When possible, focus will be centred upon sites contemporary (5th millennium BCE, Late/Final Neolithic) to the main archaeobotanical phase at Ploča Mičov Grad and/or proximal to the upland Lake Ohrid basin.

0.2.1 THE SPREAD OF CROPS FROM SOUTH-WEST ASIA

Almost all of the principal crops of the European Neolithic originated from areas of south-west Asia (Willcox, 2005; Coward et al. 2008; Zohary et al. 2012). Through dynamic human actions and genetic adaptations, wild plants, animals and people together entered long-term "pathways of domestication" (Fuller et al. 2010, p.13) over 10,000 years ago in the ecologically diverse Fertile Crescent (Lev-Mirom and Distelfeld, 2023; Weiss and Zohary, 2011). This arable 'Neolithic founder package' included cereal (emmer wheat, einkorn wheat and barley), pulse/legume (lentil, pea, chickpea and bitter vetch) and oil and fibre (flax) crops (Table 1; Weiss and Zohary, 2011). These primary domesticates can all be considered 'grain crops' and are agronomically and dietarily complementary (Weiss and Zohary, 2011). Accompanying these crops, other adventive or commensal species including arable weeds and crop pests became strongly associated with cultivates and are frequently found alongside the Neolithic crop spectrum where preservation allows (Colledge et al. 2005; Coward et al. 2008; Panagiotakopulu and Buckland, 2018).

Table 1: Common Neolithic crops. An asterisk indicates those not traditionally included in the 'Neolithic founder package' but relevant to this thesis.

Common English name	Binomial name
Einkorn wheat	*Triticum monococcum* L.
Emmer wheat	*Triticum dicoccum* Schrank ex. Schübl.
*Timopheev's wheat	*Triticum timopheevii* (Zhuk.) Zhuk.

*Bread wheat	*Triticum aestivum* L.
*Durum wheat	*Triticum durum* Desf.
Barley	*Hordeum distichon* L. (2-rowed) and *Hordeum vulgare* L. (six-rowed)
Lentil	*Lens culinaris* Medik.
Common pea	*Pisum sativum L.*
Bitter vetch	*Vicia ervilia* (L.) Willd.
Chickpea	*Cicer arietinum* L.
Flax	*Linum usitatissimum* L.
*Opium poppy	*Papaver somniferum* L.

Agricultural practices and crops first entered Europe through the southern Balkans by the mid-7th millennium BCE (Valamoti and Kotsakis, 2016; Kotzamani and Livarda, 2018; Valamoti, 2023). Many of the earliest archaeobotanical assemblages with cereal and pulse crops come from northern Greece such as the Early Neolithic sites of Nea Nikomedeia (van Zeist and Bottema, 1971), Revenia, Paliambela (Kotzamani and Livarda, 2018) and Mavropigi (Valamoti, 2011; Valamoti, 2023). It seems that the "Neolithic founder package" was adopted almost in its entirety in many parts of the southern Europe with a Mediterranean climate (Kotzamani and Livarda, 2018; Krauß et al. 2018; Valamoti, 2023). Climate models suggest that during the Neolithic, the annual temperature of the southern Balkans was broadly analogous with today,

with temperatures were only slightly higher than present, specifically during the summer and with slightly higher precipitation rates during the winter (Samartin et al. 2017). The climatic similarity between western Anatolia and 'Mediterranean' zones of southern Europe (both 'CSa' in Köppen-Geiger climate classifications; Kottek et al. 2006) likely facilitated the relatively rapid transfer of agricultural practices and domesticated crops between these regions (Colledge et al. 2005; Krauß et al. 2018).

Movement of crops between different parts of the southern Balkans, however, presented a far greater challenge. North of this 'Mediterranean' bioregion, one finds areas classed as 'Alpine' (including the highlands of the Pindos Mountain range in northern Greece and eastern Albania, and parts of western North Macedonia) and 'Continental' (encompassing the majority of the northern Balkans with a more temperate climate). Both Köppen-Geiger climate classifications (Kottek et al. 2006) and the European Environment Agency's biogeographic regions (European Environment Agency, 2017) identify a stark contrast between the southern and central Balkans. The interface of this shift matches that of the 'gross Querlinie,' a division of vegetation zones initially identified between northern and southern Albania (Markgraf, 1932) and recently extended across southern Europe (Malatesta et al. 2023). Thus, differences between southern and central Europe (with winter frosts and wetter summers) could have presented a climatic barrier to the movement of south-west Asian crops northwards. The Lake Ohrid basin, biogeographically characterised as 'Alpine', is positioned along the 'gross Querlinie' within the transitional zone between different 'Mediterranean' and 'Continental' ecosystems and climates.

One of the main agricultural limiting factors in the 'Mediterranean' bioregion is summer droughts due to high temperatures and low precipitation rates (Krauß et al. 2018; de Vareilles

et al. 2022). In contrast, in temperate Europe, characterised by milder summer temperatures, weaker seasonality and year-round precipitation, a greater challenge faced by introduced crops was winter frosts and short day-lengths, which impacted cereal germination and early-stage growth (de Vareilles et al. 2022). Lower temperatures, snow cover and higher precipitation rates are also found in the high-elevation zones of the Alpine bioregion (de Vareilles et al. 2022). The impact of climatic variability is not solely seen through the spread of introduced crops. Tree fruits collected by Neolithic populations and possibly managed to an extent are similarly geographically restricted in the Balkans based on climatic gradients, with wild distributions of olive, fig and grape all confined to different latitudes within the Mediterranean bioregion (Krauß et al. 2018).

Key differences observed between southern Balkan prehistoric archaeobotanical assemblages are likely a product of both the ecological potential of a given area and cultural decisions, together shaping the relative importance of different founder crops and wild resources (Colledge et al. 2004; Colledge et al. 2005; Coward et al. 2008). Cultural choices ultimately determine the nature of food systems; the adoption or rejection of plant foods reflects individual- and community-level preferences (Kreuz et al. 2020). Yet, environmental parameters offer constraints within which cultural practices develop. With northwards migration, founder effects also play a part, for instance, with bottlenecks reducing the crop spectrum (de Vareilles et al. 2022). As such, the spectrum of plant foods at different Neolithic sites was adapted to suit localised landscapes and cultural priorities, as a form of 'niche reconstruction', reflecting the interplay of environmental, economic, and social considerations (Rowley-Conwy and Layton, 2011) with each crop and environment presenting different affordances.

0.2.2 THE CEREALS

Glume wheats differ morphologically from free-threshing wheats due to their thick glumes which requires an additional crop processing stage to manually separate the cereal grains from their chaff (Hillman, 1981). While this further crop processing step required additional labour and time, it also presented an advantage to Neolithic farmers: glume wheats could be stored as spikelets so that the chaff protected the grains from pests (Sigaut, 1988) and from moisture in humid regions (Hillman, 1981; 1984; Nesbitt et al. 1996; Colledge et al. 2005). Despite their relatively small yields, the low fertility requirements of glume wheats render these cereals particularly well suited to many semi-arid regions of the Mediterranean (Vaghar and Ehsanzadeh, 2018; Cadeddu et al. 2021).

The glume wheats einkorn (*Triticum monococcum*) and emmer (*T. dicoccum*) were two of the most important cereals for Early to Late Neolithic communities in south-eastern Europe (Valamoti, 2023). Both einkorn and emmer were found at the upland dryland Late Neolithic site of Maliq, Korça plain, Albania, to the south of Lake Ohrid (Xhuveli and Schultze-Motel, 1995). Einkorn was the most abundant cereal recovered from upland dryland Early Neolithic tell sites in the Republic of North Macedonia's Pelagonia Valley (including Vrbjanska Čuka, Veluška Tumba and Vlaho; Sabanov et al. 2024) and similarly, from the majority of lowland dryland Early to Late Neolithic sites in northern Greece (Livarda, 2014; Kotzamani and Livarda, 2018) such as the Late Neolithic sites of Makri and Apsalos (Valamoti, 2004). In both cases, emmer is usually the second most prevalent crop. A geographic gradient has been observed with emmer being found in greater abundance towards the south of Greece than towards the north (Livarda 2014; Roushanaffas et al. 2022). This finding could relate to drought tolerance. Experiments using modern wheat varieties have found emmer to be the most resilient to

water shortage (Konvalina et al. 2014), which occurs with increased frequency in southern Greece. However, other studies have argued the reverse given that wild einkorn is more drought tolerant than wild emmer (Colledge et al. 2005), implying that the extent of drought tolerance may be cultivar specific. A few exceptions to the archaeobotanical trend are noted – sites with more emmer than einkorn in northern Greece include the Late Neolithic site of Mandalo in Central Macedonia where emmer represented over 80% of all glume wheats (Valamoti et al. 2022). Altogether this suggests that while differential physiological attributes of einkorn and emmer could influence where they were cultivated, ultimately cultural preferences determined the relative importance of einkorn and emmer in the southern Balkans.

A final glume wheat is very relevant to this discussion. At many sites across the region, Timopheev's wheat (formerly known as 'new type' or 'new glume' wheat) has been found (Filipović et al. 2023). This ancient glume wheat was first identified at the end of the twentieth century following work on 'unusual' glume wheats from prehistoric northern Greece (Jones et al. 2000; Filipović et al. 2023). Its absence from the traditional 'Neolithic founder package' does not reflect its lack of importance, but rather its relatively recent identification. This glume wheat was identified as a member of the *Triticum timopheevii* group following ancient DNA analysis (Czajkowska et al. 2020), which is supported by Geometric Morphometric analysis (Roushannafas et al. 2022). While its domestication is thought to have taken place in south-west Asia including a distinctive sequence in which dehiscence was lost through the 7th millennium BCE at Catalhöyük (Badaeva et al. 2022; Roushannafas et al. 2022), prehistoric finds of Timopheev's wheat now span Europe, thanks to its adaptation to cold temperatures (e.g. in France, Toulemonde et al. 2015; in Austria, Kohler-Schneider, 2003; and across south-

eastern and eastern Europe, Ulaş and Fiorentino, 2021; Filipović et al. 2023). It was likely misidentified as 'emmer' or 'spelt' or left unidentified from assemblages analysed before 2000 (Jones et al. 2000), which could explain it absence at sites such as the dryland Late Neolithic site of Maliq, Korça plain, Albania (Xhuveli and Schultze-Motel, 1995). At some sites (e.g. Late Neolithic Dikili Tash and Mandalo, northern Greece; Valamoti, 2023), Timopheev's wheat appears numerically to be a minor crop, perhaps even a commensal in stands of emmer or einkorn or part of a mixed (maslin) crop (Filipović et al. 2023). However, the abundance of Timopheev's wheat at others (e.g. within some samples from Middle Neolithic Apsalos, Valamoti, 2006 and Late Neolithic Kleitos, northern Greece; Valamoti and Stylianakou, 2015) and the presence of pure Timopheev's wheat storage deposits (e.g. Early Neolithic Mursalevo, south-western Bulgaria) likely signifies deliberate cultivation (Filipović et al. 2023).

Free-threshing wheats including common/bread wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*) were another feature of prehistoric archaeobotanical assemblages from the Balkans (Sabanov et al. 2024; Valamoti, 2023). The tough rachis and thin glumes give durum and bread wheats their characteristic comparatively easy threshing (Hillman, 1981). While free-threshing wheats are commonly found at Neolithic sites, they are often a minor component in northern Greece (e.g. at Late Neolithic Makri and Arkadiko, northeastern Greece, Valamoti, 2023). It is unclear whether these species were intentionally cultivated or whether they were commensals to other cereals (Valamoti, 2002; Halstead, 1994). It is not until the Bronze Age that large numbers of free-threshing wheat have been identified in northern Greece (Halstead, 1994; Valamoti 2002). Both physiological attributes and cultural practices influence the cultivation and use of these crops. The two free-threshing wheats have distinct characteristics (e.g. grain hardness, gluten structure and protein content) which

determine their culinary uses (e.g. pasta, couscous, bread and other baked goods; Mastrangelo and Cattivelli 2021). Another geographic trend is observed here with finds of the hexaploid bread wheat more frequent in the northern Balkans and the tetraploid durum wheat more numerous at prehistoric sites towards the south (Kirleis and Fischer, 2014; Roushannafas et al. 2023). Many sites, particularly in the central Balkans, have both types of free-threshing wheat (Roushannafas et al. 2023). This distribution pattern could be attributed to durum wheat's higher drought tolerance. However, there is significant diversity within the free-threshing wheats and prevalent gene flow. Recent studies have suggested that durum wheat's proposed drought tolerance came from research considering only a limited range of cultivars (Mastrangelo and Cattivelli et al. 2021). Further work demonstrates that many bread wheat cultivars could in fact be better suited to such semi-arid conditions suggesting that the prevalence of durum wheat in southern Europe may be a result of cultural traditions (Marti and Slafer, 2014; Giunta et al. 2019; Mastrangelo and Cattivelli et al. 2021). Bread wheat is considered highly versatile, being equally suited to temperate climates and as such thrives in central Europe (Colledge et al. 2005).

Barley is the final cereal of the Neolithic founder crops to be considered. Wild barley has a brittle rachis and is two-rowed (two grains positioned on opposing sides of the culm). Cultivated barley developed a non-brittle rachis, easing processing, and can be two-rowed (*Hordeum distichon*) or six-rowed (with two opposing sets of three grains each, *Hordeum vulgare*). The grains of both cultivated types can be hulled or naked, the latter a product of human selection (Lister and Jones, 2013). Barley is a common feature of Early to Late Neolithic sites in the study region and was found at the Late Neolithic site of Maliq, Korça plain, Albania (Xhuveli and Schultze-Motel, 1995). Identification of rachis internodes to variety is dependent

upon adequate levels of preservation (Charles et al. *in prep*). Grains can be identified as hulled or naked (based on the presence of hull impressions) and twisted or straight (six-rowed barley has both twisted and straight grains, while two-rowed barley only has straight, Jacomet et al. 2006). Both six-rowed and two-rowed, and hulled and naked varieties have been found at Early to Late Neolithic sites in Greece (Valamoti, 2023). For example, at Late Neolithic Arkadiko, north-eastern Greece, both two- and six-row barley was identified (Valamoti, 2004). Barley is particularly well-suited to semi-arid regions of southern Europe, tolerating dry and hot climates with low soil fertility (Weiss and Zohary, 2011). Due to the limited numbers of barley remains from some Neolithic sites in the southern Balkans, researchers have questioned whether this cereal was grown as a crop for food or for fodder, or whether, at some sites, it could have been a commensal to wheats (Valamoti, 2002). However, high concentrations of barley have been recovered from other Late Neolithic sites such as Dikili Tash (Valamoti, 2023) suggesting that at least at certain sites barley was a valued crop.

0.2.3 THE PULSES

Four pulse crops were introduced from south-west Asia to south-east Europe – lentil, bitter vetch, pea and chickpea. Pulse crops are highly nutritious offering a reliable source of protein, energy and fibre to Neolithic populations. Further, as nitrogen-fixers, pulses enrich soils increasing their fertility, rendering legumes an ideal cover crop (Asghar and Kataoka, 2022), part of a rotation with cereals or inter-crop (Rubiales and Mikić, 2015) supporting the health of prehistoric agrosystems. While lentil, bitter vetch and pea were present in the study region from the Early Neolithic, they became more prevalent towards the end of the Neolithic. This has been associated with environmental parameters such as soil exhaustion (Blouet, 1986) or use as animal fodder (e.g. in the case of bitter vetch to support an increase in cattle and pig

husbandry; de Vareilles et al. 2022), but such hypotheses are currently unsubstantiated (Valamoti, 2023). A variety of pulses is often recovered from Late Neolithic sites in northern Greece such as at Dikili Tash (lentils, grass pea and bitter vetch) and Arkadikos (grass pea, pea and lentils; Valamoti, 2004).

The lentil (*Lens culinaris*) is commonly found in Neolithic sites across southern Europe and south-west Asia. With approximately 25% protein, lentils nutritionally complement cereals (Weiss and Zohary, 2011). While wild lentils have been identified at some Mesolithic Greek sites and it is difficult to distinguish wild and cultivated lentils, consensus remains that lentils were first domesticated in south-west Asia (Sonnante et al. 2009). At many sites across the Neolithic period, lentils in the southern Balkans are the most numerous pulse crop (de Vareilles et al. 2022; Valamoti, 2023). Large caches of pure lentils were recovered at the lowland Late Neolithic sites of Arkadikos (Valamoti, 2004) and Dikili Tash (Kokkidou, 2018) in north-eastern Greece highlighting the importance of lentils within prehistoric agriculture. Lentils were also present in uplands such as at the Late Neolithic settlement of Maliq, Korça plain (to the south of Lake Ohrid, Albania; Xhuveli and Schultze-Motel, 1995) and Early Neolithic sites in the Pelagonia Valley (to the east of Lake Ohrid, North Macedonia, Sabanov et al. 2024). A Late Neolithic cache of lentils alongside human remains within a funerary pot at the upland site of Avgi, Lake Kastoria (south-east of Lake Ohrid) points to the possible cultural or ritual significance of this pulse (Valamoti, 2023).

Another legume crop, the common pea (*Pisum sativum*), is similarly a frequent feature of Neolithic crop spectra in both Mediterranean and temperate areas with a protein content comparable to that of lentils – 22% (Weiss and Zohary, 2011). The spread of peas from south-west Asia across Europe was rapid and widespread with finds across the southern Balkans (de

Vareilles et al. 2020). This pulse is commonly found in prehistoric sites in Greece (Kotzamani and Livarda, 2018; Valamoti, 2023) such as the Late Neolithic site of Arkadikos in north-eastern Greece (Valamoti, 2004). However, it is notably absent at other Late Neolithic sites, despite extensive and systematic archaeobotanical study, such as at Dikili Tash in north-eastern Greece (Valamoti, 2004). At waterlogged wetland sites in the Alpine Foreland, finds of pulse pod identified as pea are frequent (Steiner et al. 2022).

Bitter vetch (*Vicia ervilia*, not to be confused with *Lathyrus linifolius* which is also sometimes referred to as bitter vetch in English) has been found at many prehistoric sites in south-eastern Europe (e.g. the early Neolithic sites of Nea Nikomedeia, northern Greece (van Zeist and Bottema, 1971) reaching particular prominence in the Late Neolithic in the northern Balkans (Filipović et al. 2022; de Vareilles et al. 2022). For example, large numbers of bitter vetch were recovered from the Late Neolithic site of Dikili Tash, north-eastern Greece (Valamoti, 2004). At the 6th millennium BCE site of Tumba Madžari in northern North Macedonia, a rich concentration of bitter vetch seeds was recovered within a child burial (Stojanova-Kanzurova and Rujak, 2013), suggesting that some pulses may have had a broader cultural or ritual importance similar to Late Neolithic Avgi, Lake Kastoria (see above). Vetches have high drought tolerance and low soil fertility requirements, rendering pulses such as bitter vetch a practical choice in semi-arid environments (Francis et al. 2000). Bitter vetch contains a low concentration of the toxin canavanine (ranging from 0.04-0.11%, Berger et al. 2003, p.201). However, processing of the pulse through boiling, soaking, leaching and removal of the toxin-rich skin can render the pulse safe for human consumption (Enneking, 1994; Enneking et al. 1995; Francis et al. 2000). Processing of bitter vetch using water has been suggested for charred cotyledons from early Bronze Age Agios Athanasios (northern Greece, Valamoti et al.

2011) and at Late Bronze Age Wöllstadt (northern Germany, Kreuz and Feth, 2021). Even without processing, bitter vetch's mild toxicity is relatively harmless to ruminant livestock (Enneking, 1994). Its current limited use as an animal fodder in areas of Morocco, the Mediterranean and Turkey (Abdullah et al. 2010) could lead archaeologists to assume that it occupied a similar role in prehistory. However, without archaeological evidence such assumptions are just that (Zohary et al. 2012; Valamoti, 2023). The distinction between food and fodder will be interrogated further in the following section.

Of the founder pulse crops, chickpea (*Cicer arietinum*) occupies the most restricted geographic distribution, requiring subtropical climates as its growth occurs directly after summer rain utilising precipitation stored in the soil (Weiss and Zohary, 2011). As such, chickpeas encounter climatic barriers at the lowest latitude, rarely being found above central Greece or Mediterranean coastal zones (finds in Bulgaria being a notable exception, de Vareilles et al. 2020). This pulse is particularly affected by the length of the growing season and is not suited to the seasonality of temperate zones (Colledge et al. 2005). Even within suitable regions, finds of chickpeas are exceedingly rare in southern Europe. As of 2023, only forty-eight seeds were reported from Neolithic or Bronze Age sites in Greece (Valamoti, 2023), thirty-two of which originate from a single Late Neolithic site, Dimini in Thessaly (Kroll, 1979; Valamoti, 2023).

0.2.4 THE OILSEED CROPS

A single oil and/or fibre crop (flax, *Linum usitatissimum*) was introduced to south-eastern Europe as part of the Neolithic founder crops. With approximately 40% oil, flax seeds (also known as linseed) have been a valued crop both for culinary and other purposes. Flax stems

are used for construction and their fibres in textile manufacture (Weiss and Zohary, 2011). Flax also has medicinal applications (Valamoti, 2011). The size of the flax seeds has been connected to the use of the plant as those with smaller seeds have more fibrous stems and thus would have been more suited to fibre production. On the other hand, those with larger seeds would provide more oil (Herbig and Maier, 2011). Unlike in the prehistoric waterlogged wetland assemblages of the circum-Alpine region where abundant plant macrofossils and associated artefacts have been connected to fibre processing and consumption of the oil-rich seeds (Leuzinger and Rast-Eicher, 2011; Jeraj et al. 2009), evidence for flax use in the southern Balkans is sparce (Valamoti, 2011; Valamoti, 2023). This is, at least in part, due to taphonomic biases, as flax is less commonly preserved through charring and few waterlogged assemblages have been analysed in the southern Balkans (Valamoti, 2011). That considered, rare finds of flax seeds suggest that this oilseed was a crop of the southern Balkan Neolithic, such as at the Late Neolithic site of Makriyalos, northern Greece (Pappa, 2008). One mineralised possible flax seed was recovered from the upland site of Vrbjanska Čuka, Pelagonia Valley, North Macedonia, but its attribution to the Early Neolithic is uncertain (Sabanov et al. 2024). Late Bronze Age textual evidence demonstrates that flax was cultivated and used by this period, despite the limited archaeological evidence (Valamoti, 2011).

One final crop that was not introduced from south-west Asia as part of the Neolithic founder crop spectrum will be briefly considered here - opium poppy (*Papaver somniferum* subsp. *somniferum*). Based on the wild distribution of the progenitor of opium poppy (*Papaver somniferum* subsp. *setigerum*) and early findings of opium poppy in the archaeological record, current consensus supports a south-west European domestication of this oilseed (Antolín, 2016; Salavert et al. 2018; 2020). However, early finds of opium poppy from south-eastern

Europe may call this into question (e.g. from upland, Early Neolithic sites in the Pelagonia Valley, Sabanov et al. 2024). Opium poppy most famously is the source of opiates and as such has been historically used for medicinal purposes (Jesus et al. 2021). It can also be cultivated for oil and the seeds can be consumed raw or cooked and whole or processed (Merlin, 1984). Poppy seeds are underrepresented in charred assemblages (Märkle and Rösch, 2008), due to taphonomic biases and past recovery methods (e.g. sieve sizes), and thus in the archaeobotanical record of the prehistoric southern Balkans (Valamoti, 2023).

0.3 TOWARDS AN INTEGRATED SYSTEM

An understanding of the physiological properties, growing conditions and cultural affordances of each crop is imperative to evaluate the role of individual south-west Asian crops in southern Balkan prehistoric diets. However, the term 'Neolithic crop package' gives a false impression of a set of domesticates statically and uniformly transplanted across space and time (cf. Budja, 2005). There is also a danger with such a domesticate-centric approach that the role of wild edible food plants and the interconnectivity of prehistoric communities, arable plants and wild vegetation are under-emphasised. Rather, to fully evaluate why certain introduced crops succeeded or failed in different situations, we need to place crops within the broader food system to explore the dynamic and interwoven network of human and non-human agents in ever-changing food systems. Part of this comes with the dismantling of binary divisions such as 'farmer' and 'hunter-gatherer,' 'wild' and 'domesticated,' and finally 'food' and 'fodder,' to interrogate how agriculture may have been experienced by past populations, moving from botanical conceptions of plants to prehistoric lifeways.

By describing a southern European population as 'farmers' and 'Neolithic', there is assumption that this community was fundamentally different from 'hunter-gatherers' and the 'Mesolithic,' and as such consumed little wild plant resources, such that "a new Neolithic way of living and thinking broke completely with the past" (as critiqued in Budja, 2005, p.53). This assumption stems from both archaeological theory and evidence.

The nature of the 'Neolithisation' of Europe has been a polemic debate in archaeology (Colledge et al. 2004; Budja, 2005). Two polarised models were presented in the mid-20th century regarding the identity of the first European agriculturalists – one suggesting mass migration of farmers from south-west Asia displacing indigenous hunter-gatherer populations ('demic diffusion', Renfrew, 1990; or 'pioneer colonisation', Perlès, 2005), while the other advocated for the adoption of agricultural practices by indigenous groups through trade of ideas and domesticates ('cultural diffusion', Whittle, 1996). In the former, the term 'farmer' was not just linked to a subsistence strategy, but also a way of life and an ethnic identity, with associated material technology, a new agricultural economy, and socio-cultural traditions (Ammerman and Cavalli-Sforza, 1984; Budja, 2005). This was seemingly supported by the perceived uniformity of Neolithic material cultural (Rodden, 1965), genetic evidence (Menozzi et al. 1978, Ammerman and Cavalli-Sforza, 1984) and radiocarbon dates showing a gradual spread of Neolithic sites from south-west Asia to north-west Europe (Clark, 1965; Ammerman and Cavalli-Sforza, 1984).

However, current archaeological evidence and genetic analysis supports an intermediate model with some movement of people from south-west Asia, some genetic and cultural exchange between agriculturalists and hunter-gatherers and a fluidity of lifeways (Dennell, 1985; Budja, 1999; Gkiasta et al. 2003; Scharl, 2004; Bánffy et al. 2008; Horejs et al. 2015;

Hofmanová et al. 2016; Schulting and Borić, 2017; Mathieson et al. 2018). The emerging conception of a dynamic process with ongoing interactions and the reshaping of identities overturns simplistic conceptions of prehistoric lifeways with discrete categories of 'farmer' or 'hunter-gatherer.'

Key to this is that once people began farming, hunting and gathering did not simply cease to be. Instead, Neolithic archaeobotanical and zooarchaeological assemblages show a continuation of such practices alongside agricultural activity (e.g. the use of wild fauna at Middle Neolithic Dispilio, Greece, Samartzidou, 2012, and the use of gathered fruits and nuts at Late Neolithic Dikili Tash, Greece, Valamoti, 2015; 2023). Charred European Neolithic assemblages are routinely dominated by crop material. However, it is known that wild plants are often underrepresented in charred terrestrial plant assemblages owing to taphonomic biases and this likely explains the limited presence of wild plant resources at many Neolithic sites in the southern Balkans (Colledge and Conolly, 2014; Antolín and Jacomet, 2015; Valamoti, 2023). As such it is likely that occasional finds of nuts, such as almond and pistachio, and fruits, including strawberry, cornelian cherry, fig and grape (Valamoti, 2023) are rare representatives of important but poorly preserved food resources. Consideration of the contribution of all edible plant foods, by transcending traditional 'farmer' and 'hunter-gatherer' divisions, contextualises arable agriculture, offering a richer understanding of Neolithic food system diversity.

Another facet to this debate is the extent to which the terms 'wild' and 'domesticated' are accurate or useful. The coevolution of plants, animals and people result in genetic and morphological changes that both passively reflect and actively alter human-environment relationships (Zeder, 2015). While archaeologists aim to distinguish wild and domesticated

plants and animals, this is often challenging and has required careful scientific approaches such as ancient DNA or geometric morphometric analysis (Jesus et al. 2021; Bogaard et al. 2021; Valamoti, 2023). It also often is driven by an unrealistic conception of domestication as being about human control (Bogaard et al. 2021). Both archaeological and ethnographic evidence have been used to dismantle this ontological division (Hastorf, 1998; Valamoti, 2023). The existence of hybrids between 'domesticated' and 'wild' varieties further demonstrates a continuum between these two terms (Bogaard et al. 2021). As such, while it can be useful for archaeologists and biologists to use these concepts to investigate complex and long-term human-plant relationships, it is imperative to take an integrated approach to consider the importance of the full spectrum of 'wild' and 'domesticated' in prehistoric lifeways.

One way to explore how different plant foods were perceived in prehistory is to investigate the means by which plants were cultivated or collected. The nature of early European agriculture has been the subject of much debate (Brombacher and Jacomet, 1997; Bogaard, 2002; Jacomet et al. 2016; Halstead, 2018). For central Greece, the presence of long-lived, densely constructed, tell sites encouraged Childe (1957) to posit that the Neolithic inhabitants practised permanent cultivation, but the more ephemeral occupation layers further north within the Balkans were interpreted as the product of shifting agricultural communities. In shifting cultivation, primary or secondary woodlands are cleared using fire to create arable land which is cultivated for a short duration (c.1-5 years), before being abandoned for decadal woodland regeneration as cultivation is shifted to another newly cleared plot. On the other hand, permanent cultivation entails the long-term cultivation of a fixed plot of land (Bogaard, 2002; Bogaard, 2004).

The degree of permanence of early cultivation was debated strongly with respect to lakeshore sites in the Alpine Foreland, where off-site data collection was more prevalent than in southern Europe. The off-site evidence showed a decline in arboreal pollen in tandem with an increase of cereal pollen and microscopic charcoal which was interpreted as evidence for shifting cultivation (e.g. Late Neolithic settlements on Lake Constance, southern Germany, Rösch, 1992). However, on-site evidence such as the plant macrofossils and stable carbon and nitrogen isotopic analysis did not support this suggestion (Bogaard, 2002; Jacomet et al. 2016; Baum et al. 2016; Styring et al. 2016; 2017). Consensus generally now agrees that intensively managed small-scale permanent cultivation was the most common form of early agriculture across south-west Asia and Europe, perhaps after initial woodland clearance using fire (Jacomet et al. 2016). Such evidence can be complemented by stable isotopic analysis which can be used to infer the growing conditions of different crops. For example, at Hornstaad-Hörnle IA (3918–3902 cal BCE) and Sipplingen (4000–c. 2800 cal BCE), analysis of both the weed flora and crop stable isotopic ratios indicated that Neolithic agrosystems were permanent plots managed with intensive (if varying) input levels (Styring et al. 2016). Understanding how and where plants were cultivated, as well as whether plants were cultivated together (as a mixed crop) or separately, brings us closer to understanding how prehistoric communities perceived different cultivars.

Long-lived arable plots plausibly associated with long-lived woodland-edge habitats would become persistent parts of the cultural landscape. Many light-loving fruit and nut trees and shrubs, such as blackberries, benefit from small-scale land clearance and are routinely found near to settlements in disturbed environments. Prehistoric populations may have also managed fruit and nut trees through activities such as pruning and coppicing, initiating long-

term domestication processes (Favre and Jacomet, 1998; Waller et al. 2012; Miller, 2008; Pagnoux et al. 2021; Valamoti, 2023). Such activities may have been opportunistic or more formalised, as has been explored elsewhere in Europe using roundwood age/diameter analysis to differentiate between managed and unmanaged trees (Out et al. 2020).

Following cultivation and harvesting, the next question is how edible plants (cultivated, differently managed or 'wild') were used. We can look to various sources of evidence such as processed food remains (Valamoti, 2002; Valamoti et al. 2021), lipid residue analysis (Mitkidou et al. 2008) and stable isotopic analyses of humans, plants and animals (Vaiglova et al. 2018, 2023) to try to determine which foods were consumed and how frequently. Both cultivated and gathered plants may have been intended for human consumption, but it is equally possible that they were for livestock fodder. At Late Neolithic Makriyalos and Makri in northern Greece, cereal chaff and fig seeds has been found within charred ruminant dung (although it is possible that the plant macrofossils were intentionally or incidentally added to the dung during fuel preparation) (Valamoti and Charles, 2005). Animal dung from Mooswinkel (c. 3770 to 3371 BCE) in Austria contained dried leaf hay which was interpreted as a collected and stored winter fodder (Jakobitsch et al. 2023). As such, cultivated plants, fruits and nuts and other 'wild' plants could have been eaten by livestock (either as fodder or through grazing). The ratio of glume wheat grain to chaff within an archaeobotanical assemblage can be used by researchers to distinguish food from fodder as time-consuming processing steps such as dehusking is thought unnecessary and counter-productive if the cereal was intended for livestock (Nesbitt et al. 1996; Valamoti, 2002). By-products of food-processing could however have also been used as fodder (Weiss and Zohary, 2011). A clear distinction between 'food' and 'fodder' is one that is not ethnographically supported. Rather,

certain plant foods may have been grown for different purposes depending on cultural traditions and particular situations, such as times of hardships (Halstead and Jones, 1995; Valamoti, 2002). Present-day conceptions of edibility and ethnographic analogies can influence a researcher's interpretation of archaeobotanical datasets (Valamoti, 2023).

0.4 THE POTENTIAL OF WATERLOGGED ARCHAEOBOTANICAL ASSEMBLAGES

The emphasis given to the crops (particularly cereals) in Neolithic diets and lifeways is understandable for many reasons. The new relationships initiated by the cultivation of cereals are interesting phenomena and evidently the onset of agricultural activities had wide-ranging and long-lasting implications on ecosystems, food-production and human physical and social health, extending to the present day (Zeder, 2015). Yet, a focus on cereals also has a taphonomic explanation. Archaeobotanical assemblages from dryland sites in the southern Balkans are most commonly preserved through charring (syn. carbonisation, Livarda, 2014; Valamoti, 2023).

For a plant to become part of a charred assemblage, it needs firstly to encounter a fire of the right conditions and secondly it needs to survive this charring process in a recognisable form (Jones, 2000; Charles et al. 2015). Cereal grains and chaff conform to both criteria as they are commonly handled near to fire either during crop processing such as parching or during cooking and food preparation (Jacomet et al. 1989). As cereals are routinely stored year-round within the settlement, they are also more likely to become charred during an accidental fire. Finally, cereal chaff can be used as fuel (Jones, 2000). Both cereal chaff with a high lignin-cellulose content and large, starch-rich grains can survive heating up to approximately 300°C

(Charles et al. 2015; Stroud et al. 2023). Pulse seeds are also often found in charred archaeobotanical assemblages and can survive relatively high temperatures with little distortion (Nitsch et al. 2015). However, it is thought that they are underrepresented relative to cereals as they can be eaten fresh as well as dried. Further, diagnostic features such as the fragile seed coat (known as the testa) of pulses can be lost following charring, sometimes reducing the taxonomic resolution of pulse identification (cf. Fuller and Harvey, 2006; Melamed et al. 2008).

Oilseed crops including flax and poppy are likely underrepresented in charred assemblages. Owing to their high lipid content, such seeds rarely survive charring in a recognisable state (Märkle and Rösch, 2008; Valamoti, 2011). Despite being large, durable plant items, tree fruits and nuts are thought to be underrepresented in charred assemblages, as such collected plant foods are less likely to encounter fire to become charred in large numbers and so occasional finds of tree fruit and nut plant foods perhaps represent far greater importance (Jones, 2000). Arable weeds are more likely to become charred if associated with a crop, while those pertaining to the wider environment less likely to become charred unless entering a heating event with a resource of interest (e.g. Behre and Jacomet, 1991).

Waterlogged assemblages, on the other hand, are not biased towards material that comes into contact with and survives fire (Green, 1982). Instead, uncharred plant remains can be preserved within anoxic permanently waterlogged conditions. Waterlogged assemblages have far greater densities of plant macrofossils, and a greater range of plant parts (including flowers, leaves and capsules) and taxa (with far greater representation of fragile plants such as oilseed crops and wetland, arboreal and other wild taxa, Brombacher and Jacomet, 1997; Jacomet, 2004; Jacomet, 2012; Colledge and Conolly, 2014). A comparison between wetland

waterlogged and dryland charred archaeological sites from the Alpine Foreland suggests that dryland sites represent only approximately 35% of the range of plant foods that could be present in waterlogged samples (Colledge and Connolly, 2014).

In some cases, charred assemblages preserve plant remains better than uncharred assemblages. For example, while commonly well-preserved in charred assemblages, the endosperm of cereal grains and pulses (the starch-rich tissue inside a seed) does not preserve uncharred in waterlogged conditions (Colledge and Connolly, 2014). However, the cereal bran and pulse testa do preserve in waterlogged conditions. Waterlogged assemblages can preserve both uncharred and charred material (as well as partially charred macrofossils) and so, while the uncharred and charred components are both incomplete, together they provide a rich understanding of both plant foods and prehistoric landscapes. Further the charred assemblage can be preserved better in the protective waterlogged environment than in a dry, terrestrial deposit.

Charred terrestrial and uncharred waterlogged assemblages are formed through complex depositional practices which impacts how they should be interpreted. Charred terrestrial archaeobotanical assemblages can gradually accumulate through repeated activities involving fire such as food preparation or the burning of vegetal fuels, providing insights into the spatial arrangement of a site and the use of different plants. However, they can also provide a 'snap-shot' into one particular event or practice. For example, at the Late Neolithic site of Dikili Tash in northern Greece, the accidental burning of House 1 in the second half of the 5th millennium BCE preserved a rich range of cultivated and collected plant foods within the destruction level, providing a window into the use of space, storage practices and plant processing (e.g. the pressing of grapes) at one particular moment in time (Valamoti, 2015). In contrast, thick

organic assemblages from waterlogged sites are rarely associated with distinct contexts (such as a storage deposit) but can attest to longer-term human activities, diverse cultural landscapes and high-resolution diachronic changes. For example, at the multiphase Neolithic site of lake-dwelling of Zug-Riedmat, Switzerland, it was possible to identify decadal changes in the relative importance and diversity of cultivated and collected plant foods through the analysis of small-volume samples from sediment cores reinforced by the analysis of large-volume bulk samples collected from excavation areas (Steiner et al. 2022). The waterlogged archaeobotanical assemblage from the early 4th millennium BCE lake-dwelling of Hornstaad Hörnle I, Germany, has affinities with both examples, as a settlement-wide fire in 3910 or 3909 cal BCE provided a charred destruction level in an otherwise primarily uncharred waterlogged deposit, offering insights into both longer-term activities and distinct events (Maier, 1999).

0.5 WETLAND SITES IN SOUTH-EAST EUROPE

Archaeological waterlogged assemblages occur within discrete contexts beneath the water table such as wells (e.g. Lodwick, 2017), pits (e.g. Hajnalováa et al. 2018) or ditches (e.g. Johnston, 2023) or within waterlogged sites in coastal, riverine or lacustrine environments (Celant et al. 2015). The most common and well-known form of waterlogged prehistoric site type in Europe is the pile-dwelling.

'Pile-dwelling' is a descriptive term used to characterise prehistoric structures supported or elevated by wooden piles or stilts (Hafner, 2014). The extent to which these structures were situated above water or seasonally flooded land, or upon the ground level has been extensively debated. It seems that a diverse range of structure types can be found between and within different settlements (Menotti, 2001). The term was first used in 1854 to describe

the unexplained waterlogged wood piles observed by fishermen and archaeologists alike on the shores of Swiss lakes (Hafner et al. 2021). Such reports sparked archaeological interest in pile-dwellings across the circum-Alpine region (Austria, France, Germany, Italy, Slovenia and Switzerland), resulting in the identification of almost 1000 such sites and prompting research into the understanding and protection of waterlogged organic remains (Hafner, 2014; Hafner et al. 2021). The wetland setting of the pile-dwellings along with the wooden piles offered remarkable preservation of organic materials (Jacomet and Brombacher, 2005) and the ability to precisely date the structures using dendrochronology (Billamboz and Martinelli, 2015).

While some non-Alpine pile-dwellings were discovered broadly in parallel to the circum-Alpine pile-dwellings (e.g. the Croatian marshland pile-dwelling found near the village of Budinščina in the Hrvatsko Zagorje by a local archaeologist in the late 19th century), such sites failed to enter international archaeological discourse or be subject to intensive excavations (Jerbić, 2024). As such, pile-dwellings have been approached as a primarily circum-Alpine phenomenon. Interest in non-Alpine pile-dwelling sites is relatively nascent, yet the number of identified sites and excavations are growing (Hafner et al. 2021). Consequently, circum-Alpine pile-dwelling sites are currently being revaluated as part of a wider and diverse phenomenon.

One of the first Balkan pile-dwelling sites to be archaeologically excavated was that of the Early Iron Age riverside settlement of Donja Dolina (Bosnia and Herzegovina) in the early 20th century. In contrast to many circum-Alpine pile-dwellings, the waterlogged organic preservation was considered secondary to the remarkable material culture burial assemblages, which included armour, swords and jewellery (Majnarić-Pandžić, 2002; Dizdar and Potrebica, 2020; Dizdar and Kapuran, 2021). Only relatively recently, bioarchaeological

investigations have become a primary research focus at this site (Telenta, 2018). In the Korça plain in southeastern Albania, excavations at the wetland settlements of Maliq, Dunavec and Vashtëmi began in the 1960-70s. (Andoni, 2018). The end of the 20th century saw an increase in excavations of Balkan pile-dwellings. Traces of the Neolithic lakeshore settlement of Dispilio (Greece) were first recognised in 1932 (Keramopoulos, 1932) with systematic excavations lead by the Aristotle University of Thessaloniki commencing in the 1990s (Facorellis et al. 2014).

Research projects focused on the discovery of new wetland sites and the analysis of waterlogged organic remains are still increasing in the Balkans. For example, the relatively recently discovered (2008) submerged pile-dwelling settlement in Zambratija Bay acted to rejuvenate interest in Croatian prehistoric pile-dwellings (Jerbić, 2024). Another recently identified pile-dwelling settlement can be found in on the shores of the Alepu lagoon of the western Black Sea coast in Bulgaria, where multi-proxy bioarchaeological investigations of the Early Bronze Age Alepu pile-dwellings show use of wild plant and coastal resources (Flaux et al. 2016). The exceptional preservation of these sites has enabled identification of human environmental impacts such as the forest reduction caused by fuel procurement and the creation of clearances for livestock grazing and small-scale arable fields (Flaux et al. 2016).

Together, these sites indisputably demonstrate that pile-dwellings are not a uniquely circum-Alpine phenomenon, as the academic community is increasingly recognising (Hafner et al. 2021). Indeed, many pile-dwellings from other regions predate those of the Alpine Foreland (e.g. La Draga, Spain, Andreaki et al. 2020). They also demonstrate the plurality of forms of pile-dwelling settlements, spanning the Neolithic to Iron Age and situated within riverine, lacustrine and marine settings, and have exceptional potential for bioarchaeological

investigations. However, archaeobotanical datasets from wetland sites in the southern Balkans are currently lacking.

0.6 THE LAKE OHRID BASIN

The focus of this thesis is the prehistoric pile-dwelling site of Ploča Mičov Grad (Плоча Миќов Град), one of many known pile-dwellings within the Lake Ohrid basin (Hafner et al. 2021). This settlement lies on the lake's eastern shore, at the south-western corner of the Republic of North Macedonia (41°00'N, 20°45'E). The area of Lake Ohrid is designated by UNESCO as the "Natural and Cultural Heritage of the Ohrid region". This UNESCO world heritage status is two-fold, recognising both the natural and cultural value of the area (UNESCO World Heritage Centre, 2024).

The oligotrophic Lake Ohrid is thought to have formed 2-5 million years ago, making it one of few ancient lakes in Europe (Albrecht and Wilke, 2008). Formed tectonically, Lake Ohrid is part of a karstically connected larger lake system with the Lakes Prespa. Within the Pindos Mountain range at 693m above sea level (Matzinger et al. 2006), it is both one of the largest and deepest lakes in Europe (Albrecht and Wilke, 2008). The Ohrid basin's climatic conditions is classed within the "CSb" (warm temperate, warm summer) Köppen-Geiger climate classifications (Kottek et al. 2006, Figure 1). Today, Ohrid's mean daily temperature ranges from -1.5 to 6.2 °C in January and from 14.0 to 27.6 °C in July, with a mean total annual precipitation of 662 mm (WMO WWIS, 2023). Climatic reconstructions suggests that conditions are relatively unchanged since the Neolithic following the 8.2-kiloyear event (6200 BCE), with only slightly higher Neolithic temperatures particularly during the summer and slightly higher precipitation rates during the winter than present (Samartin et al. 2017).

Combining the geological, topographical and climate data, the region is broadly classified as part of the ‘Alpine’ biogeographical zone of Europe (European Environment Agency, 2017, Figure 1). Regions to the south and west in northern Greece and Albania are classified as ‘Mediterranean’ and further north as ‘Continental’ (European Environment Agency, 2017). Lake Ohrid rests along the extended ‘gross Querlinie’, an ecologically informed division between the northern and southern Balkans (Markgraf, 1932; Malatesta et al. 2023, Figure 2). As such, this area lies at the intersection between different biogeographic regions signifying a transition in ecosystems.

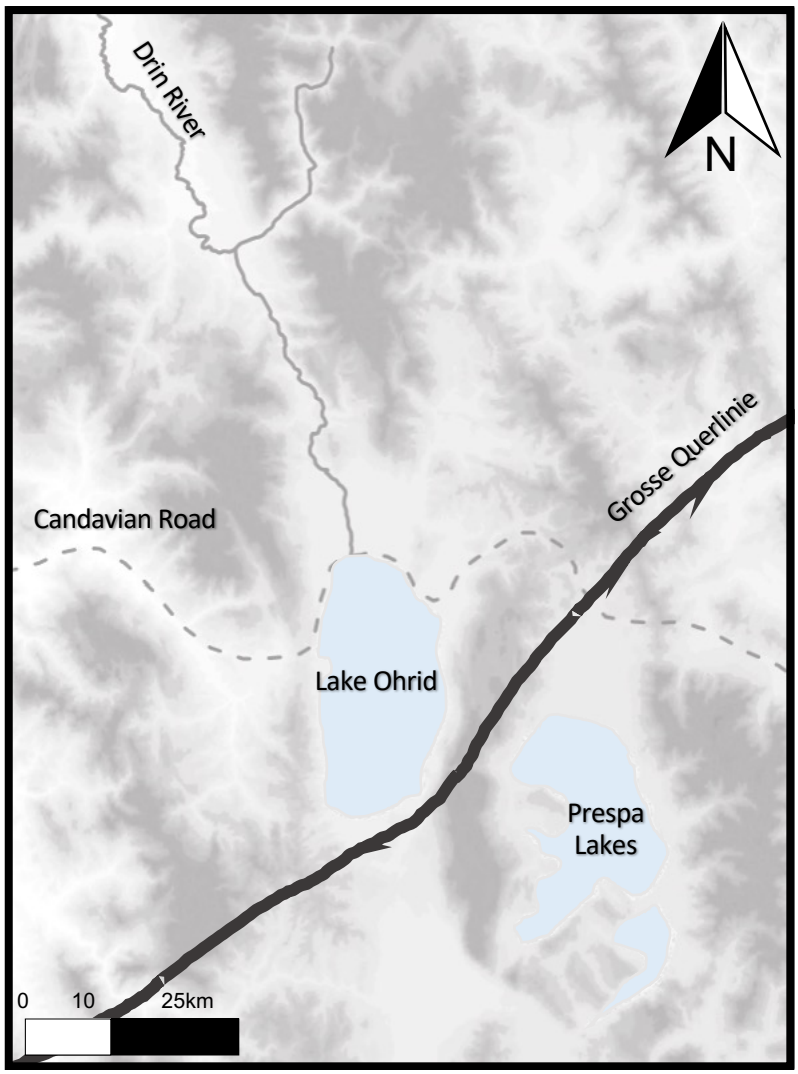


Figure 2: The Lake Ohrid basin is situated at the foot of the Galičica Mountain range. The approximate location of the extended Grosse Querlinie (a division between vegetation zones in the northern and southern Balkans) follows Malatesta et al. (2023). Possible route of Via Egnatia/Candavian Road based on Filipović (2018) and https://www.viaegnatiafoundation.eu/, last accessed 26/03/2024.

The shelter of the Lake Ohrid basin provided by the Galičica Mountain to the east and Mokra to the west offered a protected microclimate and, in some ways, enclosed landscape for the ecosystem growth and development. This geologically and limnologically impressive lake basin is home to equally remarkable floral and faunal biodiversity and endemism, with over

1,200 native and at least 212 endemic species (Albrecht and Wilke, 2008), rendering the area a focus for conservation, protection and biological enquiry. It is situated within the Pindus Mountains mixed forest ecozone (European Environment Agency, 2017) and a diverse ecosystem extending from the wetland to the montane vegetation. Surveys show oak-dominated forests (including the Macedonian oak, *Quercus trojana*, and the downy oak, *Q. pubescens*) extending to the lakeshore with the upper limit of the forest dominated by European beech (*Fagus sylvatica*) above which grasslands and shrubs, such as juniper varieties (including *Juniperus communis*) can be found (Brechbühl et al. 2023).

In addition to Ploča Mičov Grad, ten prehistoric sites are known on the shore of Lake Ohrid (Hafner et al. 2021), yet few have been excavated. The pile-dwelling of Lin 3, on the western Albanian shore, is under excavation as part of the EXPLO project with results forthcoming. Ceramic typology places the site of Ohridati, to the north-east of the lake, within the early Late Neolithic, while two radiocarbon dates from a wooden pile suggest an earlier phase c. 5620-5380 BCE (Westphal et al. 2010). Loom weights interpreted as for fishing nets and harpoons suggests fishing occurred at the site (Naumov, 2020). To the north of the Lake Ohrid basin, material culture from the site of Ustie na Drim shares characteristics with those found at Ohridati, suggesting a similar chronology. Ustie na Drim rests upon the Drin riverbank near to its confluence with Lake Ohrid, and so offered dual lacustrine-riverine affordances (e.g. fishing and movement). Four kilometres upstream, another pile site, Crkveni Livadi, has been interpreted as a small settlement, fishing system or fencing on marshland (Naumov, 2020). Across the lake, at its southernmost point, the site of Pogradec has been radiocarbon dated to 6000 to 5700 cal BCE (Allen and Gjipali, 2014). Little is known about the remaining

prehistoric sites on the lake shore. Prior to the EXPLO project, none of these sites have been extensively excavated or archaeobotanical analysed (Hafner et al. 2021).

A prehistoric trade route (the Candavian Road, Figure 2) runs to the north of Lake Ohrid. This is thought to be the most accessible lowland pathway between regions to the west and the east, through the challenging mountainous terrain (Lolos, 2007; Jovanova, 2013; Mitrevski, 2015; Weissová et al., 2018). It later became the route for the Via Egnatia and a modern-day road, emphasising the continued importance of this route over time (Filipović, 2018). Material cultural similarities between settlements in the Lake Ohrid basin and areas to the north along the Black Drin River valley (Kuzman, 2017; Weissova et al. 2019), south in the Korçë Plain (Kuzman, 2017) and east to Pelagonia (Kuzman, 2013; Naumov, 2020) suggests that this region was interconnected in prehistory, underlying the importance of accessible pathways.

0.7 THE SITE OF PLOČA MIČOV GRAD, LAKE OHRID

The prehistoric pile-dwelling of Ploča Mičov Grad was officially discovered in the 1970s following reports by a local fisherman (Naumov, 2016). Along the eastern shore of Lake Ohrid, within the Bay of Bones, ceramic sherds and the remains of wooden piles were visible on the lakebed. It soon became one of the most well-known prehistoric wetland sites in the southern Balkans, with underwater excavations commencing in 1997. Typologically dated to the Late Bronze Age and Early Iron Age, the settlement was estimated to cover approximately 8000 square metres and over 6000 wooden piles were identified (Kuzman, 2013). This work led to the creation of an open-air museum and a prehistoric village reconstruction directly above the site in 2008, based upon archaeological interpretations of a settlement comprised of a series of houses constructed upon a wooden platform on stilts (Kuzman, 2013; Naumov, 2016;

Hafner et al. 2021). This reconstruction resonates with the image painted by Herodotus of a Late Bronze Age settlement (thought to have been located in the Lake Ohrid basin): “platforms supported upon tall piles stand in the middle of the lake, which are approached from the land by a single narrow bridge” (V, 16). The extraordinary potential of the site for further bioarchaeological analysis was recognised along with a 150 cm thick organic archaeological layer just beneath the surface of the lakebed (Kuzman, 2013).

Excavations were resumed at Ploča Mičov Grad with a pilot study in 2018 led by the University of Bern, the Museum of Ohrid and the Center for Prehistoric Research in Skopje and continued as part of the ERC-synergy EXPLO project in 2019, a collaboration between the Universities of Oxford, Bern and the Aristotle University of Thessaloniki. Archaeological surveys during the pilot excavations of 2018 confirmed the bioarchaeological potential of the site for dendrochronological and archaeobotanical investigation (Hafner et al. 2021). Eroded wooden piles were easily recognised within the lakebed and the thick organic layer was present across the excavated area (Hafner et al. 2021). Dendrochronological analysis and radiocarbon dating of botanical material from the organic layer proposed an earlier phase of the site dating to the Late Neolithic – the middle of the 5th millennium BCE. Later settlement phases seen through the material culture and dendrochronological analysis confirmed successive occupation of the settlement into the Late Bronze Age (Bolliger et al. 2023; Hafner et al. 2021).

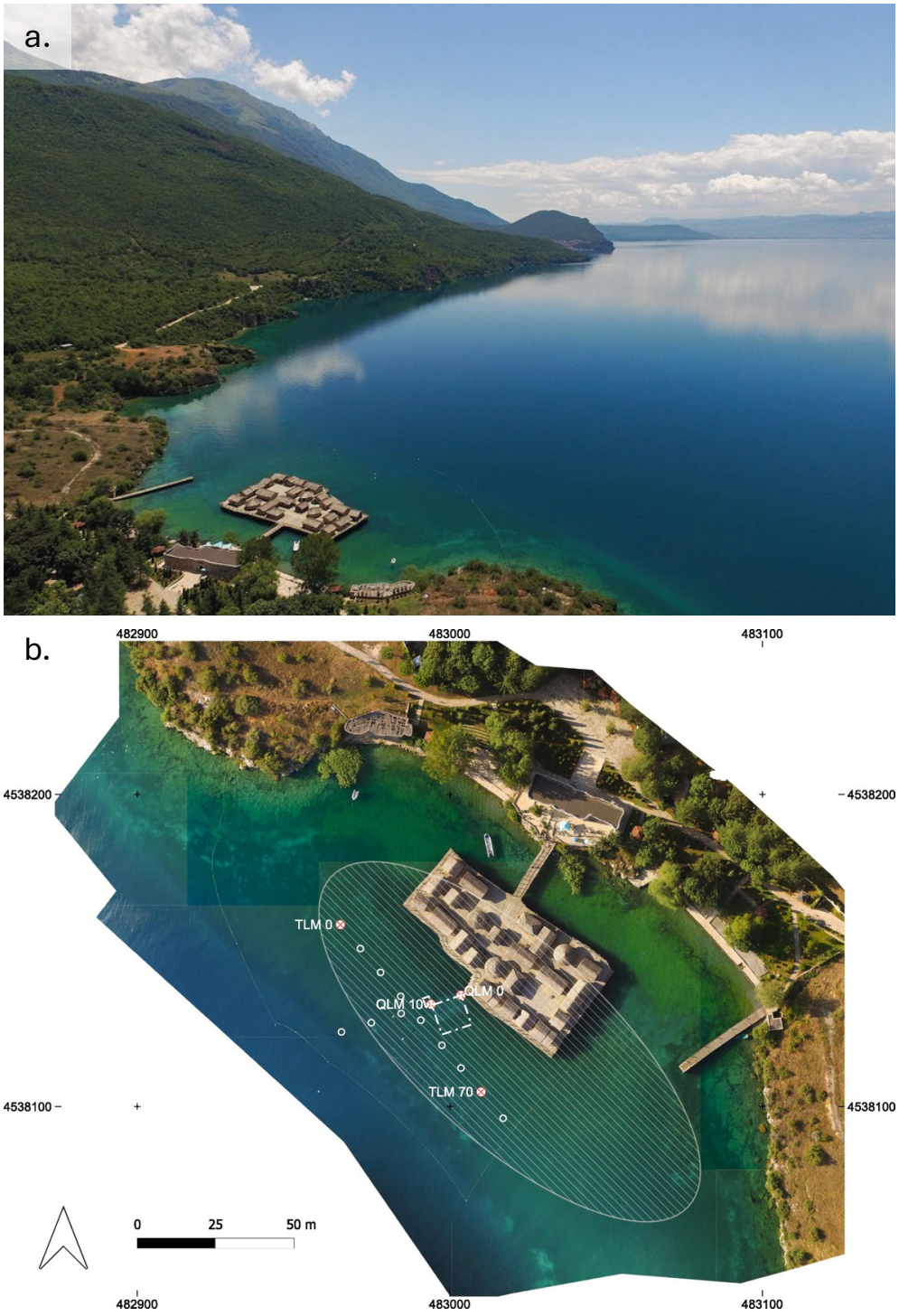


Figure 3: a. The site of Ploča Mičov Grad lies within the Bay of Bones on the eastern shore of Lake Ohrid (photo: G. Milevski). b. an aerial orthophoto showing the archaeological site (indicated by a hatched oval) underneath the modern pile-dwelling reconstructions. The fourteen cores are indicated by a circle. The four cores which are the focus of the

archaeobotanical study in this thesis are labelled and indicated with a red cross (orthophoto: M. Hostettler; Hafner et al. 2021).

Within the exceptionally thick organic layer, visible plant remains presented a tantalising window into the Late Neolithic food system. Fourteen sediment cores were extracted along a cardinally orientated transect from the settlement vicinity. Thirteen of fourteen contained the rich cultural layer (up to 1.5 m thick), which was interpretated as continuous between the cores. These cores were separated by a maximum distance of 80 m (Hafner et al. 2021). The archaeobotanical analysis of four of these cores is the focus of this thesis.

0.8 CONTEXTUALISATION OF RESULTS

As few wetland sites in the southern Balkans have been excavated and even fewer have had archaeobotanical analysis, this thesis looks to dryland sites to contextualise the results from Ploča Mičov Grad, south-west North Macedonia, within the broader region. Upland sites from southern North Macedonia, eastern Albania and north-western Greece from the 5th millennium BCE are particularly relevant here, but few have had extensive archaeobotanical analysis to facilitate detailed, direct comparisons. For example, the upland Late Neolithic site of Maliq, Korça plain, Albania is proximal and broadly contemporary to Ploča Mičov Grad, but its assemblage included only five taxa in low numbers (einkorn, emmer, barley, lentil and bitter vetch; Xhuveli and Schultze-Motel, 1995). The paucity of prehistoric sites in Albania and North Macedonia with archaeobotanical data is highlighted in Filipović et al. (2022). As such, in this thesis comparisons are also made to earlier sites (e.g., the upland dryland Early Neolithic sites of Vrbjanska Čuka, Veluška Tumba, and Vlaho in the Pelagonia basin, North Macedonia, Sabanov et al. 2024) or sites in the central/northern Balkans (e.g., late 6th to mid-5th

millennium BCE Vinča-Belo Brdo, Serbia) and across Greece (where a large number of sites have been investigated archaeobotanically, Valamoti, 2023). For example, despite its location in the lowlands of north-eastern Greece, many comparisons are made with the Late Neolithic dryland site of Dikili Tash which is broadly contemporary with the Late Neolithic phase at Ploča Mičov Grad (c.4300 cal BCE) and preserves an exceptional range and quantity of cultivated and foraged plant foods (Valamoti, 2015). Further, improved recovery techniques mean that archaeobotanical assemblages from recent excavations (e.g., those in the Early Neolithic sites in the Pelagonia Valley, Sabanov et al. 2024) are more likely to recover small, fragile taxa which are rare in dryland assemblages (e.g. opium poppy), highlighting the importance of these sites when contextualising Ploča Mičov Grad, despite the chronological disparity. Following the Balkan chronology, the mid-5th millennium BCE could be considered eNeolithic or Chalcolithic. We choose to use the term Late Neolithic here (following the Greek chronology), due to the broader scope of the EXPLO project and the number of comparisons made to Greek sites. While the limited number of contemporary and proximal sites inhibits detailed discussion between similar sites, such broader comparisons enable the consideration of how different variables such as elevation (upland-lowland), preservation (dryland-wetland), location (e.g. southern-northern) and time (earlier-later) could have impacted prehistoric food systems and the taphonomy of the archaeobotanical assemblages.

0.9 STRUCTURE AND AIMS OF THIS THESIS

This thesis takes the integrated approach with three discrete papers intended for individual publication. In the first paper of this thesis, the archaeobotanical results from the four sediment cores from Ploča Mičov Grad are presented and analysed. Preliminary archaeobotanical findings from one of the cores has been accepted and will be published in

late 2024 in a volume entitled “Prehistoric Wetland Sites of Southern Europe. Archaeology, Chronology, Palaeoecology and Bioarchaeology” (Holguin et al. *in press* – Appendix 3). In this thesis, the paper reporting on all four cores expands and strengthens the preliminary archaeobotanical analysis of the first core, interrogating the similarities and differences between the four spatially distinct sediment cores to identify site-wide trends. The diversity of the food system is evaluated by considering the role of both cultivated and collected edible plants. Further radiocarbon dating and Bayesian modelling is reported, offering greater chronological resolution. Contrary to expectations, a small amount of later Bronze Age material remained uneroded from the top of one core, while another core contained a small number of plant remains dating to the Middle Neolithic in its basal cultural sequence. Comparisons between Middle and Late Neolithic and later Bronze Age food systems are thus framed. This is contextualised within the broader ecosystem considering whether the wetland environment influenced the nature of plant food use and production.

The second paper of this thesis takes an integrated approach, combining pollen data from the near-site sediment cores published in Brechbühl et al. (2023) and the on-site archaeobotanical evidence to explore land-use change during the Late Neolithic. The taxa identified in the palynological and archaeobotanical records are aligned to provide a richer understanding of human activity and the cultural landscape in the sheltered bay. An increase in rosaceous shrub populations (inferred from the pollen record) coincided with increased human activity during the Late Neolithic settlement phase. As abundant rosaceous fruits and nuts (including almond, apple and blackberry) were present in the archaeobotanical assemblage, it is suggested that these plant foods were routinely collected and that systematic foraging activities encouraged rosaceous populations to flourish. Human-led disturbance within the Bay of Bones likely also

created an environmental niche within which these light-loving species thrived. The agrosystem of Ploča Mičov Grad was investigated through the weed flora and found to be small-scale and labour-intensive, in agreement with inferences from the palynological study for small-scale land-use. Combining the pollen and archaeobotanical evidence provided a richer understanding of food systems situated within changing vegetation dynamics.

The final paper of this thesis is focused upon the mildly toxic pulse, bitter vetch. This currently underutilised pulse is a common component of prehistoric archaeobotanical assemblages in the southern Balkans. However, due to its mild toxicity, its role in prehistoric human or livestock diets is unclear. Recent interest in drought-tolerant vetches and ancient crops with calls to diversify food systems encourages an examination of the prehistoric use of this pulse. An unusual feature of the archaeobotanical assemblage from Ploča Mičov Grad is the large number of fragile bitter vetch seed coats, preserved through a combination of charring and waterlogging, relative to low numbers of charred pulse seeds. Given that toxins are concentrated in the seed coat, this paper hypothesises that these macrofossils are the by-product of pulse processing for detoxification prior to human consumption. This is considered through careful assessment of the pulse macro-remains in comparison with the by-products of modern experimental processing. This potential processing evidence is interrogated alongside indications of pulse pest infestation, enriching our understanding of the agroecology. Bitter vetch processing also complements other evidence of food preparation at the site, including 'bulgur' remains of cereals (presented in Paper 1). Considering the role of bitter vetch past and present in agricultural systems, and from food to fodder, as well as its possible revival as a climate-resilient 'lost crop', situates this discussion of prehistoric food systems within present-day concerns.

In Appendix 1, the full archaeobotanical dataset is presented. A descriptive catalogue details the identification protocols for the archaeobotanical remains in Appendix 2. This supports the archaeobotanical identifications made in this thesis and demonstrates the exceptional levels of preservation. A paper presenting the preliminary results from one sediment core from Ploča Mičov Grad is included in Appendix 3. The individual contributions of co-authors can be found in Appendix 4.

Overall, this thesis aims:

1. To evaluate the impact of the upland, temperate, wetland setting on prehistoric cultivation practices and use of wild plant foods;
2. To consider the role of plant foods that are underrepresented in typical charred, dryland assemblages;
3. To integrate on-site archaeobotanical evidence with near-site palaeoecological evidence to situate findings within the cultural landscape; and
4. To investigate how plants became foods through evidence for processing and preparation activities.

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1.0 LIVING BY THE LAKE: PLANT FOOD DIVERSITY IN A PREHISTORIC PILE-DWELLING COMMUNITY IN NORTH MACEDONIA

Holguin, A.[1]; Charles, M.[1]; Antolín, F.[2,3]; Ballantyne, R.[1,4]; Ergun, M.[1]; Hafner, A.[5,6]; Jacomet, S.[3]; Lotter, A.[5,8]; Naumov, G.[8]; Reich, J.[6]; Soteras, R.[6]; Stroud, E.[1]; Tinner, W.[6,7]; Wood, R.[1] and A. Bogaard[1]

[1]School of Archaeology, University of Oxford, Oxford, OX1 2PG, UK.

[2]Division of Natural Sciences, German Archaeological Institute (DAI), Im Dol 2-6, 14195, Berlin, Germany

[3]Department of Environmental Sciences, Integrative Prehistory and Archeological Science (IPAS), University of Basel, Basel, Switzerland

[4]McDonald Institute for Archaeological Research, University of Cambridge, Downing Street, Cambridge CB2 3ER, UK

[5]Oeschger Centre for Climate Change Research, University of Bern, Hochschulstrasse 4, 3012, Bern, Switzerland

[6]Institute of Archaeological Sciences, University of Bern, Mittelstrasse 43, 3012, Bern, Switzerland

[7]Institute of Plant Sciences, University of Bern, Altenbergrain 21, 3013, Bern, Switzerland

[8]Center for Prehistoric Research, Kiro Krstevski Platnik 11, Skopje, 1000, North, Macedonia

1.1 ABSTRACT

The Lake Ohrid basin fosters exceptional biodiversity and is home to numerous under-researched prehistoric wetland sites. As part of the EXPLO project, this paper explores the relationship between wetland ecosystems and prehistoric pile-dwellings by considering prehistoric plant food use and production at Ploča Mičov Grad, North Macedonia, with a particular focus on its Late Neolithic occupation phase (c. 4697-4500 to 4436-4257 cal BCE). The waterlogged archaeobotanical assemblage provides a high-resolution record of human subsistence, with a broad spectrum of crops and 'wild' resources. Similarities with both Middle Neolithic (c. 5790-5722 to 5755-5714 cal BCE) and later Bronze Age (c. 1878-1688 cal BCE) phases attest to recurrent patterns of plant use alongside shifts in preferred crops. Waterlogged preservation of anthropogenic 'midden' deposits permits inferences regarding complex food systems and prehistoric biodiversity without the biases and limitations of charred assemblages.

1.2 KEYWORDS

Wetlands; Prehistory; Archaeobotany; Pile-dwelling; North Macedonia; Biodiversity; Food systems

1.3 INTRODUCTION

Straddling the border of present-day North Macedonia and Albania, the Lake Ohrid basin is a biodiversity hotspot, home to over 1,200 native and at least 212 endemic species of flora and fauna (Albrecht and Wilke, 2008). Recognising the biological importance and the cultural

significance of its (pre-)historical landmarks, the Ohrid region is one of few to be awarded both UNESCO Natural and Cultural Heritage Status (Hafner et al. 2021; UNESCO World Heritage Convention, 2024). The exceptional biodiversity of this modern wetland landscape challenges traditional views of wetlands in archaeology as environmentally or socially marginal (Van de Noort and O'Sullivan, 2006; Walsh, 2008). High levels of biodiversity today could also reflect high levels of biodiversity in prehistory, including an abundance of edible native plant foods. On the other hand, the colder winters and wetter summers of the upland Lake Ohrid basin likely imposed challenges for the cultivation of southwest Asian crops, established initially in regions of the southern Balkans with milder Mediterranean climates (Krauß et al. 2018; Ivanova et al. 2018; Ivanova, 2020; de Vareilles et al. 2022). The adaptation of farming in such upland lake basins may have been part of an important transition into the temperate continental interior of Europe. At present, such hypotheses are underexplored with archaeobotanical evidence as few prehistoric wetland sites in the southern Balkans have been the subject of systematic investigation (Hafner et al. 2021). As part of the ERC Synergy EXPLO project (2019-2025), this paper explores wetland prehistoric plant food systems within the Lake Ohrid basin to consider how biogeographic parameters shaped the local establishment of farming and the range of edible plant resources used by prehistoric inhabitants. We also investigate how prehistoric Lake Ohrid food systems compare with archaeobotanical evidence from dryland sites in the wider region and how far Lake Ohrid's biodiversity translated into a biodiverse prehistoric food system.

Following initial cultivation and domestication in Southwest Asia, cereals and pulse crops were first introduced into Europe through Greece in the mid-later 7th millennium BCE (Bogaard and Halstead, 2015; Kotzamani and Livarda, 2018; Valamoti and Kotsakis, 2016; Valamoti, 2023).

At present, the earliest evidence for agricultural practices in Europe comes from lowland, dryland sites in Greece lacking waterlogged preservation of uncharred material (e.g. Perlès et al. 2013; Kotzamani and Livarda, 2018; Valamoti, 2023). The climatic similarity between areas of Greece (classified biogeographically as 'Mediterranean'; European Environment Agency, 2017a) and southwest Asia and Anatolia accounts for the relatively rapid transfer of many agricultural practices and crops around the Aegean (Douka et al. 2017; Krauß et al. 2018). However, for agriculture to spread further north, into central Europe and regions biogeographically classified as 'Alpine' or 'Continental' (European Environment Agency, 2017a) with cooler, wetter summers and winter frosts, it is thought that genetic adaptations as well as cultural changes were necessary (Krauß et al. 2018; Ivanova, 2020; Gutaker and Purugganan, 2023). Due to such barriers, a reduction in diversity of the Neolithic plant-food spectrum with increased latitude has been hypothesised and observed through charred archaeobotanical assemblages between areas of the southern and northern Balkans (Ivanova et al. 2018; de Vareilles et al. 2022).

Many synthetic studies have traced the spread of crops through archaeobotanical assemblages from dryland sites (e.g. Colledge et al. 2004; Pinhasi et al. 2005; Zohary et al. 2012). Well-preserved charred archaeobotanical assemblages present valuable insights into the character of food systems such as the relative importance of different cereals and pulses (e.g. Filipović et al. 2022) and crop growing conditions via analysis of weed flora and stable isotopic analysis of crops (Bogaard and Halstead, 2015; Vaiglova et al. 2014; 2020) as well as agricultural activities such as storage practices (Valamoti and Jones, 2003) and food-processing (for example, the production of 'bulgur'; Valamoti et al. 2021). However, exclusively charred preservation at such sites biases information on plant subsistence towards

cultivation, as crops (particularly cereals), stored and consumed in houses year-round, are more likely to encounter fire and, as such, be preserved in the charred state that is most common on terrestrial sites (Green 1982; Jones and Rowley-Conwy, 1985; Jacomet et al. 1989). In contrast, wetland sites contain exceptionally well-preserved and diverse waterlogged botanical remains including a greater range of uncharred plant parts, such as pods, flowers and leaves, and plant types, such as fragile oilseed crops and foraged plants consumed in season (Jacomet, 2004; Jacomet, 2012; Colledge and Conolly, 2014) in remarkable numbers (Brombacher and Jacomet, 1997; Colledge and Conolly, 2014). Using datasets from the Alpine Foreland, Colledge and Conolly (2014, 199) estimated that charred dryland archaeobotanical assemblages only preserved approximately 35% of the range of edible plants that could have been preserved on waterlogged sites. The richness of waterlogged assemblages presents great inferential promise for investigating food production, grounded within a consideration of landscape biodiversity (Behre and Jacomet, 1991; Jacomet, 2012; Jakobitsch et al. 2023).

Archaeological interest in wetland sites in the southern Balkans is relatively nascent. Currently, the best-known prehistoric European wetland sites can be found on lakes, rivers and marshes across the Alpine Foreland, where Neolithic to Bronze Age pile-dwellings now number almost 1000 (Hafner et al. 2021). Characterised as structures supported above open water or upon wetland surfaces by vertical ‘piles’ (wooden stakes or stilts), pile-dwellings have been researched for over a century in the circum-Alpine region and demonstrate exceptional organic preservation (Hafner, 2014; Hafner et al. 2021). Organic remains ranging from an Early Bronze Age wooden plough (Lavagnone, Italy; Perini, 1988) and Late Neolithic ‘bread’ flavoured with celery (Parkhaus Opéra, Switzerland; Heiss et al. 2017) to Late Neolithic animal

dung composed of dried leaf hay (Mooswinkel, Austria; Jakobitsch et al. 2023) and a Late Neolithic moss insole fitting an EU size 37 shoe (Zug-Schützenmatt, Switzerland, Reichert, 2000; Leuzinger, 2004) provide insights into varied human-environment interactions including those relating to human food production and other uses of plant resources. Such information offers evidence for the ecological diversity of prehistoric human ecologies, as well as the human activities which may have impacted the local ecosystem.

The Lake Ohrid basin lies in the transitional zone between 'Mediterranean' and 'Continental' biogeographic regions, itself classified as 'Alpine' (European Environment Agency, 2017a; Figure 1 a). Situated within a sheltered upland valley influenced by the thermal capacities of the lake and proximity to the Adriatic Sea, the lake's basin experiences temperate climates (Figure 1 b, Köppen-Geiger classification 'warm temperate with a warm summer', "CSb", Kottek et al. 2006). The prehistoric pile-dwelling site of Ploča Mičov Grad is one of many pile-dwellings on Lake Ohrid's shore. The identification of over 6000 wooden piles and a thick (up to 1.5 m) waterlogged organic-rich cultural layer on the lakebed promised extraordinary potential for archaeobotanical analysis (Kuzman, 2013; Hafner et al. 2021). As part of the ERC Synergy EXPLO project, dendrochronological analysis of the vertical wooden piles and radiocarbon dating of plant macrofossils attested to several Late Neolithic (mid-5th millennium BCE) and later Bronze Age (2nd millennium BCE) settlement phases (Kuzman, 2013; Hafner et al. 2021; Bolliger et al. 2023). The location of the site in an accessible and interconnected lake basin (Figure 1 c, Lolos, 2007; Kuzman, 2017; Weissová et al. 2018; Naumov, 2020; Holguin et al. *in press*) and at the interface between different biogeographic regions presents a rare opportunity to better understand the nature of prehistoric lakeshore food systems. This paper builds upon published preliminary results from a restricted set of samples (Holguin et al. *in*

press – Appendix 3), expanding the archaeobotanical dataset from Ploča Mičov Grad and shedding new light on the diverse spectrum of both wild and cultivated plant foods utilised by the lakeside prehistoric populations in this under-researched region.

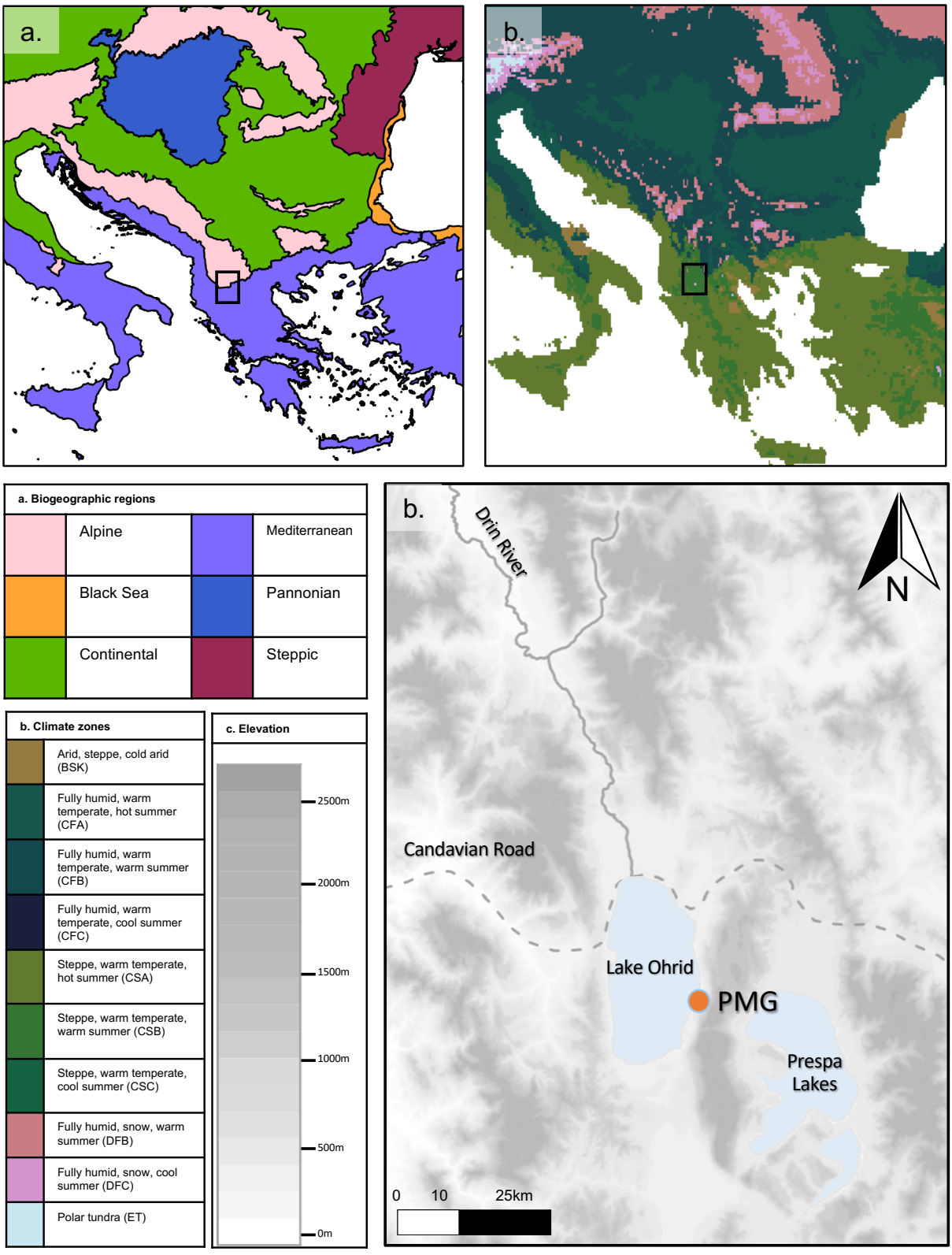


Figure 1: Lake Ohrid rests at the interface between 'Mediterranean' and 'Alpine' biogeographic regions (a) and between different Köppen-Geiger climate zones (b), at the foot of the Galičica mountain range. Ploča Mičov Grad (PMG) lies near to the possible path of the prehistoric trade

route (c). The black rectangle in a. and b. matches the area shown in c. Data for biogeographic regions from the European Environment Agency (© Council of Europe (CoE), Directorate-General for Environment (DG ENV), European Environment Agency (2017a). Köppen-Geiger climate classification after Kottek et al. (2006) downscaling after Rubel et al. (2017) © Climate Change & Infectious Diseases Group, Institute for Veterinary Public Health, Vetmeduni Vienna, Austria. Elevation data from USGS Global Multi-resolution Terrain Elevation Data. Possible route of Via Egnatia/Candavian Road based on Filipović (2018) and https://www.viaegnatiafoundation.eu/, last accessed 26/03/2024.

1.4 MATERIALS AND METHODS

1.4.1 THE SITE OF PLOČA MIČOV GRAD

The prehistoric site of Ploča Mičov Grad (Плоча Миќов Град, 40.994°N, 20.798°E) rests on the eastern shore of Lake Ohrid (North Macedonia) (Figure 1 c). An open-air museum with a pile-dwelling village reconstruction was built directly over the submerged prehistoric pile field (Kuzman, 2013; Naumov, 2016; Hafner et al. 2021). With a surface area of 358 km^3 and a volume of 55.5km^3, Lake Ohrid is both one of the largest and deepest lakes in southern Europe (Matzinger et al. 2006; Panagiotopoulos et al. 2014). At its maximum depth of 293m, annual sediment accumulation rates are estimated to be c. 0.5 mm (Lacey et al. 2015). Located within the Bay of Bones at an altitude of 693m a.s.l., the site of Ploča Mičov Grad lies at the foot of the Galičica mountain range within a relatively deep valley. Climate models suggest that during the Neolithic year-round temperatures were only minimally higher than today (particularly in the summer) with slightly higher precipitation rates during the winter (Samartin et al. 2017).

The climate is relatively temperate with mean daily temperature ranges from -1.5 to 6.2°C for January and from 14.0 to 27.6°C for July, and with a mean total annual precipitation of 662 mm, the highest monthly precipitation falling in November (WMO WWIS, 2023). Part of the 'Alpine' biogeographic region (Figure 1 a), the area is situated within the Pindus Mountains mixed forest ecozone (as defined by the European Environment Agency, 2017b) characterised by mixed broadleaf forests in the lowlands (with a predominance of oak forests by the lakeshore; Dinaric Arc and Balkans Environment Outlook, 2010; Brechbühl et al. 2023) and coniferous forests at higher elevations (Dinaric Arc and Balkans Environment Outlook, 2010), with grasslands and shrubs including various juniper varieties above the treeline (Brechbühl et al. 2023).

1.4.2 CORING, SAMPLING AND PROCESSING OF SAMPLES

Fourteen sediment cores were extracted underwater across the pile field on the shoreline plateau using a Niederreiter drill coring system by the EXPLO palaeoecological team from the University of Bern. Directly associated with the settlement, these cores were taken at approximately 10 m intervals along an 80 m approximately north-west transect (TLM19) intersecting a 50 m approximately east-west (QLM19) transect. The cores were extracted using a UWITEC piston corer with a diameter of 9 cm for the TLM19 transect and 5.9 cm for the QLM19 transect. The water depth ranged from approximately 3.5 to 7.5 m. The main organic layer was visible across thirteen cores (Figure S1 in Supplementary Materials). The fourteenth (core QLM19 40) was mostly lake marl.

Four of these cores were selected for archaeobotanical analysis (QLM19 10, QLM19 0, TLM19 0 and TLM19 70, Figure 2) due to the thickness of the visible layer and to provide sufficient

spatial coverage of the pile field. Due to their length, cores QLM19 0 and QLM19 10 were sub-sampled into approximately 1-m sub-cores to ease further processing. The lowermost 38.5 cm of core QLM19 0 was considered mostly lake marl and discarded in the field. The cores were photographed and stratigraphically described on-site. Sampling followed stratigraphic horizons. If stratigraphic layers were not discernible, samples were taken at regular intervals based on depth. Over half of the divisions between samples were based on visible stratigraphic changes. Samples were on average 6 cm in depth (with a minimum of 1 cm and a maximum depth of 20 cm). In total, 98 samples were taken from across the four cores (Figure S2 in Supplementary Materials).

The volume of each sample was measured by water displacement before further processing (Antolín et al. 2015). The samples ranged from 15 ml to 630 ml with an average volume of 137ml. Samples were processed using the wash-over method described by Steiner et al. (2015). This separated the heavier inorganic fraction from the lighter organic fraction, with the latter suspended in water and sieved through 2 mm and 0.35 mm meshes. The inorganic and <0.35 mm organic fractions were retained unanalysed. The volumes of the 2 mm, 0.35 mm and inorganic fractions were measured by water displacement.

The 2 mm fraction was analysed in full (ranging in volume from 1 to 200 ml, with an average of 38ml). The volume of the 0.35 mm fraction ranged from 2 to 110 ml with an average volume of 25ml. The 0.35 mm fractions were randomly sub-sampled to 10 ml using the grid sampling method (Steiner et al. 2017) if it exceeded approximately 15 ml. Forty-three samples were analysed in full. In some cases (particularly the lowermost sub-core of QLM19 0), the samples were not rich and so the full 0.35 mm fraction was analysed regardless of total volume. The smallest 0.35 mm sub-sample was $1/15^{th}$ of the total sample.

Preliminary archaeobotanical results from 28 samples from the upper two sub-cores of Core QLM19 0 have been accepted for publication (Holguin et al. *in press* – Appendix 3).

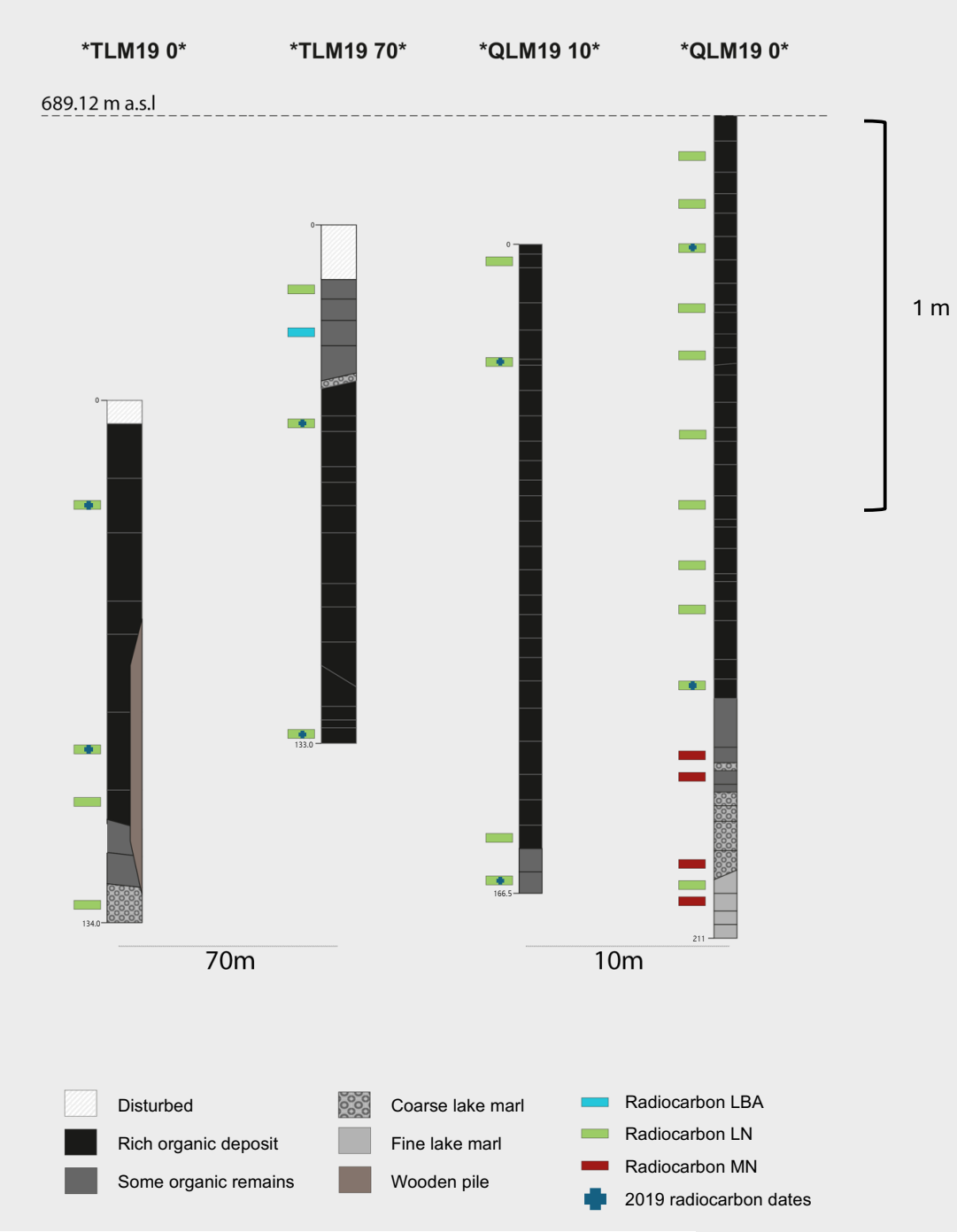


Figure 2: The four sediment cores subject to archaeobotanical analysis. The rich organic layer (show in black is present across all four cores). The blue, green and red boxes indicate the position of samples which gave later Bronze Age (LBA), Late Neolithic (LN) and Middle

Neolithic (MN) radiocarbon dates. A cross indicates the 2019 radiocarbon dates published in Hafner et al. (2021). The scale shows 1 m. Note the bottom 38.5 cm of core QLM19 0 is not shown in this diagram.

1.4.3 RADIOCARBON DATING

Eight radiocarbon dates, taken by colleagues at the University of Basel in 2019 and analysed by the EXPLO team at the University of Bern, have already been published (Hafner et al. 2021). Bulk plant macrofossils of uncharred cereal chaff were taken for radiocarbon dating from the top and bottom of the visible organic layer from these four cores, dated to c. 4600 to 4300 cal BCE. Uncharred cereal chaff was used to ensure that cultural material was directly dated (Hafner et al. 2021). Henceforth, these dates will be referred to as the '2019 radiocarbon dates.' These dates frame the modelled felling dates from dendrochronological and radiocarbon analysis of the primarily oak (*Quercus sp.*) and juniper (*Juniperus* sp.) piles which suggested continuous settlement activity for at least 87 years in the mid-5th millennium BCE between 4469 and 4383 cal BCE (Hafner et al. 2021; Bolliger et al. 2023).

This paper reports twenty additional radiocarbon dates from across the four cores (figure 2). Given that the 2019 radiocarbon dates suggested little mixing of or intrusions into the Late Neolithic deposit, for this further analysis, single entity samples were selected to improve the precision of the dates obtained using bulk macrofossils (average precision of ±48 years for the 2019 radiocarbon samples). Single-entity high-mass macrofossils can provide dates with a precision of ±20 years. Three of the four 'end-dates' fitted well with the 2019 radiocarbon dates providing greater precision (average of ±22 years). Additional dates were measured to investigate the lower lenses in core QLM19 0 (5 dates) and to improve the precision of the

'start-date' and/or 'end-date' of all four cores (7 dates). In addition, eight dates were sampled sequentially from the main organic cultural layer in core QLM19 0 to improve resolution, to refine estimation of the sedimentation rate and to identify the extent of material redeposition.

Samples were selected and photographed using a Leica Z6 AP0 camera and LAS Core software in the Archaeobotany Laboratory at the School of Archaeology, University of Oxford. Uncharred plant macrofossils (blackberry/*Rubus fruticosus* agg. seeds, rosehip/*Rosa* seeds, acorn/*Quercus* nutshell, cornelian cherry/*Cornus mas* seeds, hazelnut/*Corylus avellana* nutshell and juniper/*Juniperus* seeds) were chosen with a weight of at least 2 mg. Cereals were avoided for single-entity radiocarbon dating due to their lower mass. Samples were prepared and analysed by the Oxford Radiocarbon Accelerator Unit (ORAU) at the University of Oxford. The pretreatment followed the ABA method (1 M HCl 80 °C, 0.2 M NaOH 80 °C, 1 M HCl 80 °C) for plant material described in Brock et al. (2010). Further details of the chemical pretreatment alongside the target preparation and AMS measurement can be found in Brock et al. (2010).

OxCal 4.4 was used to calibrate the ^{14}C ages against IntCal20 (Reimer et al. 2020) and to perform Bayesian chronological modelling (Bronk Ramsey, 2009a). P-sequence models were used to produce age-depth sequences for each core, for which sediment deposition is modelled as a Poisson (random) process (Bronk Ramsey, 2008). The 2019 radiocarbon dates were included alongside the twenty new dates. The average depth of each sample was included. For two radiocarbon dates which were taken from the same sample, the ages were combined using the function 'R_Combine'. The Bayesian modelling combines the raw dates with the inputted prior information (relative depths) to produce a statistical calendar-age estimate for the phase in each core. All dates were assumed to have a 5% chance of being an

outlier within the General t-type Outlier Model (Bronk Ramsey, 2009b), with the exception of one sample from the Bronze Age layer which returned a Late Neolithic date. Without additional prior information (provided by the archaeobotany and sedimentary profile), the model would likely suggest that the Bronze Age date was the outlier. As such, the Late Neolithic date was given an 100% probability of being an outlier. All probability distributions are given at the 95.4% probability.

1.4.4 IDENTIFICATION AND COUNTING OF BOTANICAL MACROFOSSILS

Samples were sorted under a low-powered (x6.3-50) microscope. Plant macrofossils were compared with the reference collection in the Archaeobotany Laboratory at the School of Archaeology, University of Oxford, and images and descriptions in references atlases (Berggren, 1969, 1981; Körber-Grohne, 1991; Anderberg, 1994; Bojňanský and Fargašová, 2007; Cappers et al. 2012). Relevant species were identified using the online *Flora of Greece: Vascular Plants of Greece, An Annotated Checklist* filtered for the 'North Pindos' and 'North Central' regions (Dimopoulos and al. 2013). Following common archaeobotanical convention, the notation 'cf.' (confers/compares) is used to indicate uncertainty in the identification, either due to preservation, fragmentation or morphology. Nomenclature follows *Flora Europaea* for crops and *World Flora Online* for all other taxa. All photographs were taken using a Leica Z6 AP0 camera and LAS Core software.

All cereal, pulse and oilseed macrofossils were quantitatively recorded, following the principle of MNI (Minimum Number of Individuals). Cereal grains with the embryo end were counted. If only an apical end was present, this was counted. Fragments of cereal grains with a pre-charring break were counted regardless of the presence or absence of the embryo or apical

ends. Fragments of pulse pod and nutshell were counted using a size threshold. The nutshell size threshold was equivalent to approximately one eighth of a whole nut. Whole nut numbers were as such estimated by dividing the nutshell counts by eight. Spikelet forks were counted as two glume bases. All other seeds and capsules were counted using the principle of MNI. Additional tissues and capsules for which an MNI was challenging to estimate were counted using a 12 mm^2 threshold. These thresholds were chosen following common procedure at the IPAS at the University of Basel to ensure comparability of results with Alpine lake-dwellings (cf. Antolín, 2013; Antolín and Jacomet, 2015). In the text and figures, the reported counts from the sub-sampled 0.35 mm organic fractions have been multiplied to estimate their absolute number in the full sample, rounded up to a whole number and then combined with the counts from the 2 mm fraction.

1.4.5 CORRESPONDENCE ANALYSIS

Correspondence analysis was performed to explore compositional variance in the dataset. The raw dataset was simplified to exclude rare taxa. For this, taxa identified as 'cf' were combined with certain identifications. Uncharred and 'singed' counterparts were combined, as were 'browned' (lightly charred) and fully charred remains of the same taxa. Some taxa were merged into botanically and ecologically similar groups. For example, species of the same genus were combined (e.g. *Hordeum distichon* and *Hordeum vulgare* rachis), unless one species was highly numerous (>100 specimens) in which case the species remained in the dataset (e.g. *Hypericum perforatum* seeds – n=999 was kept while *Hypericum* spp. not *perforatum* seeds – n=86 were excluded) taking care that species with different ecological habitats were not combined. Different plant parts (e.g. chaff and grain) were kept as separate categories. Following merging, all taxonomic groups with less than 100 specimens were

removed. Samples with less than 100 specimens were removed (three Middle Neolithic samples). The resulting dataset included a total of 95 samples and 65 taxa present in at least 14 samples each.

The R-package 'vegan' was used with the function 'cca' with parametres set for correspondence analysis (CA). The raw results from the correspondence analysis were extracted and visualised in R. As a multivariate statistical technique, correspondence analysis arranges samples along two axes (the primary horizontal and secondary vertical) based on their compositional similarity. The relative position of samples reflects their compositional similarity. Equally, the relative position of taxa reflects their degree of co-occurrence in samples. Six variants of the dataset were explored, with anomalous taxa and samples removed, to better understand compositional relationships between the samples.

Further details of coring, sampling and processing, radiocarbon analysis and correspondence and cluster analyses can be found in the Supplementary Materials. The full archaeobotanical dataset can be found in Appendix 1. Identification and counting protocols can be found in catalogue (Appendix 2).

1.5 RESULTS

1.5.1 RADIOCARBON DATING

The radiocarbon results demonstrate that at least three occupation phases are represented in the sediment cores (Figure 3). The new radiocarbon dates suggest that most samples (n=82, including all samples from cores QLM19 10 and TLM19 0) relate to the Late Neolithic occupation(s), fitting with the eight dates obtained in previous work (Hafner et al. 2021). The

assemblage accumulated from approximately 4697-4500 cal BCE (earliest modelled start boundary, 95% confidence interval) until approximately 4436-4257 cal BCE (latest modelled end boundary). The start and end boundaries of each core from the Late Neolithic suggest that the cultural layer in the different cores can be considered broadly contemporary. The sedimentation rate for the Late Neolithic was an average of 2.9cm/year (with a maximum rate of 7.2cm/year for a part of QLM19 0 and a minimum rate of 0.7cm/year for QLM19 10.).

However, the top of core TLM19 70 dates to the later Bronze Age (approximately 1878-1688 cal BCE), based on one radiocarbon date. A second date gave a Late Neolithic age. This has been interpreted as contamination from the Late Neolithic deposit, perhaps during core extraction, given that, firstly, the archaeobotanical results show a distinct shift between the Late Neolithic phase and later Bronze Age phase, secondly, the presence of taxa (e.g. spelt) which are generally associated with the Bronze Age in this region and, thirdly, the absence of signs of stratigraphic disturbance. As such, this Late Neolithic date (OxA-44387) was set as an outlier during modelling (Table S6, Supplementary Materials).

Eight samples from the lower part of core QLM19 0 are likely Middle Neolithic based on four dates (accumulating from approximately 5790-5722 until 5755-5714 cal BCE). One sample gave a Late Neolithic date of 4451-4355 cal BCE. The model gave an 100% likelihood that this sample was an outlier and thus is interpreted as contamination, perhaps from during core extraction. The archaeobotanical composition of the layer itself was distinct from the overlying Late Neolithic deposit (see following section) further suggesting that this material was from a different phase. Further details can be found in the Supplementary Materials (Tables S1-6). Two samples (QLM19 0.2.1 and 0.2.2) positioned underneath the MN samples

were not directly radiocarbon dated, as they did not contain any cultural material. For the MN deposit the sedimentation rate ranged from 2.6-2.7cm/year.

The three samples that connected the MN and LN (sample QLM19 0.2.11 and 0.2.12), and the LN and LBA phases (sample TLM19 70.15) are considered transitional/boundary samples, likely containing an amalgamation of material from two different phases. As such they are not included in discussions of each phase.

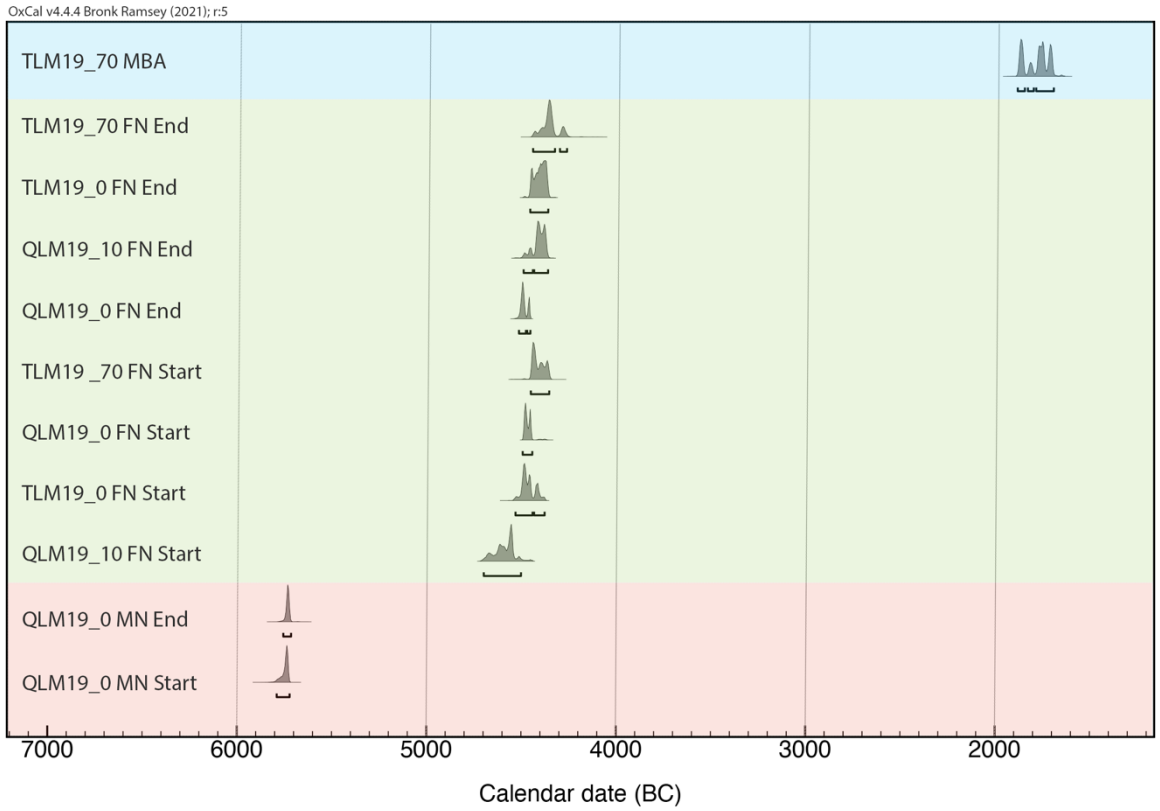


Figure 3: The modelled radiocarbon start and end boundaries for the Middle Neolithic (lower section, highlighted in pale blue), the Late Neolithic across the four cores (middle section, pale green) and the single Later Bronze Age date (upper section, pale orange). The p-sequence age-depth models can be found in the Supplementary Materials (Figure S4-8).

1.5.2 THE OVERALL ASSEMBLAGE

The LN organic-rich cultural layer measured up to 1.5 m thick and was present across all four cores analysed for archaeobotanical analysis. One of the sediment cores (TLM19 0) cut through a vertical wooden pile. Within the samples, cultural artefacts were recovered including large fragments of ceramic, twisted plant fibres and burnt clay. Some plant macrofossils had fragments of daub adhering.

The LN organic layer is visually consistent and undivided by sterile layers, suggesting a relatively uninterrupted continuous accumulation. Attrition of the vertical piles and the poor preservation of the uppermost LBA material culture on the lakebed (Hafner et al. 2021) suggests erosion processes could have removed material or disturbed the plant macrofossils. Organic material dating to the overlying LBA layer has been completely eroded from all but one of the cores (TLM19 70). However, the preservation of plant macrofossils with high sensitivity to corrosion and mechanical erosion including articulated cereal chaff, intact hairs on barley rachis (Figure 6 a and e), leaves of deciduous trees, complete tree buds and moss stems with leaves, alongside well-preserved insect remains suggest that the majority of the organic layer was not subject to highly destructive or disruptive taphonomic processes (Antolín et al. 2017).

Across all of the samples, 201,573 plant remains were fully quantified from 13.4 litres of soil sediment. Overall, the assemblage was rich with an average density of 12,345 fully quantified plant items per litre of sediment (Figure 4 a). The 98 samples were variable in density, ranging from 1,285 items/litre (sample QLM19 0.2.3, the lowermost sample with the cultural material) to 40,445 items/litre of sediment (sample TLM19 10). Most samples (n=21) have densities

between 8,000 and 11,000 items/litre. 49 of the 98 samples had densities of over 10,000 items/litre of sediment corresponding to typical densities in well preserved lakeshore cultural layers in the Alpine Foreland (e.g. Jacomet et al. 2004; Favre, 2002). Density estimates do not include items partially quantified such as uncharred wood, charcoal, roots and leaves.

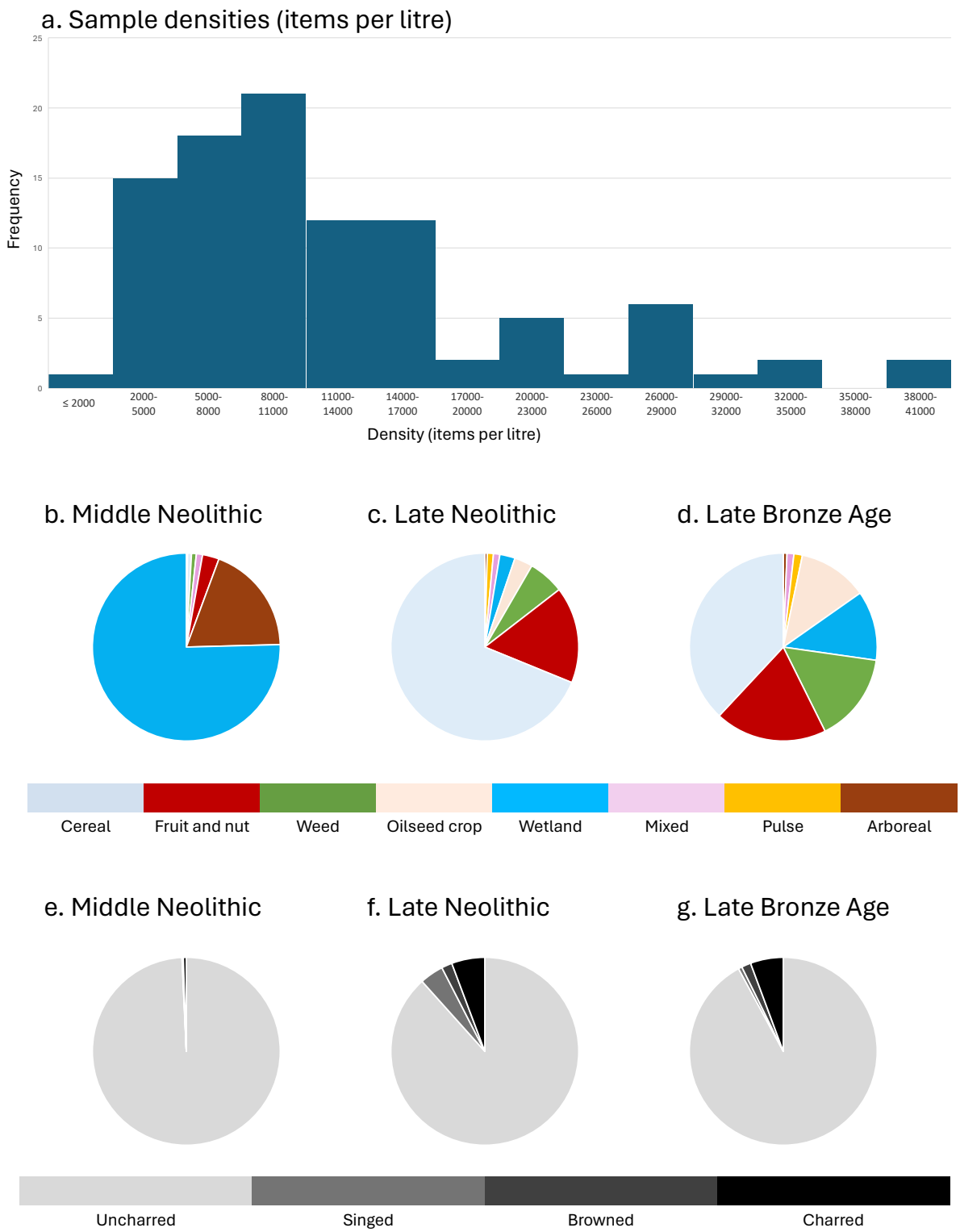


Figure 4: In a., a histogram shows the range of sample densities. The pie-charts in b-d show the proportions of eight different botanical groups for the three phases. The pie-charts in e-g show the proportions of macrofossils preserved in different states from uncharred to fully charred for each of the three phases. Both 'singed' and 'browned' material was partially

charred, the former being irregularly or heterogeneously charred while the latter had a browned appearance suggesting exposure to a low heat (see Appendix 3, figures 5 and 6, pages 515 and 516).

1.5.3 BOTANICAL CATEGORIES

Sample composition was characterised by classifying the plant macrofossils into seven botanical categories: 'cereal crops', 'pulse crops', 'oilseed crops,' 'edible tree fruits and nuts', 'weed/wild', 'arboreal' and 'wetland'. A small number of plants were not classified due to identification limitations or habitat flexibility (e.g. small-seeded unidentified grasses could come from drylands including as arable weeds, or from wetlands). Taxa habitats were classified based on records within *Flora of Greece* (Dimopoulos and al. 2013) and observations in the field.

The Middle Neolithic samples (n=8 samples) were dominated by wetland taxa (75%), followed by arboreal plant remains (19%). Edible fruits and nuts made up 3% of the total counted assemblage. Cereal material, weed/wild seeds and unclassified taxa each amounted to 1%, while oilseed and pulse remains were less than <1%. (Figure 4 b).

For the Late Neolithic material (n=82 samples), the cereal remains (69%) were the most numerous of the botanical categories, followed by the edible tree fruits and nuts (17%). Other categories in descending order of frequency were weed/wild remains (6%), oilseed crops (3%), wetland taxa (3%), pulses (1%) and unclassified taxa (1%). Arboreal taxa made up less than 1% of the total LN assemblage (Figure 4 c).

The relative importance of different categories was similar for the later Bronze Age as for the Late Neolithic; however, the relative abundance of cereal remains was smaller. For the LBA

(n=4 samples), cereal material was nevertheless the primary botanical category (38%) of the total quantified assemblage, followed by edible tree fruits and nuts (19%), weed/wild macrofossils (16%), oilseed crops (12%), wetland taxa (12%), crop pulses (1%), arboreal taxa (1%) and unclassified macrofossils (1%; Figure 4 d).

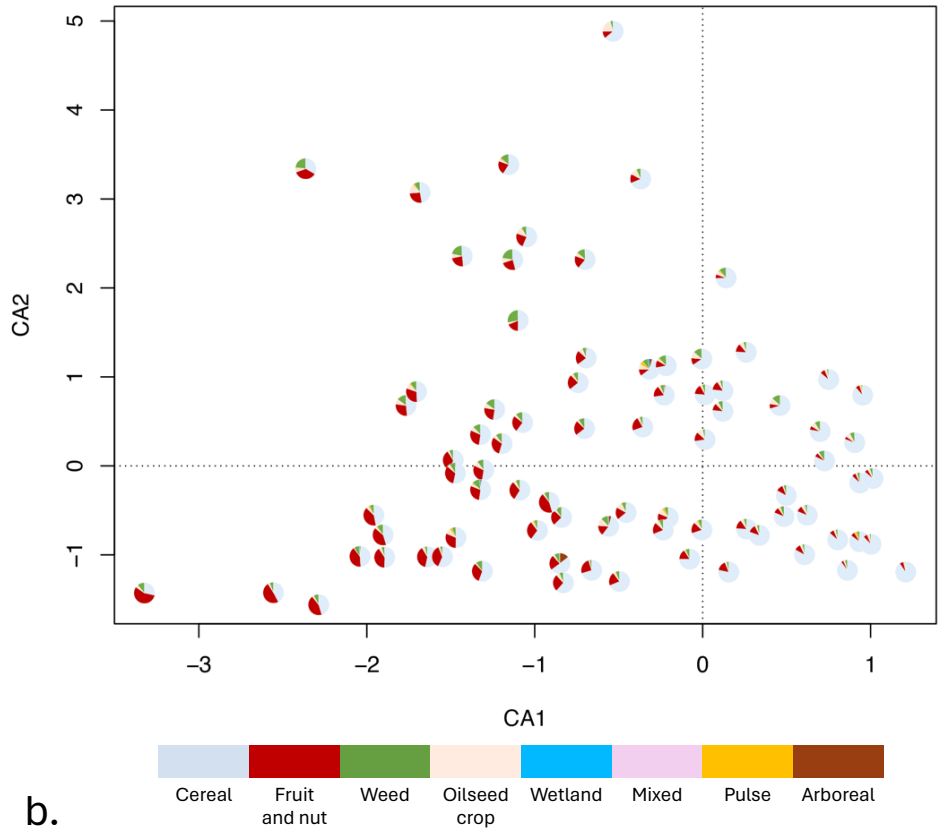
All of the analysed botanical remains (both uncharred and charred) were waterlogged, being fully submerged within the lakebed. Most plant remains were uncharred (88% for the LN; 92% for the LBA and over 99% for the MN, Figure 4 e-g). A minority of the archaeobotanical remains were charred (6% for both the LN and LBA and less than 1% for the MN; note this does not include wood charcoal). Other plant macrofossils were found partially charred, either having been irregularly charred ('singed'; 4% for the LN, 1% for the LBA and less than 1% for the MN) or having been heated to a low temperature insufficient to fully activate Maillard reactions ('browned'; 1% for both the LN and the LBA, and less than 1% for the MN). In each botanical category, material was preserved in various states from uncharred to fully charred. One dodder seed (*Cuscuta* sp.) was mineralised in one LN sample.

1.5.4 CORRESPONDENCE ANALYSIS

Correspondence analysis was used to explore compositional variation among the samples. The analysis was run with slightly different datasets (preliminarily analyses in Supplementary Materials). The final correspondence analysis showed good separation of all samples, allowing clear trends in the dataset to be identified. It included 63 taxa (list of taxa can be found in Table 7, Supplementary Materials) and 83 samples. This included all the Late Neolithic samples, except the lowermost samples in core TLM19 (0.1 and 0.2) and sample QLM19 0.1.7, as these samples were outliers. A broad trend was also apparent relating to depth for cores

QLM19 0 and QLM19 10 (with deeper samples positioned lower on the sample plot, Figure 5). However, this trend was not apparent for cores TLM19 0 and 70. While there was some grouping based on core, cores did not form discrete clusters, rather, there was significant overlap between cores and samples were widely distributed. Samples towards the right (positive end) of the horizontal axis (axis 1) contained larger proportions of cereals (up to 90% of sample content), while samples towards the left (negative end) contained larger proportions of fruits and nuts (up to 56% of sample content). Samples plotted towards the top (positive) end of the vertical axis (axis 2) derive from the tops of cores QLM19 0 and QLM19 10, and contained relatively large proportions of oilseed crops and weed seeds (Figure 5).

a.


CA2
5
4
3
2
1
0
−1
−3
−2
−1
0
1
CA1
Cereal
Fruit and nut
Weed
Oilseed crop
Wetland
Mixed
Pulse
Arboreal

b.

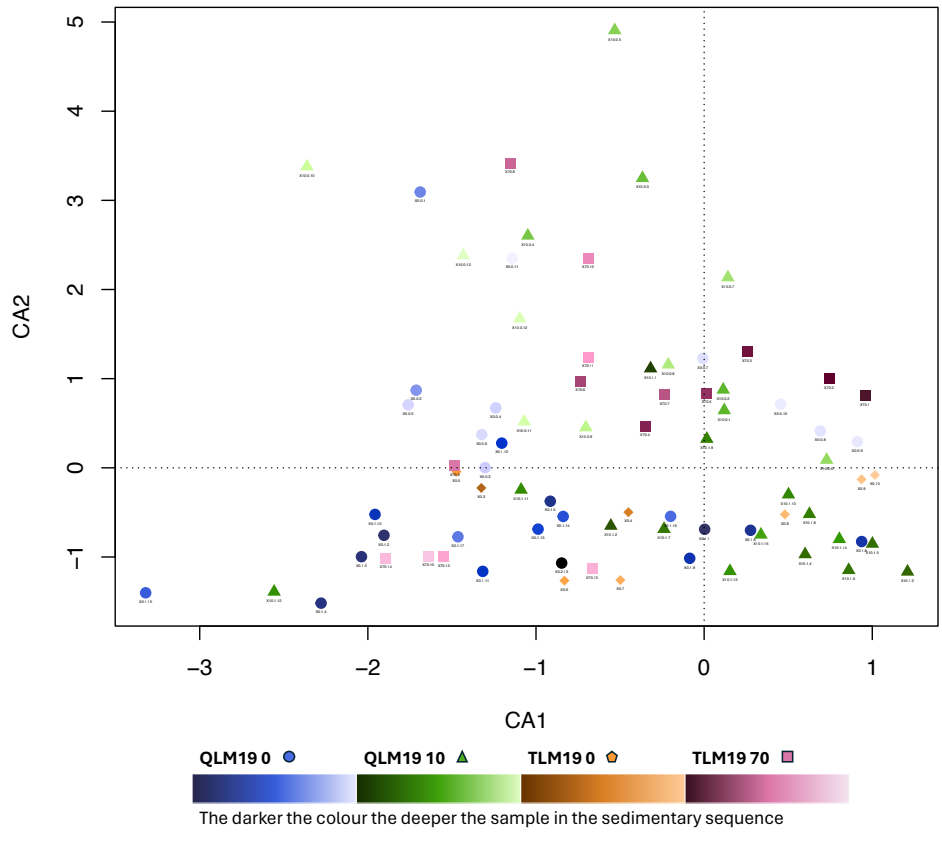

CA2
5
4
3
2
1
0
−1
−3
−2
−1
0
1
CA1
QLM19 0
QLM19 10
TLM19 0
TLM19 70
The darker the colour the deeper the sample in the sedimentary sequence

Figure 5: The correspondence analysis of the Late Neolithic samples (excluding three outliers). In a. the proportions of each botanical category in the samples show a clear trend with higher proportions of fruits and nuts towards the lefthand side (the negative end of the x-axis) and higher proportions of cereals towards the righthand side (the positive end of the x-axis). The archaeological samples show some trends based on core and depth. The archaeological samples are coded with Core QLM19 0 represented by blue circles, TLM19 70 by pink squares, TLM19 0 by orange/brown diamonds and QLM19 10 by green triangles. The shade reflects the depth of the samples with the darkest colours found at the base of the sedimentary sequence.

1.5.5 CROPS

i. The Middle Neolithic (MN):

Few cereal remains (1% of the total assemblage) were recovered from the eight MN samples. These included fifteen uncharred glume wheat chaff fragments and five fragments of uncharred cereal bran with hilum. Two charred glume bases were identified as emmer (*Triticum dicoccum*) and one as einkorn (*Triticum monococcum*), in addition to one charred rachis internode of barley (*Hordeum vulgare/distichon*) and three unidentified charred glume bases. A couple of fragments of cereal awn were also recovered, as were three fragments of pulse pod (one uncharred and two charred). Oilseed crops occurred at similarly low levels, making up less than 1% of the total MN assemblage, with a total of four fragments of flax capsule (*Linum usitatissimum*), two fragments of flax seed, and two fragments of opium poppy seeds (*Papaver somniferum*).

ii. The Late Neolithic (LN):

Cereal remains made up a significant proportion of the total LN assemblage (69% of all quantified plant macrofossils). These samples were overwhelmingly dominated by wheat (88%, n=107,704) with barley making up 4% (n=4,286) of all cereal remains and 8% (n=9,728) not identified further than cereal. Most cereal macrofossils were uncharred or 'singed' (92%), with only a small fraction (8%) of 'browned' or fully charred material.

The majority of cereal remains (93%) consisted of cereal chaff including uncharred and charred preservation states. Uncharred glume wheat glume bases were the most common cereal chaff (n= 101,285, Figure 6 d). Distinctions between uncharred einkorn, emmer and Timopheev's wheat, types of barley or between the free-threshing wheats were not possible due to the distortion of diagnostic features during waterlogging. The 'browned' and fully charred cereal chaff were generally well-preserved, and many retained diagnostic features enabling further identification. Three glume wheat species were identified - einkorn (*Triticum monococcum* 50% of all glume wheat identified to species, Figure 6 b), emmer (*Triticum dicoccum* 44%, Figure 6 h) and Timopheev's wheat (*Triticum timopheevii,* 6%, Figure 6 c). Barley rachis segments (n=3,495 uncharred and n=123 charred) and free-threshing wheat rachis (n=105 uncharred and n=45 charred) were also recovered. Charred barley rachis included multiple varieties: naked two- and six-row (Figure 6 e) as well as hulled two- and six-row varieties (Figure 6 a). When identification of free-threshing wheat to species was possible, it was all identified as bread wheat (*Triticum aestivum*, n=71 uncharred and n=105 charred).

Of all the cereal remains only a small percentage consisted of charred of uncharred cereal grains (7% of all quantified cereal remains), the majority of which were small fragments of uncharred cereal bran with hilum, contributing 6% of all cereal remains (n=7,419). Cereal bran

is highly sensitive to corrosion and mechanical erosion, attesting to high levels or organic preservation (Antolín et al. 2017). The orange-brown colour of the seed coat suggests that the majority of these cereal grain fragments are wheat (*Triticum* sp.; Holden, 1995). Charred cereal grains with an embryo/apical end (<1% of all cereal remains, n=239) included einkorn (*Triticum monococcum*, n=37, including seven 1-seeded), barley (*Hordeum vulgare/distichon*, n=34, including two hulled), emmer (*Triticum dicoccum*, n=12) and free-threshing wheat (*Triticum aestivum/durum*, n=1). No grains were identified as Timopheev's wheat. Many charred cereal grains were left unidentified as they are poorly preserved being distorted, damaged or fragmented. In addition, 149 cereal grain fragments exhibited a convex and smooth fracture surface suggesting a pre-charring break akin to 'bulgur'. A few of these grain fragments could be identified as barley (*Hordeum vulgare/distichon*, n=6) and einkorn (*Triticum monococcum*, n=5).

Pulses contributed to c. 1% of the total fully quantified assemblage. Fragments of uncharred pulse pod (>12 mm^2, n= 921) were found in almost all LN samples. The pulse pod remains were too fragmented to identify further. A few pulse pod fragments were 'singed' (n=20). Some calyces of various sizes (the attachment points between the pulse pod and the stem; uncharred n=33, charred n=4) were also recovered. 225 uncharred or partially charred pulse hila have been recovered, alongside 226 fully charred pulse hila. Charred pulse seeds of lentil (n=14, *Lens culinaris*) and bitter vetch (n=14, *Vicia ervilia*) were identified, along with a small number of possible pea seeds (n=4, *Pisum sativum*). Many pulse seed fragments (n=68) were missing diagnostic features required for species identification. One of the bitter vetch cotyledons had a borehole suggesting pest infestation. The pulse remains are the focus of the third paper in this thesis.

Two oilseed crops, constituting 3% of the total assemblage, were recovered from the LN samples. Plant macrofossils of flax (*Linum usitatissimum*) were a common component of almost all samples. While uncharred capsule fragments were numerous (n=2,958) and often found along with uncharred flax seeds (n=724), flax stem (n=12) was rarely found (Figure 6 f-g). A small number of charred flax capsule fragments were recovered (n=4). Uncharred opium poppy seeds (n=1,873, *Papaver somniferum*) were another common feature of the LN samples (Figure 6 l).


a
b
c
d
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Figure 6: Waterlogged macrofossils from Ploča Mičov Grad. All specimens are Late Neolithic and uncharred unless specified. A. Hordeum vulgare (six-row, hulled) charred rachis, b. Triticum monococcum charred spikelet fork, c. Triticum timopheevii charred spikelet fork, d. glume wheat spikelet fork, e. Hordeum vulgare (naked) charred rachis, f. Linum usitatissimum capsule fragment, g. Linum usitatissimum seed, h. Triticum dicoccum charred spikelet fork, i. Rubus fruticosus agg. seed, j. Ficus carica seed, k. LBA Papaver somniferum seed, l. LN Papaver somniferum seed, m. LN Vitis vinifera subsp. sylvestris seed, n. LBA Vitis vinifera seed and o. Pistacia terebinthus whole nutshell. All scale bars are 1 mm.

iii. The later Bronze Age (LBA):

Cereal remains made up 38% of the LBA samples (n=4) from the top of Core TLM19 70. The most common cereal item was uncharred cereal chaff (glume bases and spikelet forks) of glume wheats (65% of all cereal remains). These have not been identified to species due to distortion. Further identification of charred glume wheat chaff shows that four different species were present – einkorn (*Triticum monococcum*, n=28), emmer (*Triticum dicoccum*, n=13), Timopheev's wheat (*Triticum timopheevii*, n=10) and spelt (*Triticum spelta*, n=4). Charred barley chaff (*Hordeum vulgare/distichon*) rachis internodes (n=16) constituted less than 1% of the total LBA cereal macrofossils. No charred barley rachis could be identified to variety and no uncharred barley rachis internodes were found.

No charred cereal grains were identified as glume wheat. However, 322 fragments of cereal bran with the hilum (18% of the charred cereal remains) were present, the colour of which makes an identification of wheat most likely. A single charred grain was identified as barley

(*Hordeum distichon/vulgare*). Two charred cereal embryos and two fragments of charred cereal grains with a pre-charring break were also recovered.

Numbers of pulse remains from the LBA samples were low (<1% of the whole assemblage). In total, 47 fragments of uncharred pulse pod were identified, alongside eight uncharred pulse calyces, four uncharred pulse hila and twelve fragments of charred pulse pod. Only two pulse seeds were identified as bitter vetch (*Vicia ervilia*) and as lentil (*Lens culinaris*) both from sample TLM19 70.16 (the lowermost LBA sample).

Flax (*Linum usitatissimum*) and opium poppy were the two oilseed crops present in the LBA assemblage (12% of the total assemblage). Both fragments of flax capsule (n=25) and flax seeds (n=17) were present in all four samples. Uncharred opium poppy seeds (*Papaver somniferum*) were similarly found in all samples, totalling 531 seeds, many of which were whole and clearly larger than the Late Neolithic poppy seeds (Figure 6 k).

1.5.6 EDIBLE FRUITS AND NUTS:

i. The Middle Neolithic (MN):

Representing 3% of the total MN assemblage, edible tree fruits and nuts included terebinth nutshell fragments (*Pistacia terebinthus*, n=15), blackberry seeds (*Rubus fruticosus* agg., n=12), rosehip seeds (*Rosa* spp., n=9), acorn nutshell (*Quercus* sp., n=9), grape pips (*Vitis vinifera* subsp. *sylvestris*, n=7), strawberry seeds (*Fragaria vesca*, n=4), fig seeds (*Ficus carica*, n=4) and elder seeds (*Sambucus* spp., n=4). Some charred (n=10) grape pips were also recovered. Abundant finds of uncharred juniper seeds that closely resemble with *Juniperus* cf. *communis* (n=72) and others identified as cf. *Juniperus excelsa/foetidissima/sabina* (n=27) are a unique feature of the MN samples.

ii. The Late Neolithic (LN):

In total, 29,479 edible tree fruit and nut macrofossils were counted, the vast majority of which, (99%) were uncharred, representing 17% of the total fully quantified LN assemblage. Acorn (*Quercus* sp., n=902), terebinth pistachio (*Pistacia terebinthus*, n=726, Figure 6 o), almond (*Prunus amygdalus,* n=439) and hazelnut (*Corylus avellana*, n=97) nutshell fragments were the identified edible tree nuts. In addition, one whole almond and two whole terebinth empty shells were recovered. In terms of edible fruits from trees and shrubs, blackberries (*Rubus fruticosus* agg., Figure 6 i) were by far the most abundant (n=20,118), followed by strawberry (*Fragaria vesca*, n= 2,896), fig (*Ficus carica*, n=699, Figure 6 j), rosehip (*Rosa* spp., n=282), raspberry seeds (*Rubus idaeus*, n=244), cornelian cherry (*Cornus mas*, n=239), juniper (*Juniperus* cf. *oxycedrus.*, n=139), elder (*Sambucus* spp., n=98) and grape (*Vitis vinifera* subsp. *sylvestris*, n=137, Figure 6 m). Small fragments of juniper berry-like cones were also recovered including an almost whole cone containing juniper seeds. Seeds of the Maloideae subgroup of the Rosaceae family were common (n=225), some of which were identifiable as apple (*Malus* sp., n=60) and others to pear/rowan (*Pyrus*/*Sorbus* sp. n=22). Some fragments of the endocarp tissue that separates the seed from the fruit flesh were also found. Thirty-three robust Maloideae calyces with attached stone cells (sclereids, groups of lignified secondary cells) were identified.

iii. The Later Bronze Age (LBA):

Edible fruits and nuts made up 20% of the total LBA assemblage. In terms of tree nuts, acorn (*Quercus* sp.) was the most dominant with nutshell fragments totalling 169, followed by almond (*Prunus amygdalus,* with five nutshell fragments) and terebinth (*Pistacia terebinthus,*

three nutshell fragments). Blackberry seeds (*Rubus fruticosus* agg., n=441) were the most common edible fruit macrofossil in the LBA assemblage, followed by fig (*Ficus carica*, n=139), strawberry (*Fragaria vesca*, n=78), apple/pear/rowan seeds (Maloideae, n=12) and cornelian cherry (*Cornus mas*, n=14). Thirteen grape (*Vitis vinifera*) seeds were recovered from the total assemblage. The elongated shape of three of these grape seeds suggested a more domesticated variety than those found in the LN samples (Figure 6 n; Pagnoux et al. 2015).

1.5.7 WEED/WILD TAXA

i. The Middle Neolithic (MN):

Weed/wild taxa were rare in the MN samples. The most common weed/wild macroremains were types of small-seeded grasses that are currently unidentified (Poaceae, n=17). All of the other taxa only have a few seed representatives including a species of heliotrope (*Heliotropium europaeum*, n=3), common verbena (*Verbena officinalis*, n=3), and yellow bugle (*Ajuga chamaepitys*, n=2).

ii. The Late Neolithic (LN):

The weed/wild taxa represented 7% of the fully quantified LN assemblage. In total, 11,169 weed/wild plant macrofossils were recovered from the LN assemblage, the majority of which (84% of all weed/wild macrofossils) were uncharred. These represented 31 different families and 78 individual genera, with 56 species identified. Some of the most common uncharred weed/wild seeds were thyme-leaf sandwort (*Arenaria serpyllifolia*, n=1,146), St. John's wort (*Hypericum perforatum*, n=983), dodder (*Cuscuta* sp., n=501), mullein (*Verbascum* spp., n=393), and black-bindweed (*Fallopia convolvulus*, n=388). Some other plant items were also

recovered including capsule fragments of campion (*Silene* sp., n=375 fragments c. 12 mm^2), poppy (*Papaver* sp., n=53 sections), violet (*Viola* sp., n=39 sections) and lesser gold-of-pleasure (*Camelina microcarpa*, n=15). In addition, the flower-like exocarp of annual knawel (*Scleranthus annuus*, n=205) and clover (*Trifolium* sp., n=176), and fragments of bur medick pod (*Medicago* sp., n=116) were commonly found.

iii. The Later Bronze Age (LBA):

The spectrum of weed/wild taxa (16% of the total assemblage, n=787) present in the LBA samples was similar to that of the Late Neolithic. The most common uncharred macrofossils in this group include fat-hen (*Chenopodium album*, n=179), bellflower (*Campanula* spp., n=60) and thyme-leaf sandwort (*Arenaria serpyllifolia,* n=37). Six percent of the LBA weed/wild macrofossils were charred.

1.5.8 ARBOREAL

i. The Middle Neolithic (MN):

The arboreal macrofossils contributed 21% of the fully quantified MN plant remains. 843 needles of silver fir (*Abies alba*) were identified along with 42 pine (*Pinus* sp.) needles. Five seeds of European hop-hornbeam (*Ostrya carpinifolia*) and two seeds of European alder (*Alnus glutinosa*) were recovered.

ii. The Late Neolithic (LN):

Arboreal taxa were generally few in the total LN plant assemblage (<1%). The most numerous arboreal macroremains recovered were uncharred coniferous needles of pine (*Pinus* sp., n=294) and fir (*Abies* sp. n=218) trees. Uncharred arboreal seeds included European hop-

hornbeam (*Ostrya carpinifolia*, n=88), maple (*Acer* sp., n=31) and European alder (*Alnus glutinosa*, n=26). A few charred arboreal macrofossils were recovered including coniferous needles and scale fragments from pine (*Pinus* sp.) cones.

iii. The Later Bronze Age (LBA):

For the LBA, arboreal taxa (1%) of the total assemblage included fir needles (*Abies* sp., n=9), pine needles (*Pinus* sp., n=7) and European hop-hornbeam seeds (*Ostrya carpinifolia*, n=9).

1.5.9 WETLAND

i. The Middle Neolithic (MN):

For the MN samples, wetland taxa were the most common plant macrofossil (74% of the total assemblage). This group included the oogonia (the female reproductive organs with spirally arranged cells) of a charophyte green algae commonly known as stonewort (*Chara* spp., n= 4,134) and spiny water nymph seeds (*Najas marina*, n=17).

ii. The Late Neolithic (LN):

Wetland taxa were present in almost all samples, but their absolute and relative numbers were markedly low (3% of the total LN assemblage). The principal constituents of this group were stonewort oogonia (*Chara* spp., n=4,246), spiny water nymph seeds (*Najas marina*, n=99) and common reed seeds (*Phragmites australis*, n=32). Fragments of uncharred (n=12) and charred (n=228) common reed culm were also recovered. Some of the unclassified sedges (members of the Cyperaceae family such as *Carex* spp.) could grow in wetland habitats.

iii. The Later Bronze Age (LBA):

Constituting 12% of the total LBA archaeobotanical assemblage, wetland plants are represented by three taxa: stonewort (*Chara* spp., n=507), spiny water nymph (*Najas marina*, n=48) and brown flatsedge (*Cyperus fuscus*, n=12).

1.6 DISCUSSION

This paper reports a remarkable diversity of plant remains preserved through waterlogging associated with lakeshore settlement at Ploča Mičov Grad. Plant remains from 48 different families and 111 genera were identified. A diverse range of plant parts including leaves, flowers and capsules were also preserved, a common feature of well-preserved waterlogged assemblages (Jacomet, 2004; Jacomet, 2012; Colledge and Conolly, 2014), but rare for archaeobotanical assemblages in south-eastern Europe, the majority of which are charred (Valamoti, 2023). While archaeological assemblages will inevitably only contain a fraction of the prehistoric biodiversity, these plant remains attest to a varied and rich environment ranging from wetland zones to grasslands and woodlands. Many species represented in the archaeobotanical assemblage were also identified in modern local vegetational surveys (e.g. Brechbühl et al. 2023) and national reports (e.g. Country Study for Biodiversity of the Republic of Macedonia, First National Report, Ministry of Environment and Physical Planning, 2003) indicating substantial continuity between the prehistoric landscape and the present-day biodiversity hotspot (Albrecht and Wilke, 2008). Rather than being environmentally different or marginal due to its upland or temperate location, the plant food spectrum of Ploča Mičov Grad seems as (if not even more) diverse and rich as lowland sites in the region (Sabanov et al. 2024; Valamoti, 2023).

This work demonstrates the excellent level of preservation of the organic remains at the site of Ploča Mičov Grad. While the upper later Bronze Age deposit is largely eroded, the underlying deposit has strong stratigraphic integrity with exceptionally well-preserved plant macrofossils and a robust chronological framework. The average density of the samples exceeded 12,000 quantified plant items per litre, equivalent to well-preserved waterlogged deposits in the Alpine Foreland (e.g. the pile dwelling site of Arbon Bleiche 3, dating from the Pfyn-Horgen cultures, 3384-3370 BCE, Jacomet et al. 2004; and Horgen Scheller, 3080-3030 BCE, Favre, 2002). The preservation of the plant remains (including those highly sensitive to corrosion and mechanical erosion; Antolín et al. 2017) implies that the deposit was relatively undisturbed and remained protected within a consistently anaerobic waterlogged environment. The thickness of the main organic deposit (up to 1.5 m), its rapid accumulation and the lack of sterile layers (a common feature of circum-Alpine pile-dwellings - e.g. Late Neolithic to Chalcolithic, Sipplingen, Bodensee; Kolb, 1997), is highly unusual.

The consistent presence and uniform composition of the Late Neolithic (LN, c. 4697-4500 to 4436-4257 cal BCE) layer across all of the sediment cores suggests that it represents one prevailing occupation deposit, rather than numerous discrete contexts. This was supported by correspondence analysis of compositional variance, revealing only weak differences between the four sediment cores. The finds of ceramic sherds and daub within the samples and the direct association between plant remains and human activity (such as daub adhered to blackberry seeds and charred macrofossils) all demonstrates a strong connection between the organic deposit and the settlement. The minimal quantity of wetland and arboreal taxa in the samples, in contrast to the volume of crop by-products and edible plant foods, suggests that this deposit can be viewed as a form of midden, perhaps with refuse accumulating on the

lakebed from domestic activities in the overlying pile settlement. Similar refuse deposits have been identified at other prehistoric pile-dwelling sites (Nicosia, 2022), which compare well to ethnographically documented practices (Pétrequin, 1995, cited in Nicosia, 2022). Based on the radiocarbon and dendrochronological dating, it is likely that this deposit accumulated over approximately 150 years, through repetitive routine activities such as food preparation, crop processing and waste discard. The assemblage does not exhibit notable heterogeneity suggesting that it could represents site-wide activities. However, the uniformity of the assemblage could be the product of taphonomy or discard practices. Differences between the assemblages could have reflected zonation and use of space. Due to erosion and compaction, the surviving deposit likely represents a fraction of its former extent, emphasising the intensity of its deposition.

Despite their small numbers, the Middle Neolithic (MN, n=8 samples, c. 5790-5722 to 5755-5714 cal BCE) and later Bronze Age (LBA, n=4 samples, c. 1878-1688 cal BCE) samples provide an interesting comparison to the LN samples. The correspondence analysis does reveal a notable compositional difference (largely based on the numbers of wetland and arboreal taxa) between the MN samples and the rest of the sediment core. Cultural indicators within the MN include charred and uncharred cereal and pulse remains and charred fragments of grape pips. Further, small ceramic sherds were recovered from the inorganic fraction during wash-over. No MN material culture or structures were identified during the excavations (Hafner et al. 2021; Bolliger et al. 2023). However, an earlier phase (c. 5550-4850 cal BCE) was suggested following palynological analysis of a sediment core extracted near to the settlement with cereal pollen peaks (Brechbühl et al. 2023). The archaeobotanical lenses, thus, correspond to the start of the earliest anthropogenic phase in the pollen sequence. For the LBA, it is likely

that this deposit once covered a sizeable proportion of the site (similar to the LN layer) as the majority of excavated material pertains to the LBA (Hafner et al. 2021; Bolliger et al. 2023). However, it is now missing due to erosion. The correspondence analysis separated the LBA samples from the Neolithic samples based on their numbers of opium poppy seeds and fat-hen seeds.

For both the LN and LBA, a range of cereal varieties were cultivated including einkorn, emmer, Timopheev's wheat and multiple types of barley. While einkorn was the most numerous for both periods, other cereals were still found in significant numbers, suggesting that cultivation during both periods was diverse, protecting against crop failures. For the LN, a range of barley varieties including naked 2-row and 6-row, as well as hulled 2-row and 6-row types, alongside bread wheat, further diversified this broad-spectrum cultivation strategy. The addition of spelt wheat to the crop spectrum by the LBA follows the regional pattern of spelt wheat adoption in later prehistory (Valamoti, 2023). In both cases, cereal chaff far outnumbers cereal grains, likely (at least in part) as the by-product of cereal processing such as dehusking. The number of einkorn and barley grains with pre-charring breaks suggests food processing such as the cracking of cereal grains to produce food items like 'bulgur,' which take less time to cook than whole unprocessed grain (Valamoti et al. 2021). Frequent amorphous charred remains could also represent processed food and requires further analysis. Einkorn, emmer, Timopheev's wheat, barley and free-threshing wheat are common features of Neolithic assemblages across the southern Balkans (Kotzamani and Livarda, 2018; Filipović et al. 2023; Valamoti, 2023). Einkorn was similarly the most numerous crop recovered at many Late/Final Neolithic dryland sites in northern Greece (Valamoti, 2023) and Early Neolithic sites in North Macedonia's Pelagonia Valley (Sabanov et al. 2024). This follows a geographical trend observed across

Greece with inferred greater importance of emmer to the south and einkorn to the north, perhaps related to their drought tolerance (Livarda 2014; Roushannafas et al. 2023). However, at Ploča Mičov Grad, finds of emmer were only minimally lower, suggesting that both were important crops. The consistency of the Late Neolithic deposit and the lack of sterile layers within it suggests that the entire Late Neolithic assemblage represents relatively continuous settlement activity and possibly one occupation phase. However, short hiatuses cannot be excluded and have been suggested by the dendrochronology (Bolliger et al. 2023).

Given the frequency of uncharred pulse pods, it is perhaps surprising that only a few charred pulse seeds were recovered for both the LN and the LBA. However, such high numbers of uncharred pulse pod relative to charred pulse remains has been observed at other waterlogged prehistoric sites such as Late Neolithic Hornstaad-Hörnle 1A, 3918-3902 cal BCE, Germany (Maier, 2001). During the LN, the simultaneous cultivation of bitter vetch, lentil and pea could have further provided stability against crop failure by increasing the range of crops cultivated. Pulses are important plant foods, providing a source of protein and agroecological benefits for soil health. Possible evidence for LN pulse pests and the presence of such an unusual number of pulse hila relative to pulse seeds is the subject of another paper (Paper 3 in this thesis). A reduced spectrum of pulse seed species is expected with increased latitude due to environmental parameters (de Vareilles et al. 2020, 2022), but the abundance of pulse pod and frequent finds of pulse seed hila at Ploča Mičov Grad and numbers of pulse seeds at other sites in the region (e.g. de Vareilles et al. 2022; Filipović et al. 2022; Valamoti, 2023) suggests that the low numbers of pulse seeds is due to pre- or post-depositional factors, such as processing methods. The low number of pulse macroremains recovered from the LBA samples is intriguing, yet, without further samples, its significance is unclear.

The ubiquity and abundance of both flax and opium poppy seeds and capsule fragments in the LN and LBA samples, and occasional charred macrofossils, suggests that they were likely used as oilseed crops. Finds of both oil-crops are rare in the southern Balkans, likely due to taphonomic factors (de Vareilles et al. 2020; Sabanov, et al. 2024; Valamoti, 2023). The size and shape of the LN opium poppy seeds were most similar to the wild morphotype *Papaver somniferum* subsp. *setigerum*. This was particularly notable in comparison to many of the opium poppy seeds of LBA samples (Figure 6 k-l), which resembled the domestic morphotype, *Papaver somniferum* subsp. *somniferum* (Jesus et al. 2021). Geometric morphometric analysis has begun to confirm these identifications (Antolín et al. *in prep*.). The diversity in the size and seed coat pattern within opium poppy for both the LN and LBA suggests genetically diverse populations.

Based on the large number of macrofossils, it is likely that the LN community regularly collected several nuts (including almond, acorn and terebinth) and fruits (such as blackberry, strawberry and fig). Many of these types were also identified in palynological analysis (Brechbühl et al. 2023). The fruits of shrubs could have been brought to the site by or for livestock or collected as fodder, but very low quantities of intact animal dung were identified in the samples. This is unlikely due to preservation given the high preservation of fragile plant macrofossils and other remains such as rodent pellets. A similar but reduced spectrum of wild plant foods were identified in the LBA samples (although this could reflect biases of the smaller number of samples). While all of the LN grape pips exhibited typical wild morphology, some, but not all, of the LBA grape pips showed domesticated characteristics (Pagnoux et al. 2015), suggesting cultivation or collection of genetically diverse populations (Figure 6 m-n).

The weed/wild, arboreal and wetland taxa all provide an indication of the environment. It is plausible that the weed/wild plant macrofossils offer a reflection of the environment skewed towards arable land. Equally, some of these have medicinal and food uses and cultural significance such as St. John's wort, oregano, and horse mint. The weed/wild taxa will be the subject of another paper to explore the nature of LN agrosystems (Paper 2 in this thesis.) The range of arboreal and wetland taxa match many identified in the palynological record (Brechbühl et al. 2023), several of which are still present in the Lake Ohrid basin today (Ministry of Environment and Physical Planning, 2003; Brechbühl et al. 2023).

1.7 CONCLUSION

Waterlogged and uncharred preservation of archaeobotanical assemblages is known to give a more complete picture of the diversity of plant subsistence than dryland/charred assemblages. However, the extent to which more temperate climatic conditions reduced prehistoric levels of plant food diversity in upland areas of the southern Balkans is largely unexplored. The exceptional preservation of dense waterlogged archaeobotanical assemblages from the lakeshore pile-dwelling site of Ploča Mičov Grad includes a diverse range of plant taxa and types reflecting a rich and varied upland landscape from lakeshore wetland to arboreal stands. The crop spectrum of Ploča Mičov Grad is diverse, protecting against crop failures, and includes oilseed crops such as opium poppy which was previously little known from prehistoric sites in the southern Balkans. This likely reflects the preservation biases of charred dryland assemblages. The presence of bitter vetch follows wider trends in the central and western Balkans to increase crop diversity in the Late Neolithic. The collection of wild fruits and nuts is known to be underrepresented in charred assemblages from dryland sites in southeast Europe. This waterlogged assemblage demonstrates that, even in temperate

upland zones, a wide range of edible wild plant resources were collected and complimented agricultural systems. The archaeobotanical assemblage does not suggest that aquatic and other freshwater plants were important to the lakeshore population. Rather, most taxa would have been grown in dryland environments, emphasising the similarity between wetland and dryland sites, and overturning the assumption that wetland food systems are marginal or unique. The archaeobotanical assemblage is, thus, akin to a dryland site's assemblage with added diversity facilitated by waterlogging, rather than being orientated towards plant lacustrine resources. The range of edible fruit and nut, weed/wild, arboreal and wetland taxa, and the intra-species diversity attests to the ecosystem richness and genetic diversity of the prehistoric landscape.

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1.10 SUPPLEMENTARY MATERIALS

1.10.1 MATERIALS AND METHODS

i. Coring, sediment profiles and sampling

Nine cores were extracted along the approximately north-south (TLM19) transect and five cores were extracted along the approximately west-east (QLM19) transect at 10 m intervals by the EXPLO palaeoecological team from the University of Bern led by Andres Lotter and Willy Tinner (Figure S1). One of the cores (QLM19 40) was left unanalysed as it contained primarily lake marl and disturbed material. The organic cultural layer could be seen throughout the remaining thirteen cores (Figure S2).

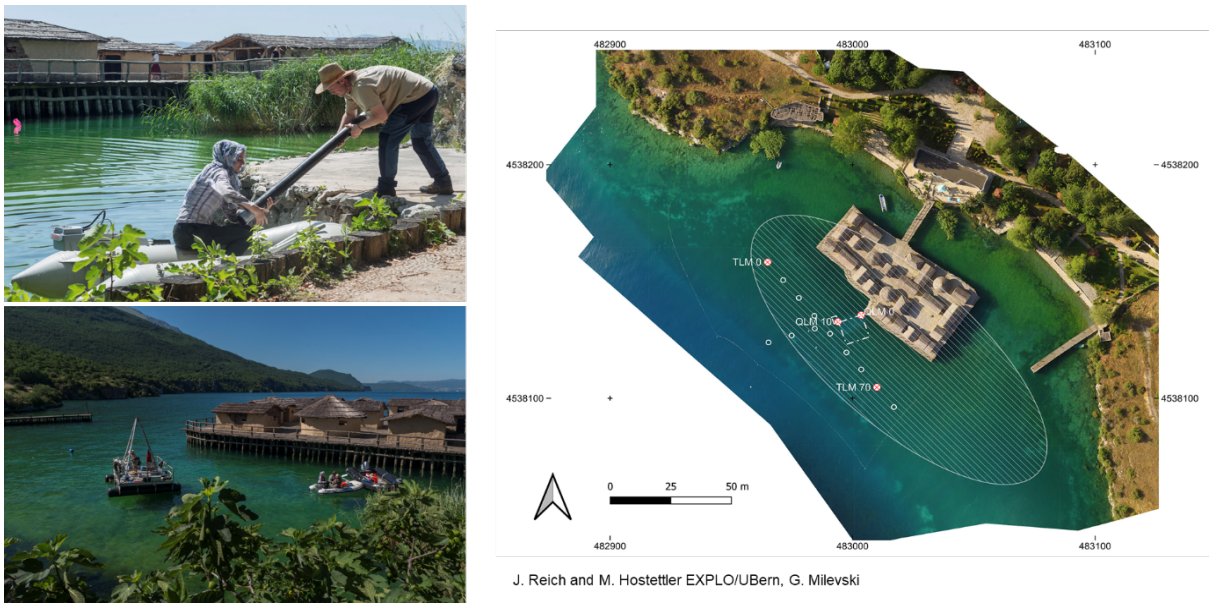


Figure S1: (Left) Members of the EXPLO team extracting the sediment cores and (right) an aerial orthophoto of the pile-field (indicated with a hatched oval) next to the modern museum. The excavated area is marked by a square (excavation details in Hafner et al. 2021). The fourteen sediment cores are marked with circles. The four cores analysed for archaeobotanical

macrofossils are outlined in red and labelled with the core name. Photographs and orthophoto R. Soteras, J. Reich, M. Hostettler, G. Milevski, EXPLO/University of Bern (Hafner et al. 2021).

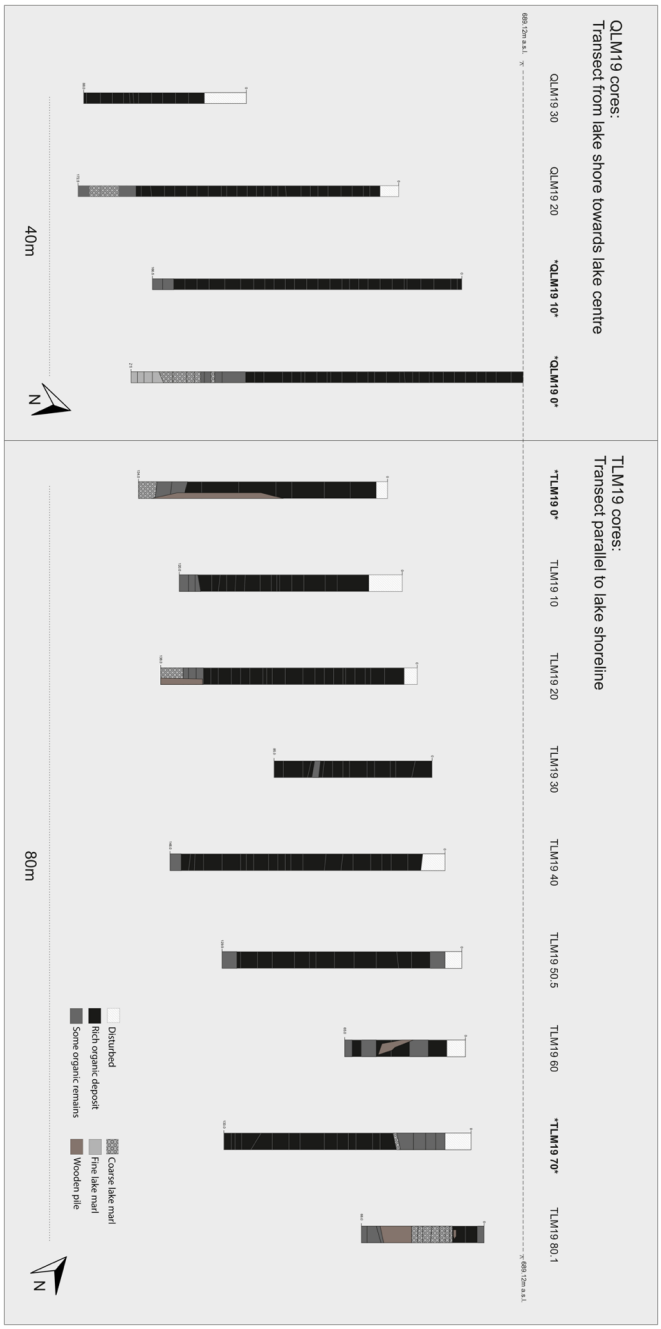


Figure S2: Schematic diagram of the thirteen sediment cores. The organic cultural layer (shown in black) was present in all thirteen cores. This diagram does not include core QLM19 40 and the lowermost 38.5 cm of core QLM19 0 as both were considered mostly lake marl and discarded in the field.

F. Antolín led the sampling of the sediment cores. Sampling followed stratigraphic horizons in the sedimentary profiles (when present). When this was not possible, samples were taken at regular intervals. Samples were on average 6 cm in depth (with a minimum of 1 cm and a maximum depth of 20 cm). In total, 98 samples were taken from across the four cores (Figure S3).

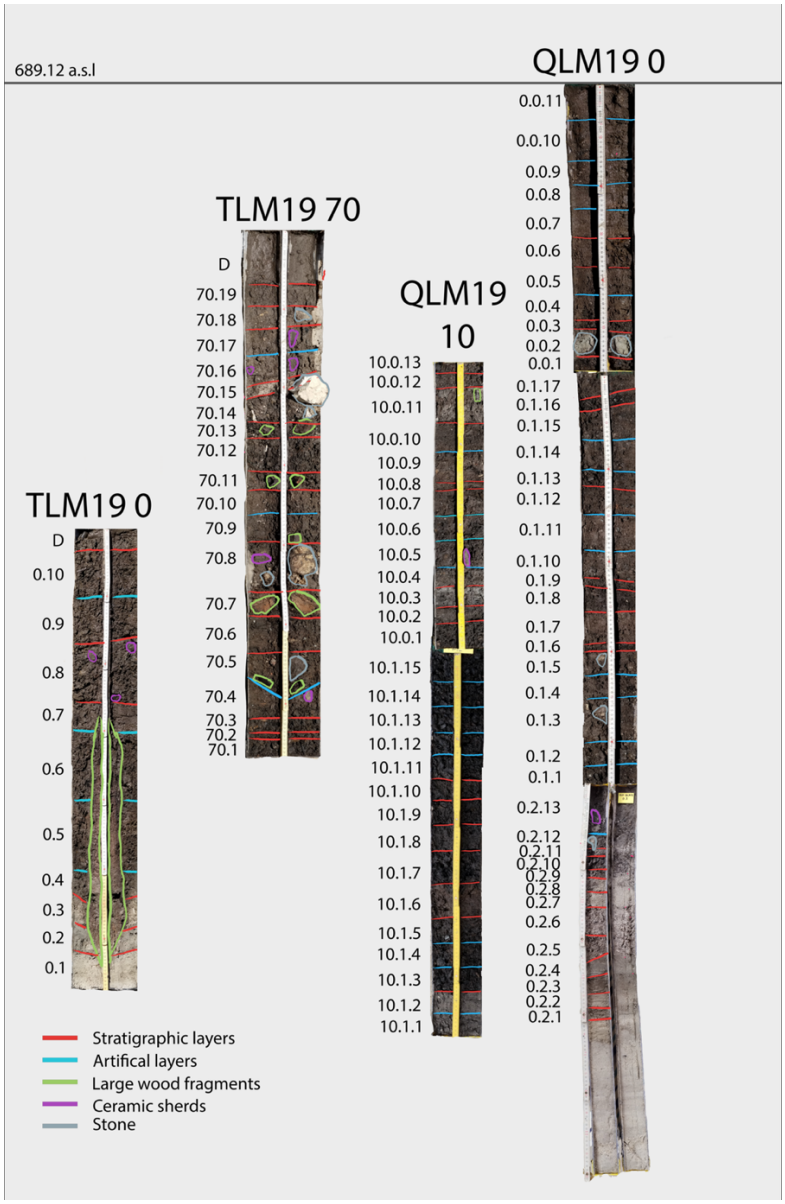


Figure S3: The sediment cores for archaeobotanical analysis. Samples were taken based on stratigraphic layers when present (red). If not, samples were taken at spits (artificial layers,

blue). Each core is labelled with the sample numbers. At the top of cores TLM19 0 and TLM19 70 some material was thought disturbed and so not sampled (D). Photos R. Soteras and F. Antolín.

1.10.2 RESULTS

i. Radiocarbon analysis

Table S1: The radiocarbon samples and measurements. Abbreviations: T0 = Core TLM19 0, T70 = Core TLM19 70, Q0 = Core QLM19 0, Q10 = Core QLM19 10, Single = single-entity samples, Bulk = bulk samples, C. mas = Cornus mas, S = seed, C = chaff, NS = nutshell. Depth is the average depth in cm for the sample.

Code	**Core**	**Sample no.**	**Single or bulk**	**Plant**	PART	**$\delta^{13}C$**	**Date**			**Depth (cm)**
OxA-44385	T0	0.1	Single	*Rubus*	S	-26.34	5615	±	26	129.5
OxA-44386	T0	0.4	Single	*Rubus*	S	-26.66	5635	±	22	105
2019-0.5	T0	0.5	Bulk	*Triticum*	C		5599	±	57	90
2019-0.9	T0	0.9	Bulk	*Triticum*	C		5512	±	61	26.5
OxA-43477	T0	0.9	Single	*C. mas*	S	-25.53	5593	±	22	26.5
2019-70.1	T70	70.1	Bulk	*Triticum*	C		5551	±	23	131
2019-70.13	T70	70.13	Bulk	*Triticum*	C		5517	±	44	51
OxA-43474	T70	70.17	Single	*Quercus*	NS	-26.46	3447	±	20	28
OxA-44387	T70	70.19	Single	*Rubus*	S	-28.57	5579	±	23	16.5
OxA-44347	Q0	0.2.3	Single	*Juniperus*	S	-25.19	6841	±	25	201.5
OxA-44315	Q0	0.2.4	Single	*Corylus*	NS	-24.23	5756	±	19	197
OxA-43491	Q0	0.2.5	Single	*Rosa*	S	-24.22	6858	±	22	191.5
OxA-43447	Q0	0.2.10	Single	*Rosa*	S	-24.36	6872	±	22	169.25
OxA-44316	Q0	0.2.12	Single	*Juniperus*	S	-22.7	6878	±	21	163.5
2019-0.1.1	Q0	0.1.1	Bulk	*Triticum*	C		5670	±	25	146.75
OxA-44317	Q0	0.1.4	Single	*Rubus*	S	-25.98	5667	±	21	127
OxA-44329	Q0	0.1.7	Single	*Rubus*	S	-25.69	5630	±	21	114
OxA-44330	Q0	0.1.10	Single	*Rubus*	S	-26.96	5617	±	21	100.25

OxA-44331	Q0	0.1.13	Single	*Rubus*	S	-25.83	5604	±	22	81.5
OxA-44332	Q0	0.1.17	Single	*Rubus*	S	-27.04	5597	±	22	61.5
OxA-44333	Q0	0.0.3	Single	*Rubus*	S	-23.79	5636	±	22	49.5
2019-0.0.6	Q0	0.0.6	Bulk	*Triticum*	C		5608	±	51	34
OxA-44383	Q0	0.0.8	Single	*Rubus*	S	-28.21	5690	±	24	22.5
OxA-43476	Q0	0.0.10	Single	*Rosa*	S	-30.05	5623	±	22	11
OxA-44384	Q10	10.1.1	Single	*Rubus*	S	-27.43	5775	±	24	163.75
2019-10.1.3	Q10	10.1.3	Bulk	*Triticum*	C		5594	±	60	152
2019-10.0.8	Q10	10.0.8	Bulk	*Triticum*	S		5536	±	60	30.5
OxA-43475	Q10	10.0.12	Single	*Quercus*	NS	-27.33	5621	±	23	4.25

The radiocarbon dates from each core were modelled using a p-sequence age-depth model in OxCal 4.4 (Bronk Ramsey, 2008), for which the sediment deposition is modelled as a Poisson (random) process. The General t-type Outlier Model downweighed dates which did not fit the overall model. All dates were given a 5% chance of being an outlier (Bronk Ramsey, 2009b), with the exception of one Late Neolithic date (OxA-44387-70.19) in a phase which was interpreted as later Bronze Age (Table S6, Figure S7) which was set as an outlier prior to modelling. In addition, one date (OxA-43491-0.2.5) was detected as an outlier (having a Late Neolithic age in a Middle Neolithic sequence) and so was downweighed in the model (Table S2; Figure S3). With the exception of these two dates, no other dates were assigned a probability of higher than 7% of being an outlier (Figures 2-7), showing high levels of agreement between the dates in the models.

Table S2: OxCal output for the Middle Neolithic samples from Core QLM19 0. Date OxA-44315-0.2.4 was assigned an 100% probability of being an outlier by the General t-type Outlier Model.

Name	**Unmodelled (BC/AD)**		**Modelled (BC/AD)**		**Indices,** Amodel 48, Aoverall 44.7.
	from_95_4	to_95_4	from_95_4	to_95_4	C
P_Sequence Ploca qlm19 MN	-2	2	-0.941724	2.00228	99.1
U(0,4)	3.99E-17	4	1.924	3.04	10.8
T(5)	-2.65	2.65			6.6
Outlier_Model General			1034	1246	91.4
Boundary			-5755	-5714	99.9
R_Date OxA-44316-0.2.12	-5831	-5717	-5755	-5714	99.9
R_Date OxA-43447-0.2.10	-5831	-5712	-5759	-5717	99.7
R_Date OxA-43491-0.2.5	-5797	-5668	-5778	-5721	99.2
R_Date OxA-44315-0.2.4	-4683	-4542	-5784	-5722	99.4
R_Date OxA-44347-0.2.3	-5785	-5661	-5790	-5722	99.6
Boundary			-5790	-5722	99.6

Table S3: OxCal output of Late Neolithic samples from QLM19 0.

Name	**Unmodelled (BC/AD)**		**Modelled (BC/AD)**		**Indices** Amodel 72.6 **Aoverall 80.1**
	from_95_4	to_95_4	from_95_4	to_95_4	C
Outlier_Model General		-107	97		99.8
T(5)	-2.65	2.65			97.3
U(0,4)	3.99E-17	4	5.38E-17	3.948	99.3
P_Sequence Ploca QLM19 0	-2	2	-1.14089	1.97511	96.7
Boundary			-4511	-4451	99.7
R_Date OxA-47476-0.0.10	-4533	-4363	-4491	-4441	98.8
R_Date OxA-44383-0.0.8	-4602	-4453	-4491	-4443	99.1
R_Date 2019-0.0.6	-4539	-4351	-4491	-4443	99.2
R_Date OxA-44333-0.0.3	-4538	-4369	-4491	-4445	99.3
R_Date OxA-44332-0.1.17	-4488	-4358	-4494	-4446	99.4
R_Date OxA-44331-0.1.13	-4492	-4359	-4495	-4447	99.7
R_Date OxA-44330-0.1.10	-4499	-4362	-4496	-4447	99.7
R_Date OxA-44329-0.1.7	-4537	-4366	-4499	-4450	99.8

R_Date OxA-44317-0.1.4	-4545	-4449	-4504	-4450	99.7
R_Date 2019-0.1.1	-4584	-4408	-4511	-4451	99.7
Boundary			-4491	-4441	98.8

Table S4: OxCal output of Late Neolithic samples from QLM19 10.

Name	**Unmodelled (BC/AD)**		**Modelled (BC/AD)**		**Indices** Amodel 40.6 **Aoverall 47.9**
	from_95_4	to_95_4	from_95_4	to_95_4	C
P_Sequence QLM19 10	-2	2	-1.70896	1.96704	98.4
U(0,4)	3.99E-17	4	5.38E-17	4	99.4
T(5)	-2.65	2.65			89.2
Outlier_Model General			-202	252	98.6
Boundary End cultural layer			-4486	-4357	99.8
R_Date OxA-43475-10.0.12	-4532	-4362	-4486	-4357	99.8
R_Date 2019-10.0.8	-4499	-4256	-4496	-4382	99.8
R_Date 2019-10.1.3	-4546	-4337	-4676	-4485	99.7
R_Date OxA-44384-10.1.1	-4702	-4547	-4697	-4500	99.4
Boundary Start cultural layer			-4697	-4500	99.4

Table S5: OxCal output of Late Neolithic samples from TLM19 0.

Name	**Unmodelled (BC/AD)**		**Modelled (BC/AD)**		**Indices** Amodel 107.3 **Aoverall 109.5**
	from_95_4	to_95_4	from_95_4	to_95_4	C
P_Sequence Ploca TLM19 0	-2	2	-1.51172	2.00428	92.4
U(0,4)	3.99E-17	4	5.38E-17	4	98.3
T(5)	-2.65	2.65			78.9
Outlier_Model General			-86	92	98.2
Boundary			-4451	-4356	98.8
R_Combine 2019-0.9/OxA-43477-0.9	-4453	-4356	-4451	-4356	98.8
R_Date 2019-0.5	-4543	-4343	-4483	-4381	99.3
R_Date OxA-44386-0.4	-4538	-4369	-4496	-4374	99.4

R_Date OxA-44385-0.1	-4531	-4358	-4529	-4376	96.7
Boundary			-4529	-4376	96.7

Table S6: OxCal output of Late Neolithic and the later Bronze Age samples from TLM19 70. Sample OxA-44387-70.19 was manually assigned an outlier based on prior information about the deposit, which suggested it dated to the later Bronze Age.

Name	**Unmodelled (BC/AD)**		**Modelled (BC/AD)**		**Indices Amodel 102.8 Aoverall 102.6**
	from_95_4	to_95_4	from_95_4	to_95_4	C
P_Sequence Ploca TLM19 70	-2	2	-1.32573	1.95027	92.4
U(0,4)	3.99E-17	4	5.38E-17	4	98.3
T(5)	-2.65	2.65			78.9
Outlier_Model General			-257	172	98.2
Boundary			-1793	-1254	98.8
R_Date OxA-44387-70.19	-4451	-4355	-4451	-4355	98.8
R_Date OxA-43474-70.17	-1876	-1688	-1878	-1688	99.3
Boundary			-1878	-1688	99.4
Boundary			-4436	-4257	96.7
R_Date 2019-70.13	-4451	-4261	-4436	-4257	96.7
R_Date 2019-70.1	-4446	-4347	-4448	-4351	98.8
Boundary			-4448	-4351	98.8

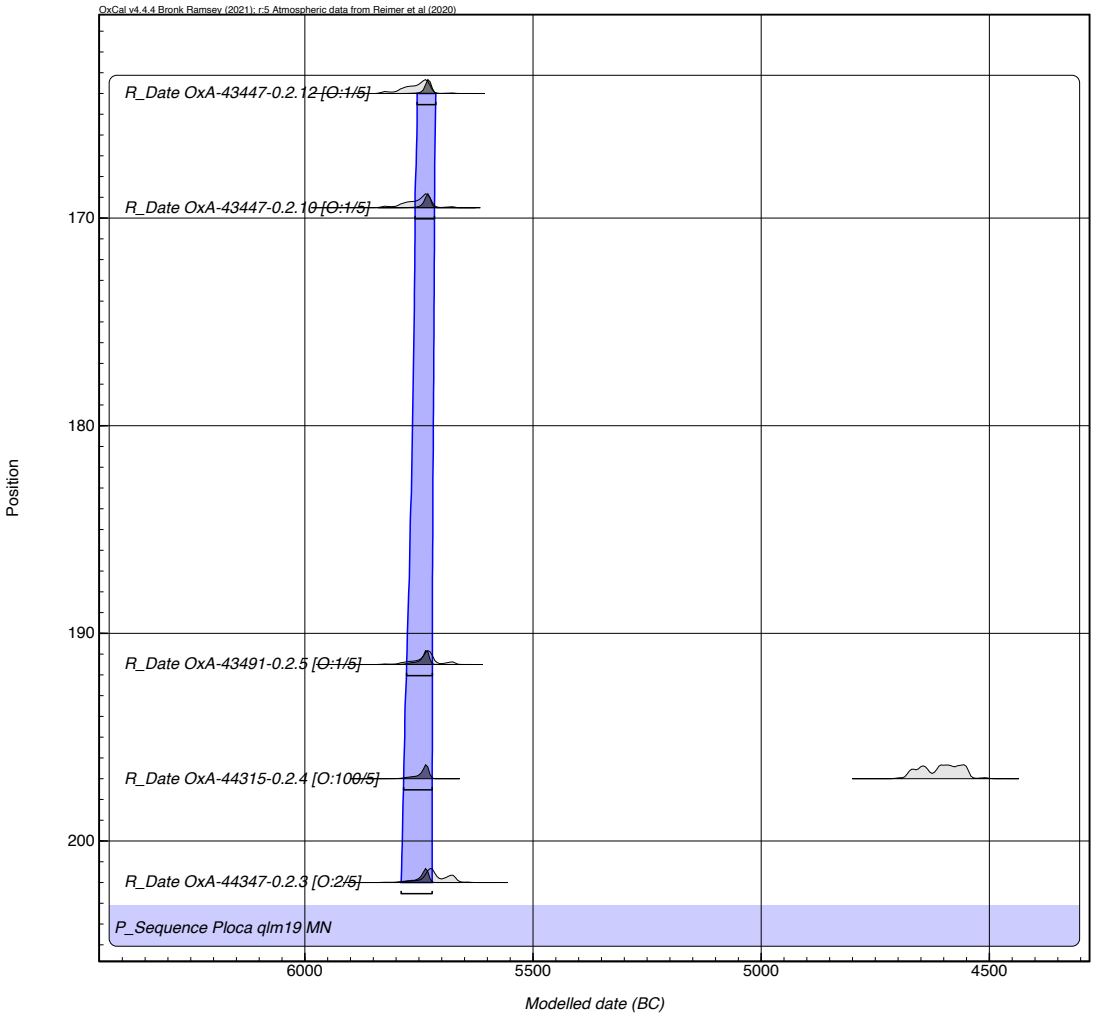


Figure S4: The p-sequence age-depth model results output for the Middle Neolithic phase in core QLM19 0. Date OxA-44315-0.2.4 was assigned a 100% probability of being an outlier by the General t-type Outlier Model, having a Late Neolithic age in a Middle Neolithic sequence. The probability of each date being an outlier is given in brackets after the sample name in the format "O (outlier): percentage probability after modelling/percentage probability assigned prior to analysis". The percentage probability assigned prior to analysis was set at 5%. Other than Date OxA-44315-0.2.4, no date was given a likelihood of being an outlier greater than 2%.

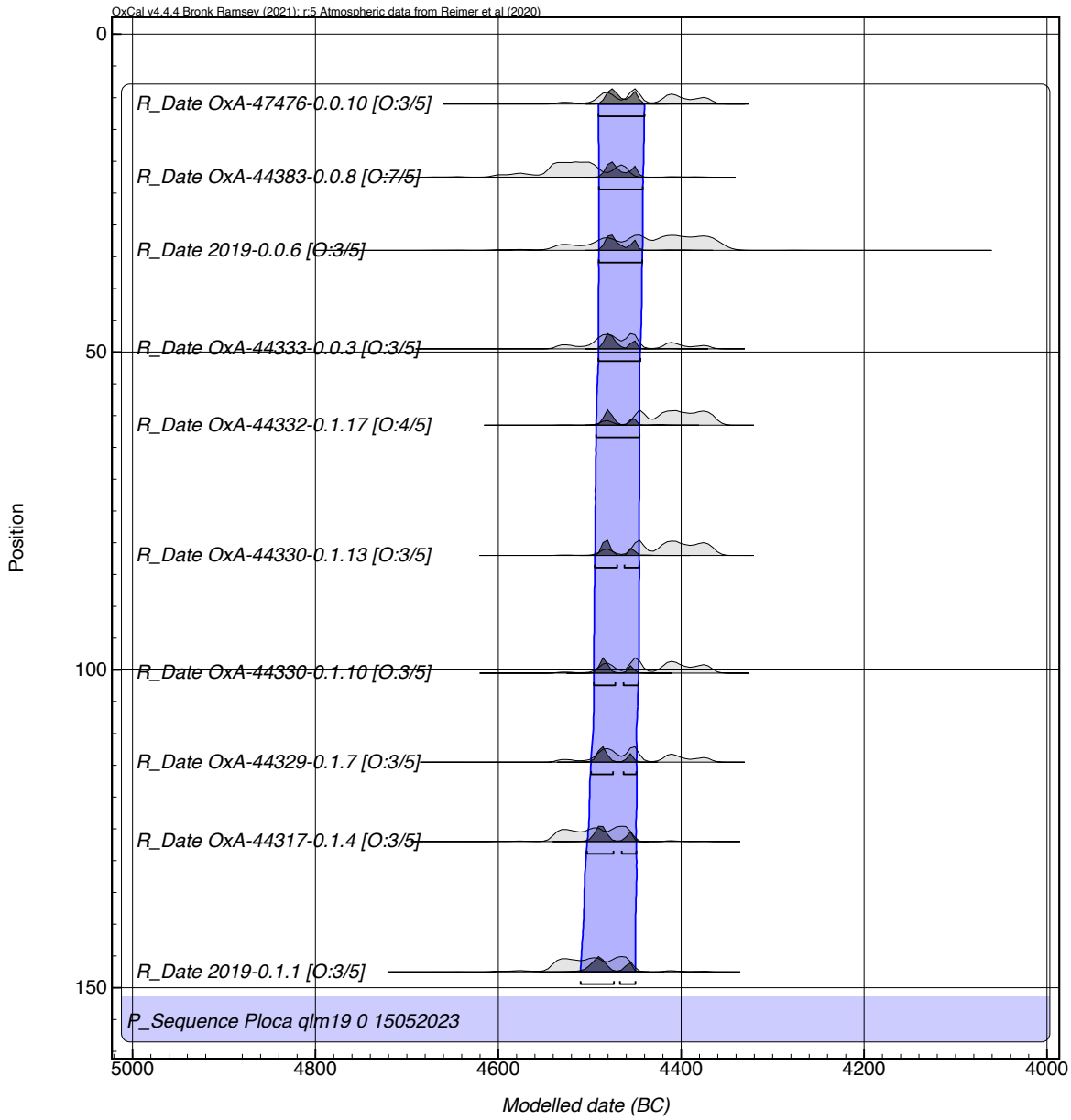


Figure S5: The p-sequence age-depth model results output for the Late Neolithic dates in core QLM19 0. The p-sequence age-depth model results output for the Late Neolithic dates in core QLM19 0. The probability of each date being an outlier is given in brackets after the sample name in the format "O (outlier): percentage probability after modelling/percentage probability assigned prior to analysis". The percentage probability assigned prior to analysis was set at 5%. No date was given an outlier likelihood of greater than 4%.

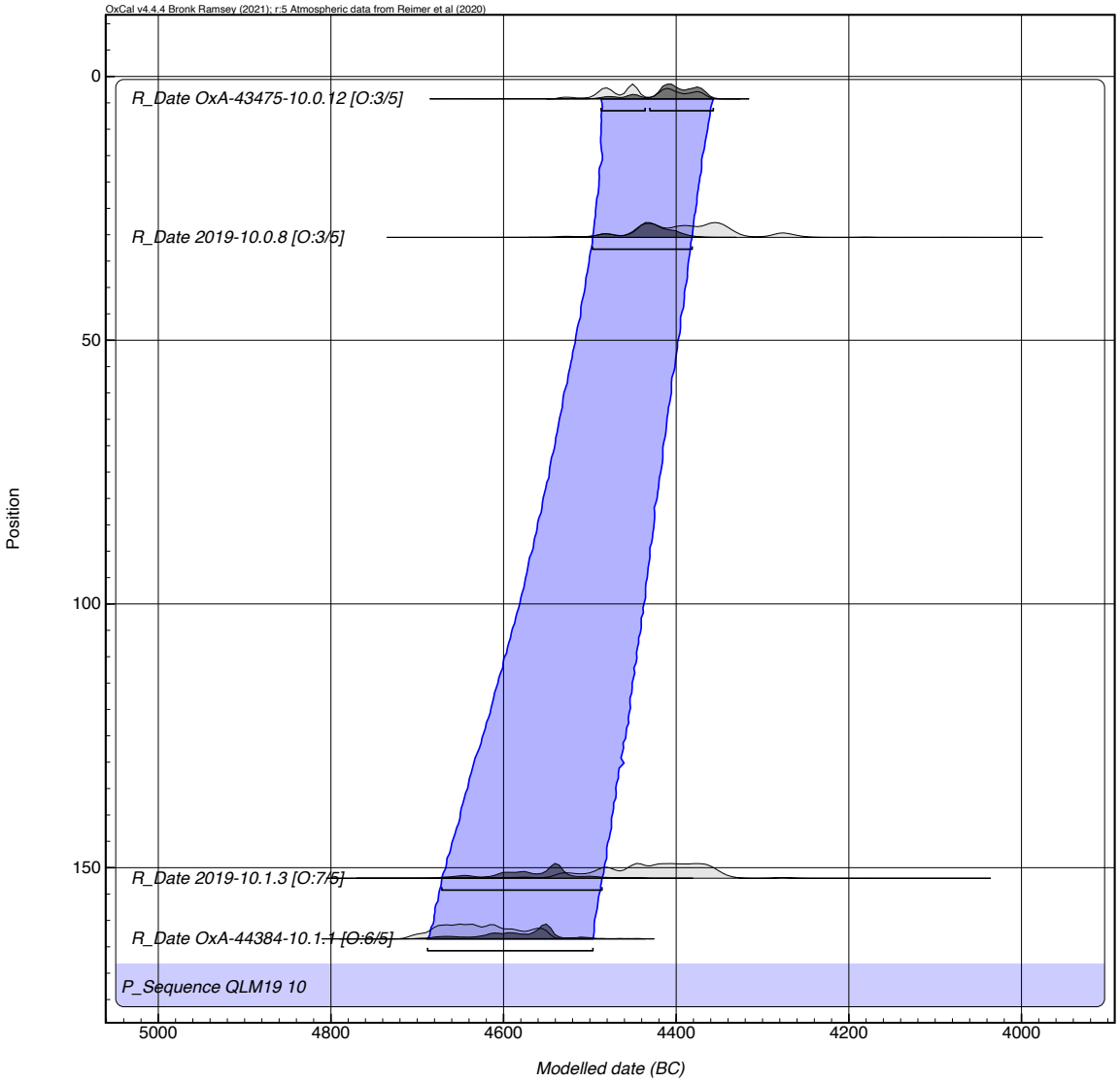


Figure S6: The p-sequence age-depth model results output for the Late Neolithic dates in core QLM19 10. The probability of each date being an outlier is given in brackets after the sample name in the format "O (outlier): percentage probability after modelling/percentage probability assigned prior to analysis". The percentage probability assigned prior to analysis was set at 5%. The largest outlier probability was 7%.

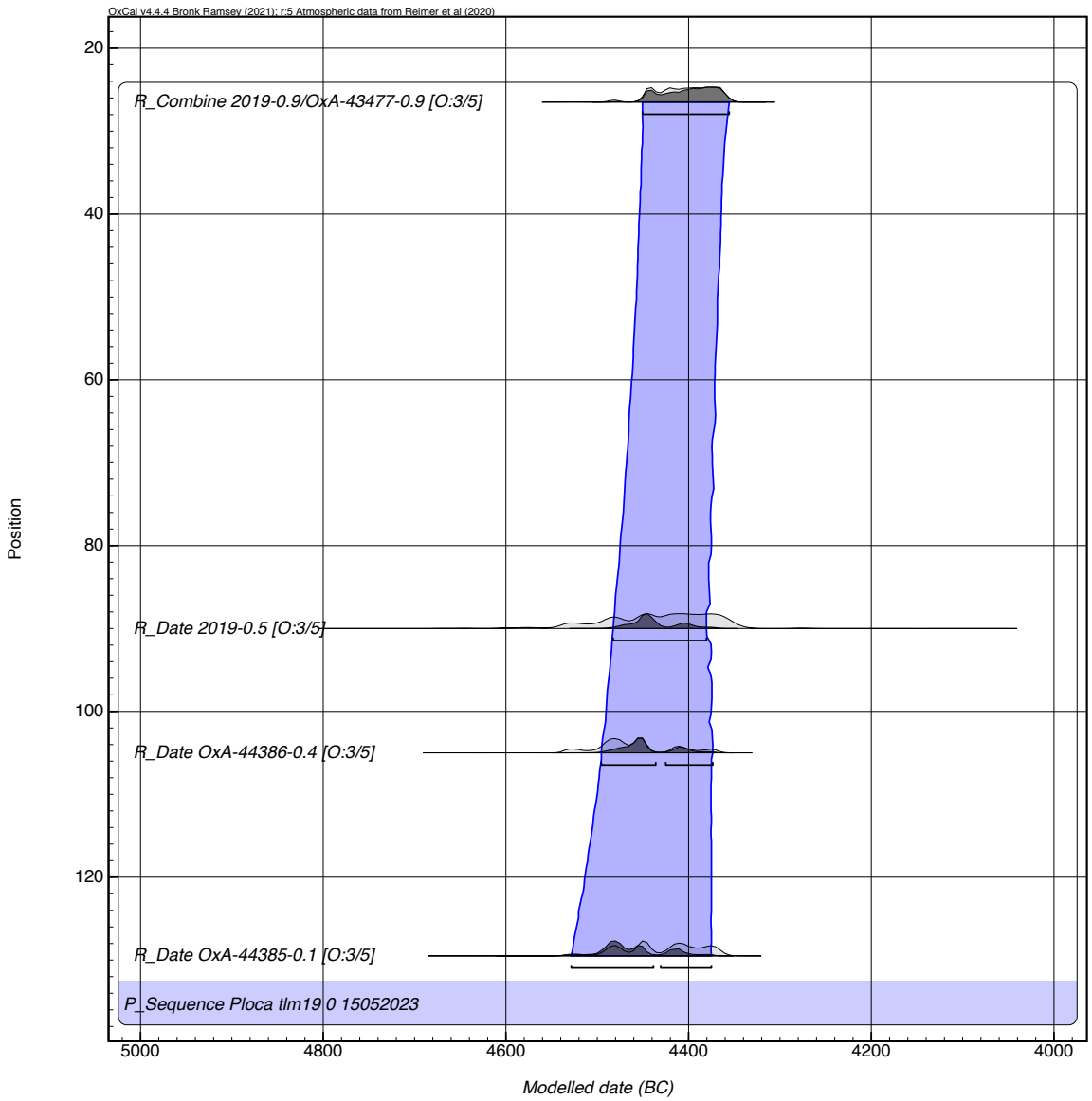


Figure S7: The p-sequence age-depth model results output for the Late Neolithic dates in core TLM19 0. The probability of each date being an outlier is given in brackets after the sample name in the format "O (outlier): percentage probability after modelling/percentage probability assigned prior to analysis". The percentage probability assigned prior to analysis was set at 5%. All dates had a 3% probability of being an outlier.

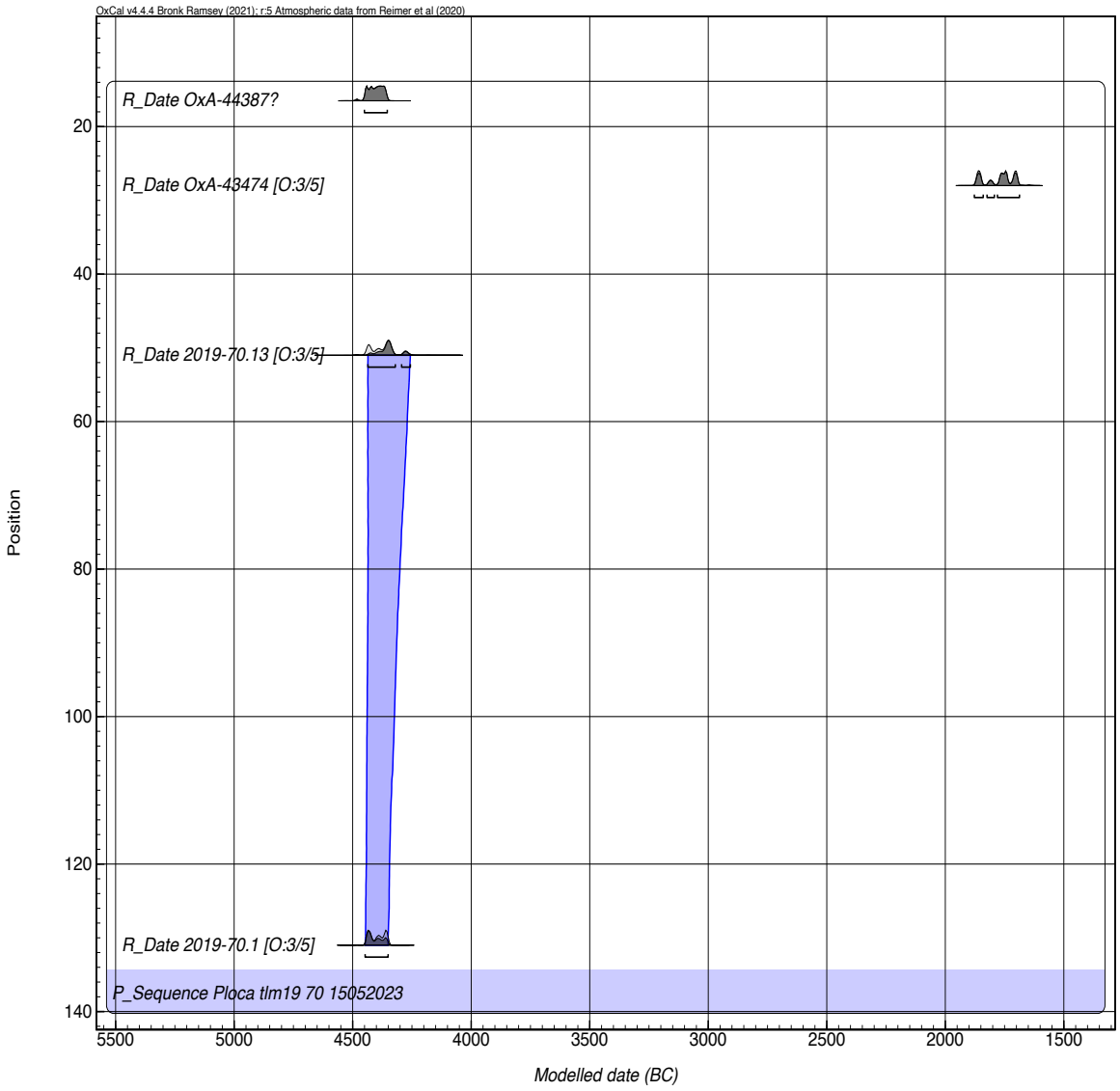


Figure S8: The p-sequence age-depth model results output for the Late Neolithic and later Bronze Age dates in core TLM19 70. Date OxA-44387-70.19 was set as an outlier prior to analysis based on the later Bronze Age character of the archaeobotanical material and Date OxA-43474-70.17. It is likely that Date OxA-44387-70.19 is contamination. The probability of each date being an outlier is given in brackets after the sample name in the format "O (outlier): percentage probability after modelling/percentage probability assigned prior to analysis". The percentage probability assigned prior to analysis was set at 5%. The three dates kept in the model had a 3% probability of being an outlier.

i. Correspondence analysis

Preliminary correspondence analyses were run with slightly different datasets to explore compositional variation among samples. In total, five different analyses were run. The final (fifth) analysis is discussed in the main text. Four preliminary analyses are presented here.

The first analysis included all 65 taxa and 95 samples (Middle Neolithic, Late Neolithic and later Bronze Age). The Middle Neolithic samples and two samples from the bottom of TLM19 0 (0.1 and 0.2) were strongly separated from the Late Neolithic and later Bronze Age samples (Figure 9). This was due to high numbers of freshwater algae (*Chara* spp.) and fir needles (*Abies* sp.). These taxa dominated the Middle Neolithic samples and samples TLM19 0.1 and 0.2. As such, in the second analysis the Middle Neolithic samples were removed. It was apparent that the *Chara* spp. (both with and without calcium carbonate deposits) still overshadowed the contributions of other taxa and so was removed for the third analysis. Without *Chara*, samples TLM19 0.1 and 0.2 had very few macrofossils and so were also removed prior to the third analysis.

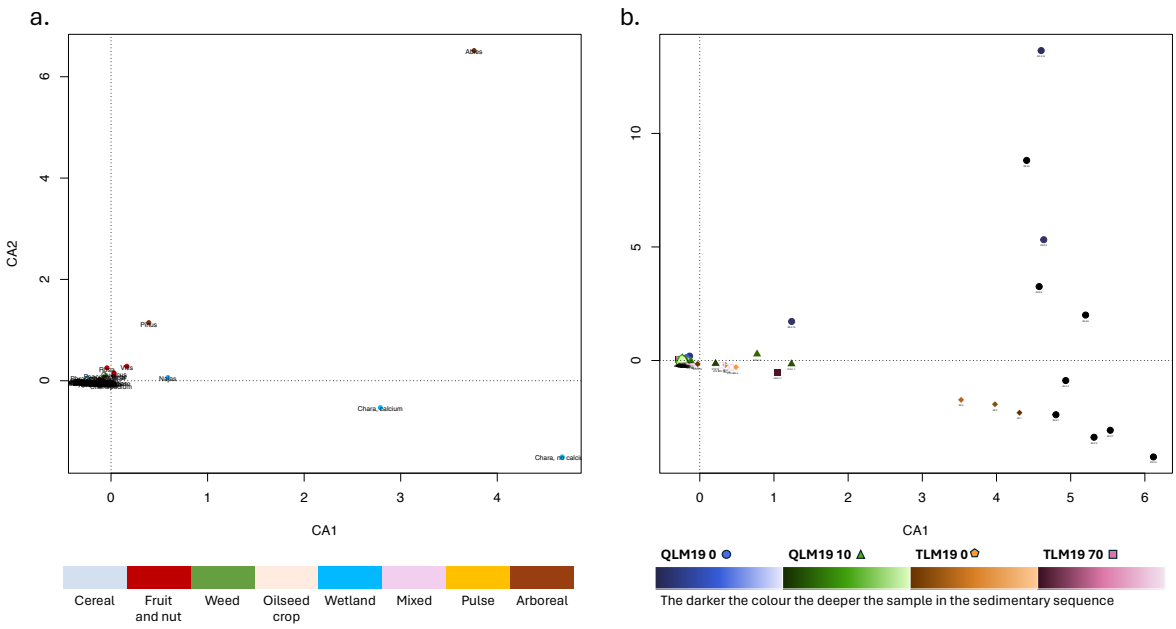


Figure S9: The first correspondence analysis included all samples and all taxa. In plot a., Chara (both with and without calcium carbonate casing) and Abies fir needles are clearly separated (towards the right, positive end of the x-axis) from the other taxa. In plot b, all of the Middle Neolithic samples (dark blue circles) and the three lowermost samples from TLM19 0 (dark orange diamonds) are separated from the other samples (towards the right, positive end of the x-axis) from the other samples.

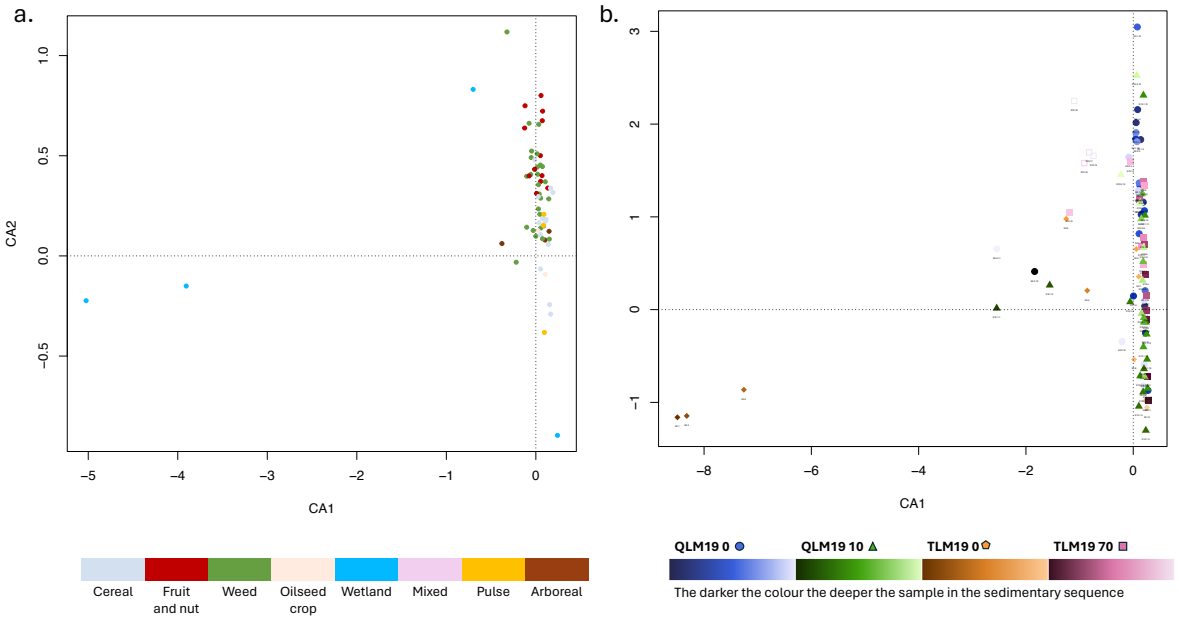


Figure S10: The second correspondence analysis included all Late Neolithic and later Bronze Age samples (excluding Middle Neolithic) and all taxa. In plot a., Chara (both with and without calcium carbonate casing) is clearly separated (towards the left, negative end of the x-axis) from the other taxa. In plot b, all the three lowermost samples from TLM19 0 (dark orange diamonds) are separated from the other samples (towards the left, negative end of the x-axis) from the other samples.

The third analysis (without Middle Neolithic samples, without TLM19 0.1 and 0.2 and without *Chara*) started to show separation between different samples dating to the Late Neolithic. The later Bronze Age samples were slightly separated from the Late Neolithic samples (towards the bottom left corner of the plot at the negative end of both the x-axis and the y-axis, Figure 11 b) as were taxa such as *Chenopodium, Papaver* and *Najas* in the plot of taxa (Figure 11 a).

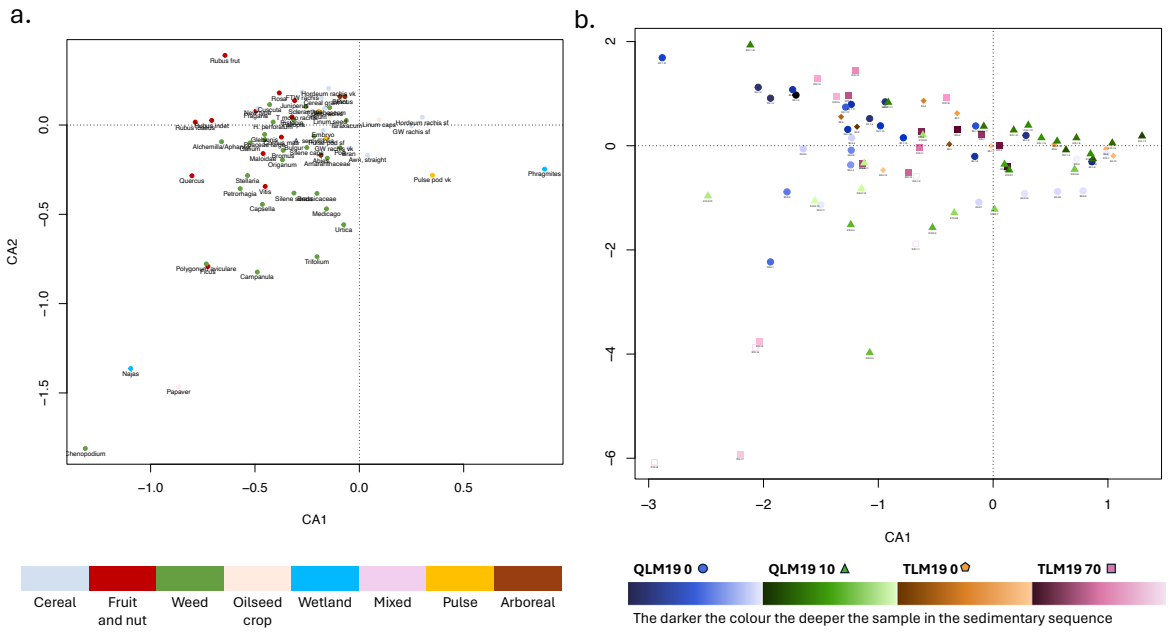


Figure S11: The third correspondence analysis included all Late Neolithic and later Bronze Age samples (excluding Middle Neolithic and TLM19 0.1 and 0.2) and all taxa (except Chara). In plot a., some taxa (e.g. Chenopodium, Papaver, Najas and Phragmites) are separated from the other taxa. In plot b, all the four later Bronze Age samples (pale pink/white squares with a pink outline) are separated from the other samples (towards the bottom left, negative end of both the x-axis and the y-axis).

In the fourth analysis (without Middle Neolithic or later Bronze Age samples, without TLM19 0.1 and 0.2 and without *Chara*) one sample (QLM19 0.1.7) was strongly separated from the other samples (positioned towards the bottom centre of the plot). This was due to large proportion of uncharred pulse pod in this sample. Without this sample, the samples and taxa were distributed across the plot, enabling the identification of trends. This plot is discussed in the main text.

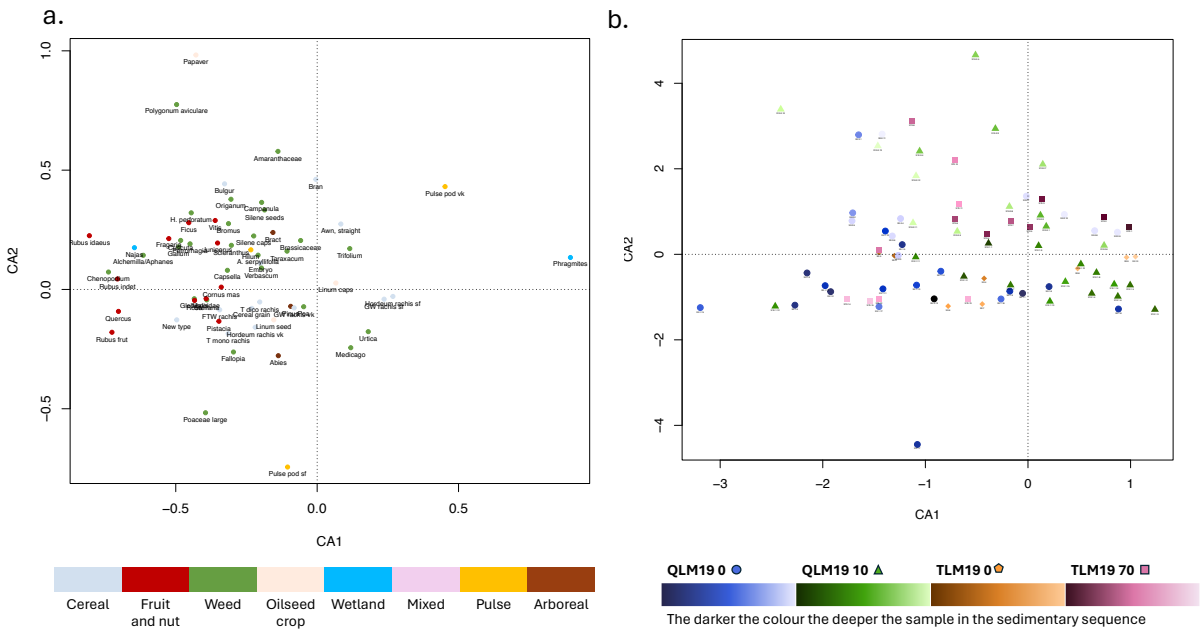


Figure S12: The fourth correspondence analysis included all Late Neolithic (excluding Middle Neolithic and later Bronze Age samples and TLM19 0.1 and 0.2) and all taxa (except Chara). In plot a., some taxa (e.g. Papaver, uncharred pulse pod and Phragmites) are separated from the other taxa. In plot b, one sample (QLM19 0.1.7, dark blue circle) is separated from the other samples (towards the bottom of the plot, negative end of the y-axis).

Table S7: Taxa included in the correspondence analyses. The codes of taxa groups included in the correspondence analyses are listed in the first column. Column 2 lists the botanical categories used to classify the taxa in the plots. Column 3 lists the preservation state of the taxa ("Unch." = uncharred and singed/'patchily' charred material; "Char." = partially charred/'browned' and fully charred material). Column 4 "No" gives number of samples that contain each taxon. Column 5 "Max" gives the maximum number of specimens of each taxon in one sample, while column 6 "Min" gives the minimum, and column 7 "Ave" gives the average. The final column provides details of the taxa included in each taxa group.

Code	Bot. cat.	Pres.	No	Max	Min	Aver	Notes
A. serpyllifolia	Weed	Unch.	77	239	0	13	*Arenaria serpyllifolia* seeds
Abies	Arboreal	Unch.	67	366	0	13	*Abies* sp. needles
Alchemilla/ Aphanes	Weed	Unch.	36	23	0	2	*Alchemilla/Aphanes* seeds
Amaranthaceae	Weed	Unch.	62	256	0	15	Amaranthaceae seeds
Awn, straight	Cereal	Char.	71	452	0	18	Cereal awn, straight
Bract	Arboreal	Unch.	32	35	0	3	Arboreal bract/cupule type
Bran	Cereal	Unch.	73	948	0	81	Cereal bran fragments with hila
Brassicaceae	Weed	Unch.	47	30	0	3	Brassicaceae seeds
Bromus	Weed	Unch.	47	33	0	3	*Bromus* spp. bran
Bulgur	Cereal	Char.	31	15	0	2	Cereal fragments with pre-charring break
Campanula	Weed	Unch.	52	60	0	5	*Campanula* spp. seeds
Capsella	Weed	Unch.	48	15	0	2	*Capsella bursa-pastoris* seeds
Cereal grain	Cereal	Char.	40	19	0	2	Cereal grain fragments
Chara, calcium	Wetland	Unch.	85	912	0	65	*Chara* with calcium carbonate deposit
Chara, no calcium	Wetland	Unch.	31	663	0	30	*Chara* without calcium carbonate deposit
Chenopodium	Weed	Unch.	56	61	0	6	*Chenopodium* sp. seeds
Cornus mas	Fruit/nut	Unch.	63	23	0	3	*Cornus mas* seeds
Cuscuta	Weed	Unch.	66	49	0	6	*Cuscuta* sp. seeds
Embryo	Cereal	Char.	38	33	0	3	Cereal grain embryo
Fallopia	Weed	Unch.	78	35	0	5	*Fallopia convolvulus* seeds
Ficus	Fruit/nut	Unch.	80	56	0	9	*Ficus carica* seeds
Fragaria	Fruit/nut	Unch.	87	295	0	32	*Fragaria vesca* seeds
FTW rachis	Cereal	Char.	23	22	0	2	Free-threshing wheat rachis
Galium	Weed	Unch.	51	38	0	3	*Galium* spp. seeds
Glebionis	Weed	Unch.	58	22	0	3	*Glebionis segetum* seeds
GW rachis sf	Cereal	Unch.	89	17937	0	1073	Glume wheat (unidentified) rachis
GW rachis vk	Cereal	Char.	82	263	0	31	Glume wheat (unidentified) rachis
H. perforatum	Weed	Unch.	81	108	0	11	*Hypericum perforatum* seeds
Hilum	Pulse	Char.	53	45	0	5	Pulse seed hilum

Hordeum rachis sf	Cereal	Unch.	79	442	0	36	*Hordeum vulgare/distichon* rachis
Hordeum rachis vk	Cereal	Char.	75	80	0	9	*Hordeum vulgare/distichon* rachis
Juniperus	Fruit/nut	Unch.	40	36	0	2	*Juniperus* cf. *oxycedrus* seeds
Linum caps	Oilseed	Unch.	86	490	0	32	*Linum usitatissimum* capsule fragment
Linum seed	Oilseed	Unch.	81	76	0	8	*Linum usitatissimum* seed
Maloideae	Fruit/nut	Unch.	65	21	0	3	Maloideae seed
Medicago	Weed	Unch.	35	31	0	2	*Medicago* sp. pod
Najas	Wetland	Unch.	66	19	0	3	*Najas* sp. seed
New type	Cereal	Char.	36	37	0	3	*Triticum timopheevii* glume base
Origanum	Weed	Unch.	35	18	0	2	*Origanum vulgare* seed
Papaver	Oilseed	Unch.	82	177	0	26	*Papaver somniferum* seed
Petrorhagia	Weed	Unch.	50	30	0	3	*Petrorhagia* spp. seed
Phragmites	Wetland	Char.	14	168	0	3	*Phragmites communis* culm
Pinus	Arboreal	Unch.	47	90	0	4	*Pinus* sp. needle
Pistacia	Fruit/nut	Unch.	80	9	0	2	*Pistacia terebinthus* estimate whole nuts
Poa	Weed	Unch.	28	22	0	2	*Poa* spp. seed
Poaceae large	Weed	Unch.	29	22	0	2	Poaceae unidentified >2mm seed
Polygonum aviculare	Weed	Unch.	41	13	0	2	*Polygonum aviculare* seed
Pulse pod sf	Pulse	Unch.	77	130	0	10	Pulse pod fragments
Pulse pod vk	Pulse	Char.	28	67	0	3	Pulse pod fragments
Quercus	Fruit/nut	Unch.	69	28	0	3	*Quercus* sp. nutshell estimate whole nuts
Rosa	Fruit/nut	Unch.	66	34	0	4	*Rosa* spp. seeds
Rubus frut	Fruit/nut	Unch.	93	1988	0	230	*Rubus fruticosus* agg. seeds
Rubus idaeus	Fruit/nut	Unch.	56	19	0	3	*Rubus idaeus* seeds
Rubus indet	Fruit/nut	Unch.	42	23	0	3	*Rubus* unidentified seeds
Scleranthus	Weed	Unch.	40	45	0	3	*Scleranthus annuus* exocarp
Silene caps	Weed	Unch.	62	30	0	5	*Silene* sp. capsule

Silene seeds	Weed	Unch.	65	30	0	4	*Silene* spp. seeds
Stellaria	Weed	Unch.	59	24	0	3	*Stellaria* sp. seeds
T dico rachis	Cereal	Char.	83	146	0	15	*Triticum dicoccum* rachis
T mono rachis	Cereal	Char.	85	264	0	18	*Triticum monococcum* rachis
Taraxacum	Weed	Unch.	54	28	0	3	*Taraxacum* sp. seeds
Trifolium	Weed	Unch.	51	31	0	3	*Trifolium* sp. exocarp
Urtica	Weed	Unch.	29	45	0	2	*Urtica dioica* seed
Verbascum	Weed	Unch.	61	60	0	5	*Verbascum* spp. seed
Vitis	Fruit/nut	Char.	70	19	0	2	*Vitis vinifera seeds*

2.0 IN THE LAKE AND ON THE SHORE: THE INTERPLAY OF LATE NEOLITHIC FOOD SYSTEMS AND LOCAL VEGETATION DYNAMICS AT PLOČA MIČOV GRAD, LAKE OHRID

Holguin, A. [1]; van Vugt, L. [2,3]; Charles, M. [1]; Brechbühl, S. [2,3]; Gobet, E. [2,3]; Stroud, E. [1]; Hafner, A. [3,4]; Tinner, W. [2,3] and A. Bogaard[1]

[1]School of Archaeology, University of Oxford, Oxford, OX1 2PG, UK.

[2]Oeschger Centre for Climate Change Research, University of Bern, Hochschulstrasse 4, 3012, Bern, Switzerland

[3]Institute of Plant Sciences, University of Bern, Altenbergrain 21, 3013, Bern, Switzerland

[4]Institute of Archaeological Sciences, University of Bern, Mittelstrasse 43, 3012, Bern, Switzerland

2.1 ABSTRACT

Synergies between palaeoecological and archaeobotanical analyses of sediment cores from Ploča Mičov Grad, Lake Ohrid (North Macedonia) provide complementary perspectives on the Late Neolithic (c. 4697-4500 to 4436-4257 cal BCE) pile-dwelling settlement and local vegetation dynamics within the sheltered Bay of Bones. Through a synthesis of near-site and on-site evidence, we consider the impact of foraging and arable agriculture on local vegetation

during the mid-5th millennium BCE settlement phase, against the background of the longer term palynological record. Archaeobotanical data from the lakeshore settlement's cultural sequence shows that the Late Neolithic plant food system incorporated a broad-spectrum of crops and collected fruits and nuts, many of which are reflected in the palynological record. An increase of Rosaceae pollen taxa during the settlement phase coincides with an abundance of collected Rosaceae macrofossils (including almond, apple and blackberry) in the archaeobotanical assemblage recovered from the cultural layer. This association suggests that systematic foraging encouraged the growth of these rosaceous taxa, possibly through protection and management of woodland edge vegetation. Ecological analysis of the arable weed flora associated with archaeobotanical crop remains suggests that cultivation during the mid-5th millennium BCE was small-scale and intensive. Arable plots were likely positioned within several hundred metres of the settlement, given the abundance of cereal pollen and associated disturbance-loving taxa in the pollen record. The impact of the settlement on local woodland likely involved small-scale land-clearance for arable farming as well as collection of wood for timber and fuel. This integration of archaeobotanical and palynological analysis offers independent lines of evidence for the nature and scale of land use by the Late Neolithic community over a period of around a century.

2.2 KEYWORDS

Archaeobotany; Palynology; Wetlands; Biodiversity; Vegetational change; Multi-proxy

2.3 INTRODUCTION

The synthesis of near-site palaeoecological and on-site archaeobotanical datasets from the sheltered Bay of Bones (Lake Ohrid, North Macedonia) presents a rare opportunity to better

understand Late Neolithic activities and impacts on local vegetation. These complementary approaches enable the reconstruction of land-use practices associated with the lakeshore pile-dwelling site of Ploča Mičov Grad using evidence taken at different resolutions reflecting complementary spatial and temporal scales. Palaeoecological studies offer a broad perspective on vegetation dynamics (Jacobson and Bradshaw, 1981; Sugita, 2007), which can be linked to human activity through the coeval appearance of cultural indicators, such as cereal pollen and microscopic charcoal (Deza-Araujo et al. 2022). While off-site palynological records from large lakes often reflect regional trends, here, the palaeoecological sediment cores were extracted in close proximity (10-30 m) of the pile field at Ploča Mičov Grad, reflecting vegetation dynamics and human activity within approximately 3-5 km of the site. The palaeoecological record spans approximately eight millennia from c. 11,000 to 3,000 cal BCE (Brechbühl et al. 2023). Archaeobotanical assemblages from waterlogged wetland sites are known to preserve a diversity of cultivated and wild plant types that are typically biased towards plant resources used by people, providing evidence for human-plant interactions during prehistory (Behre and Jacomet, 1991). At Ploča Mičov Grad, sediment cores taken from within the pile field documented a Late Neolithic organic layer (up to 1.5 m thick) rich with cereal, pulse and oilseed crop macrofossils, as well as the remains of collected fruits and nuts, reflecting broad plant food systems. This layer rapidly accumulated between c. 4697-4500 to 4436-4257 cal BCE (Paper 1 of this thesis). In this paper we integrate the palaeoecological and archaeobotanical datasets to explore the relationship between Late Neolithic food systems and reconstructed local vegetation dynamics.

Foraging for wild plant foods is an aspect of part of Late Neolithic food systems which could have (directly or indirectly) impacted local vegetation populations. In the southern Balkans,

most plant macrofossils are preserved by charring in dryland archaeobotanical assemblages (Valamoti, 2023), which are known to underrepresent foraged plant foods compared to wetland waterlogged assemblages (Jacomet, 2004; Jacomet, 2012; Colledge and Conolly, 2014). Alongside the cultivation of cereals and pulses, Neolithic food systems of the southern Balkans likely included the collection of wild fruits and nuts such as grapes, terebinth nuts and cornelian cherries (Valamoti, 2023), all of which have been identified archaeobotanically at Ploča Mičov Grad (Paper 1 in this thesis). Large numbers of edible fruits and nuts at archaeological sites can indicate human use of wild plant resources (e.g. Valamoti, 2015; Filipović et al. 2018), such as large stores of collected fruits unusually recovered from a burned house at Late Neolithic Dikili Tash in northern Greece (Valamoti, 2015; Valamoti, 2023). In particular, evidence of the prehistoric collection and processing of grapes has been a focus of archaeobotanical research across Greece. For example, biomarkers for dark grapes and fermentation have been identified in residue analysis of ceramics from Dikili Tash alongside finds of pressed grapes dating to approximately 4300 BCE, suggesting wine production (Garnier and Valamoti, 2016).

With regards to fruits and nuts distinctions between wild and managed are often blurred and domestication processes likely arose from a long history of management (Pagnoux et al. 2021). For example, while morphotypes of domesticated grapes begin to occur in Middle Bronze Age assemblages in Greece, geometric morphometric analyses of archaeological grape pips suggest the domestication processes originated from practices in the Neolithic (Pagnoux et al. 2021). As such, the collection of wild fruits and nuts during the Late Neolithic plausibly involved management practices that impacted local vegetation populations and acted as a precursor for later intensive management and full domestication. The well-preserved

waterlogged archaeobotanical assemblage from Ploča Mičov Grad contains a diverse range of 'wild' edible plants (Paper 1 of this thesis). Together with the palynological dataset (similarly, preserved in anaerobic waterlogged sediments), this presents an ideal opportunity to explore the relationship between land-use - including foraging practices - and local plant populations.

Foraging for local fruits and nuts complemented the cultivation of a wide spectrum of crops during the Neolithic. At Ploča Mičov Grad, abundant remains of the glume wheats, einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*) and Timopheev's wheat (*Triticum timopheevii*) were recovered alongside barley (*Hordeum distichon* and *Hordeum vulgare*) and bread wheat (*Triticum aestivum*). Several pulse crops (bitter vetch, *Vicia ervilia*, lentil, *Lens culinaris*, and pea, *Pisum sativum*) and oilseed crops including flax (*Linum usitatissimum*) and opium poppy (*Papaver somniferum*) were also identified (Paper 1 of this thesis). In other studies, analysis of on-site data, such as weed compositions, stable isotope analysis of crops or functional weed ecology, suggests that Neolithic arable agriculture in southeast Europe was small-scale and labour-intensive (Bogaard and Halstead, 2015; Halstead, 2018; Vaiglova et al. 2020). Sometimes described as 'intensive garden agriculture', such a practice would require high-labour inputs to remove weeds or fertilise with manure (Bogaard, 2004). For example, stable carbon and nitrogen isotopic analysis of cereals (alongside other plants and animals) from the Middle-Late Neolithic tell of Kouphovouno (northern Greece) suggested small-scale intensive agricultural practices (Vaiglova et al. 2014, 2020; 2023). For lakeshore Neolithic settlements in the Alpine Foreland, slash-and-burn has been suggested largely based upon the palynological and microscopic charcoal evidence, but this is contradicted by on-site evidence (Jacomet et al. 2016). Indeed, the intensity of the signals of both cereal pollen and associated disturbance-loving taxa in near-site cores, compared with the absence of these

signals in cores further out in the lake, suggests that arable agriculture at the site of Ploča Mičov Grad was small-scale (Brechbühl et al. 2023).

Functional weed ecology offers a method to infer the scale and intensity of archaeological agrosystems from on-site archaeobotanical datasets (e.g. Jones et al. 2000; Bogaard et al. 2016; Green et al. 2018; Hamerow et al. 2020). It uses the functional traits of arable weeds (such as the leaf size and thickness, and canopy height and diameter) to compare modern weed flora developed under known conditions with ancient crop weed flora. The functional traits reflect the potential of a species to thrive in different arable settings shaped by ecological parameters such as soil fertility and disturbance. This method compares the prevalence of functional traits of plants in modern traditional high- and low-input agrosystems with the archaeological weed assemblage through discriminant analysis (Bogaard et al. 2018; Stroud et al. 2023). Due to taphonomic biases, weed seeds are often not preserved in large numbers in charred assemblages found on terrestrial sites (Gustafsson, 2000; Stroud et al. 2023). Many excavated sites in the southern Balkans are dryland tells and, as such, do not have sufficient charred weed seed assemblages to apply functional weed analysis to model prehistoric agrosystems (for requirements see e.g. Stroud et al. 2023). The well-preserved and abundant weed seeds preserved through anaerobic waterlogging at the site of Ploča Mičov Grad, combined with their anthropogenic 'midden-like' origin, presents the rare opportunity to confirm that they represent arable weed flora and to infer the intensity and scale of Late Neolithic cultivation in an upland setting in the southern Balkans, in conjunction with palynological data.

2.4 MATERIALS AND METHODS

2.4.1 THE SITE OF PLOČA MIČOV GRAD

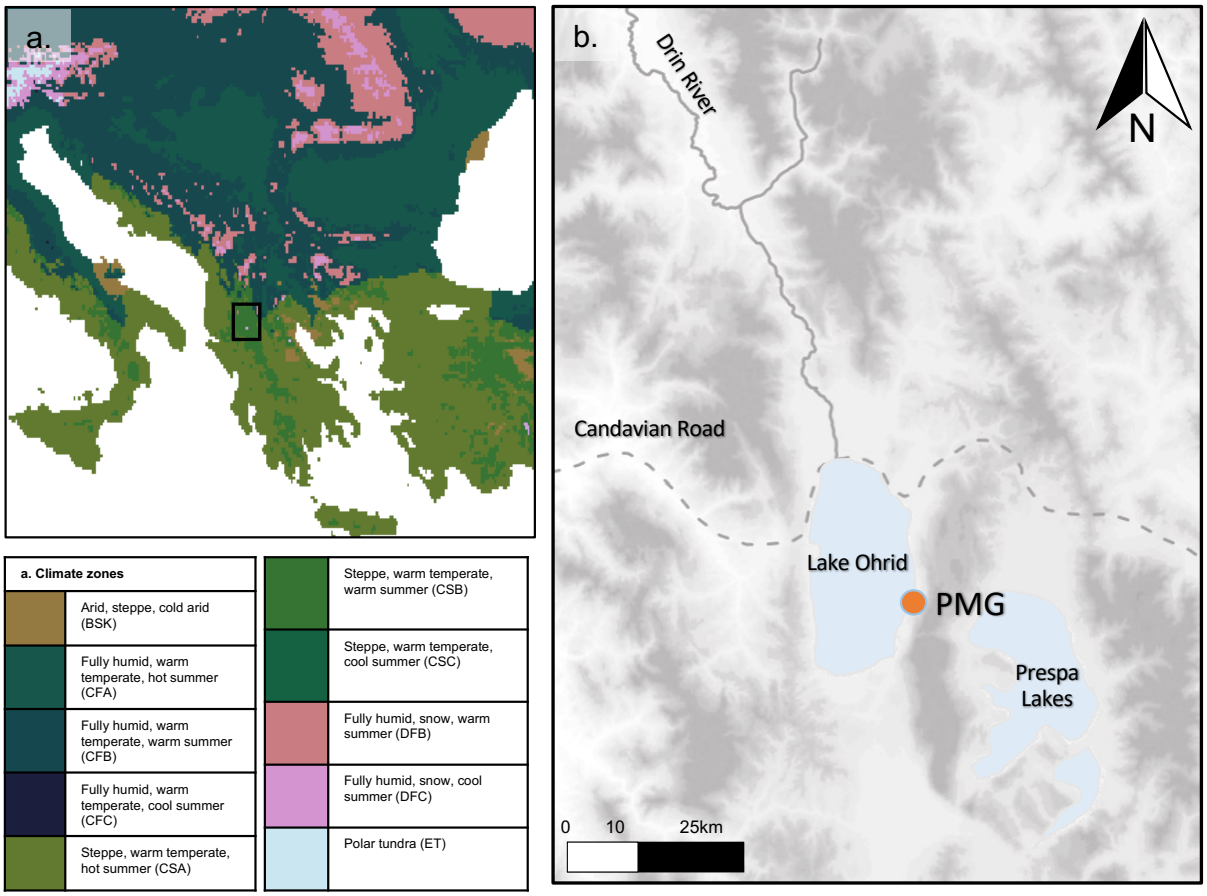
The submerged prehistoric site of Ploča Mičov Grad (Плоча Миќов Град, 40.994°N, 20.798°E) is situated upon the eastern shore of Lake Ohrid (North Macedonia; Figure 1 b) at an altitude of 693 m a.s.l. Lake Ohrid is one of the largest and deepest lakes in southern Europe (Matzinger et al. 2006; Panagiotopoulos et al. 2014). Ploča Mičov Grad lies at the foot of the Galičica mountain range within the sheltered Bay of Bones. Temperatures and precipitation rates were slightly higher during the Neolithic than present-day (Samartin et al. 2017). Today, Köppen-Geiger climate classification characterises the area as 'Steppe, warm temperate, warm summer', 'CSb' (Figure 1 a, Kottek et al. 2006). Radiocarbon and dendrochronological dating of the surviving wooden piles attests to several occupation phases from the Late Neolithic and the Late Bronze Age (Hafner et al. 2021; Bolliger et al. 2023).

Two cores were extracted near to the pile-dwelling for palaeoecological analysis (the one closest to the pile field was named 'the Ohrid settlement core' and the one closest the lake centre 'the Ohrid plateau core'). Samples were analysed for pollen and micro-charcoal (Figure 1 c). Together the sediment cores cover approximately 8000 years of vegetational changes from approximately 11000 to 3000 cal BCE, based on an age-depth model of 22 radiocarbon dates from plant macrofossils (two of the samples were rejected as outliers and considered contamination). The Middle and Late Neolithic deposits was only preserved in the Ohrid settlement core. Methodological details and results have been published in Brechbühl et al. (2023).

Four cores, extracted through an organic cultural layer (c. 1.5 m thick) associated with the site, were the focus of the archaeobotanical analysis (Figure 1 c). The main deposit dates to the Late Neolithic (c. 4697-4500 to 4436-4257 cal BCE). Minor Middle Neolithic and later Bronze Age layers are not considered here. Sampling, wash-over, quantification and identification methods are detailed in Paper 1 of this thesis. The samples were rich and dominated by cereals with a large contribution of edible tree fruits and nuts. Samples were taken following stratigraphic horizons when present or at regular intervals (Paper 1 of this thesis). All Late Neolithic samples (n=81) were included in this analysis, except the samples that were situated at the boundary between the Middle and Late Neolithic (QLM19 0.2.12), and Late Neolithic and later Bronze Age deposits (TLM19 70.15). Samples were taken based on stratigraphic layers (when present) or at spits of approximately 6cm. As the organic layer was relatively homogenous with few clear stratigraphic layers, the merging of samples was considered appropriate. The sedimentary profiles were examined to determine the confidence of identified stratigraphic layers and the similarity of sample composition was assessed through correspondence analysis (in Paper 1 of this thesis) and a depth-constrained cluster analysis (Supplementary Materials). Based on stratigraphic information and compositional similarity, after merging, 60 samples/sample groups remained. Further details of sample merging in Supplementary Materials.

The palaeoecological and archaeobotanical cores were aligned based on the correlation between the two age-depth models. The pollen core was divided into six statistically significant pollen zones. The archaeobotanical cores correspond to the pollen zone OHR-5 with the Middle Neolithic archaeobotanical material aligning with the start of OHR-5 (and the very end of OHR-4) and the Late Neolithic archaeobotanical material corresponding to the end

of the OHR-5 zone. This paper focuses on the Late Neolithic archaeobotanical material and the contemporary pollen record (end of OHR-5). Broad trends in the pollen core were identified by determining whether pollen counts were generally increasing, constant or decreasing prior to occupation, during occupation and following occupation (Figure 2).


a.
b.
Drin River
N
Candavian Road
Lake Ohrid
PMG
Prespa
Lakes
0 10 25km
a. Climate zones
Arid, steppe, cold arid (BSK)
Fully humid, warm temperate, hot summer (CFA)
Fully humid, warm temperate, warm summer (CFB)
Fully humid, warm temperate, cool summer (CFC)
Steppe, warm temperate, hot summer (CSA)
Steppe, warm temperate, warm summer (CSB)
Steppe, warm temperate, cool summer (CSC)
Fully humid, snow, warm summer (DFB)
Fully humid, snow, cool summer (DFC)
Polar tundra (ET)

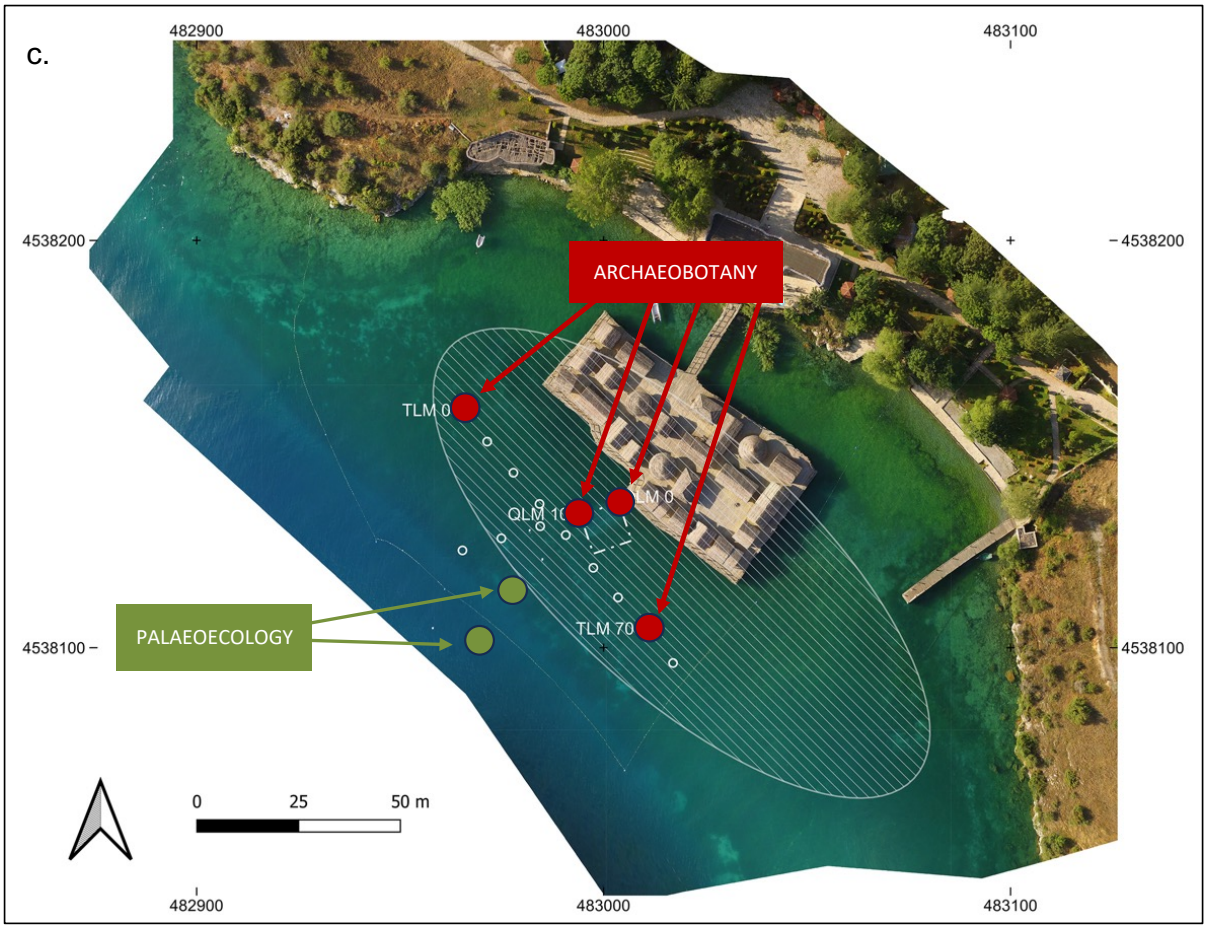

c.
482900
483000
483100
4538200
4538100
ARCHAEOBOTANY
PALAEOECOLOGY
TLM 0
TLM 70
0 25 50 m

Figure 1: The location of the site of Ploča Mičov Grad. At the interface of different climate zones (a), Ploča Mičov Grad (PMG) is situated on the eastern side of Lake Ohrid (North Macedonia) in the sheltered Bay of Bones at the foot of the Galičica mountain range. The black rectangle in a. matches the area shown in b. In c, the site (hatched oval) lies under a pile-dwelling village reconstruction. The location of the archaeobotany and palaeoecological sediment cores is indicated (Orthophoto: M. Hostettler, Hafner et al. 2021). For a, Köppen-Geiger climate classification after Kottek et al. (2006) downscaling after Rubel et al. (2017) © Climate Change & Infectious Diseases Group, Institute for Veterinary Public Health, Vetmeduni Vienna, Austria. For b, elevation data from USGS Global Multi-resolution Terrain Elevation Data.

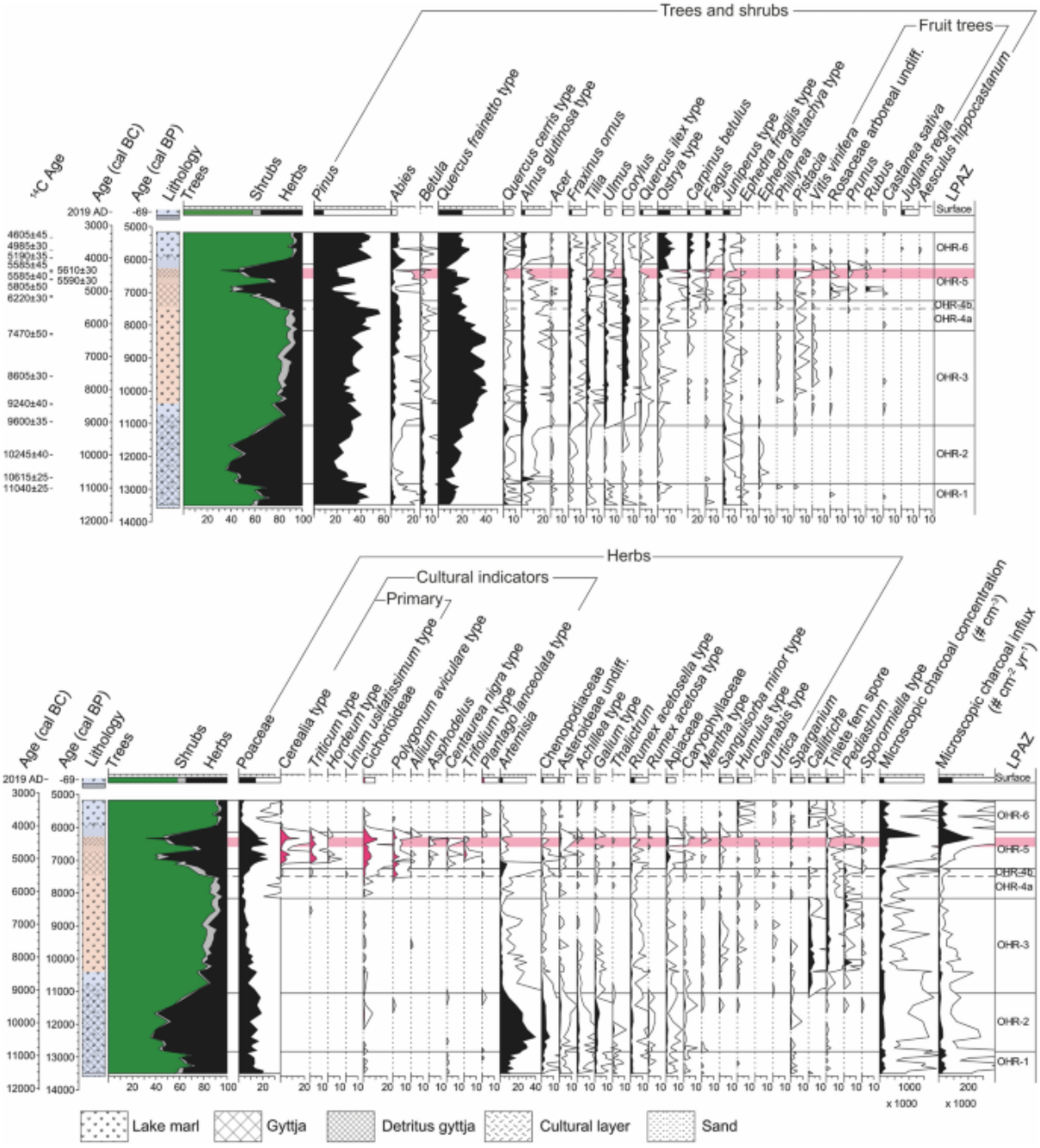


Figure 2: The key palaeoecological results. Radiocarbon dates and lithology are shown to the left. For the lithology, blue shading highlights data gained from the Ohrid plateau core and red shading the Ohrid settlement core. Pollen counts that are shown as empty curves show a 10x exaggeration. The pollen count curves of primary cultural indicators (e.g. Cerealia types) are filled bright pink. The LPAZ show the statistically significant zones. The pale pink horizontal highlight refers to the Late Neolithic settlement phase based on Hafner et al. (2021). Figure from Brechbühl et al. 2023.

2.4.2 CROP PROCESSING ANALYSIS

Within the archaeobotanical assemblage, crop remains were the most abundant type of macrofossils. In particular, cereal chaff (primarily glume bases and spikelet forks) was found in large numbers, far greater than cereal grains (Paper 1 of this thesis), suggesting that they represented the by-product of crop processing. Some wild taxa were possibly weed seeds entering the assemblage with the crops. To assess the relationship between the possible weed seeds and crop processing stages, a discriminant analysis was conducted following Jones (1984; 1987). A match between the weed-based and crop-based methods of identifying crop processing stages would suggest that these macrofossils were weed seeds harvested and processed with the associated crops. Based on comparison with an ethnographic model from the processing of cereals and pulses from Amorgos (Greece, Jones, 1984), the discriminant analysis separates archaeological weed assemblages that resemble coarse-sieving by-products, winnowing by-products, and fine-sieving products and by-products. Three physical characteristics of weed seeds (size, aerodynamics and whether they remain 'headed' e.g. enclosed in a capsule following threshing) are used to discriminate between weeds associated with different stages in crop processing (Jones, 1984; 1987).

In this analysis, all weed seeds were used that could be assigned to a particular physical type (88 seed types). Only samples/merged sample groups with over 30 weed seeds were included in the analysis. Twelve samples were removed from the analysis, leaving 48 samples or merged sample groups. The R-package 'CropPro' (Stroud et al. *in submission*) was used to perform the analyses and visualise the data. While crop processing analysis was created using ethnographic data from uncharred seeds, it has primarily been applied to charred

archaeological datasets (e.g. Bogaard, 2011) due to the greater number of such assemblages and the inferred association with charred stored crops and charred weeds. As such, the application of this method to a waterlogged dataset is exploratory and comparisons are made with caution.

2.4.3 FUNCTIONAL WEED ECOLOGY

To compare the nature of arable agriculture at Ploča Mičov Grad to modern traditional agrosystems, functional weed ecology was used. The R-package 'WeedEco' was used for the data analysis and visualisation (Stroud et al. 2023). The package's 'Model 2' was used which included modern data from Haute Provence (France), Asturias (Spain), Evvia (Greece) and oases and rainfed terrace fields in Morocco (Jones et al. 1999, 2000; Bogaard et al. 2016, 2018). The high- and low- input regimes are discriminated on the basis of four functional traits (mean specific leaf area, ratio of leaf area to thickness, canopy height and canopy diameter). The high-input regimes included weeding and fertilisation/manuring (Bogaard et al. 2018; Stroud et al. 2023). The functional trait data for the relevant species was taken from the 'WeedEco' package (Stroud et al. 2023). Again, only samples/merged sample groups with over 30 weed taxa (identified to species with known functional traits) were included in the analysis. The 48 archaeobotanical samples (or merged sample groups) were entered as unknown cases into the classification phase of the analysis. The function classifies samples as 'low-input' based on the presence of weeds with lower soil fertility attributes or conversely as 'high-input' dominated by weeds with attributes associated with higher soil fertility.

2.5 RESULTS

2.5.1 COMPARISON BETWEEN PALAEOECOLOGICAL AND ARCHAEOBOTANICAL RESULTS

The principal pollen taxa from the palaeoecological analysis were compared with types in the archaeobotanical record. In some cases, macrofossils in the archaeobotanical assemblage were identified to a higher taxonomic resolution (e.g. taxa only identified to genera palaeoecologically were sometimes identified to species archaeobotanically). It is very likely that archaeobotanically abundant taxa (e.g. *Abies alba*) contributed at least some of the pollen identified to the genus level (*Abies* sp.), but it is also possible that other species (e.g. *Abies cephalonica* and *A. borisii-regis*) were present in the landscape and contributed to the pollen record. In other words, the archaeobotanical data give indications of species (or genera) which likely contributed at least some but not necessarily all of the pollen identified to genera (or family). This is also the case for taxa identified to species types in the pollen record, but only genus or family in the archaeobotanical record (e.g. oaks, *Quercus*).

An earlier settlement phase at c. 5550-4850 cal BCE was detected based on the palaeoecological analysis (Brechbühl et al. 2023). Similarly, an initial occupation phase (c. 5790-5722 to 5755-5714 cal BCE) was identified in the archaeobotanical record in one of the sediment cores (however, numbers of plant macrofossils are low; Paper 1 of this thesis). The second occupation phase identified in the palaeoecological analysis corresponded with the main archaeobotanical phase (Late Neolithic, c. 4697-4500 to 4436-4257 cal BCE) and, as such, is the focus of this paper. The pollen counts before, during and after the Late Neolithic occupation were compared to identify broad trends in the dataset.

During the Late Neolithic occupation phase, there was a significant decrease in arboreal pollen (including pine (*Pinus*), fir (*Abies*), oak (*Quercus* types), alder (*Alnus glutinosa*) and hazel (*Corylus*; Brechbühl et al. 2023). All of these species were identified in the archaeobotanical record, with finds of pine needles (in addition to rare pinecone fragments and one pine seed), fir needles, oak/acorn nutshell fragments, alder seeds (as well as a single alder cone) and hazel nutshell fragments (Table 1; Figure 2). In addition, many of these taxa were identified during dendrochronological analyses of the wooden construction piles including oak, pine, juniper (likely *Juniperus excelsa* or *foetedissima*) and hophornbeam/hornbeam (*Ostrya/Carpinus* spp.), suggesting that these taxa were valued for timber (Bolliger et al. 2023). Hop hornbeam (*Ostrya*) pollen counts fluctuates during the settlement occupation and peaks following the Late Neolithic settlement phase. Ash (*Fraxinus*) and maple (*Acer*) were identified in both the palynological analysis and wooden piles but were not identified archaeobotanically (or only tentatively in the case of maple seeds).


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Figure 3: Arboreal, fruit and nut macrofossils from Ploča Mičov Grad. All macrofossils are uncharred seeds unless specified. A. Alnus glutinosa cone, b. Juniperus cf. oxycedrus seed, c. Corylus avellana nutshell, d. Quercus sp. nutshell base, e. Pistacia terebinthus whole nutshell, f. Rubus fruticosus agg. seed, g. Vitis vinifera subsp. sylvestris seed, h. Abies alba needle, i. Pyrus/Sorbus sp. seed, j. Malus sp. seed and k. Rosa sp. seed.

The fruits/nuts of juniper (*Juniperus cf. oxycedrus*), terebinth (*Pistacia terebinthus*) and grape (*Vitis vinifera* subsp. *sylvestris*) were identified in high numbers archaeobotanically. While juniper pollen percentages decreased during the occupation phase and terebinth and grape pollen percentages increased, the pollen numbers of these taxa fluctuated significantly over the millennia before occupation (Brechbühl et al. 2023). In contrast, pollen counts of Rosaceae arboreal undiff., *Prunus* and *Rubus* numbers, while low/non-existent prior to occupation, peaked notably during the Late Neolithic occupation before decreasing afterwards (Brechbühl et al. 2023). Two pollen grains of *Sorbus* were also identified in contexts earlier than the Late Neolithic phase. Rosaceae arboreal undiff. includes all pollen that resembles tree/shrub Rosaceae, which could not be identified further. These pollen taxa correlate with many edible fruits found in abundance within the archaeobotanical record including rosehip (*Rosa* spp.), apple and pear/rowan (*Malus* and *Pyrus/Sorbus,* known collectively as Maloideae), almond (*Prunus amygdalus*), blackberry (*Rubus fruticosus*) and raspberry (*Rubus idaeus*). Pollen grains of *Rosa, Pyrus, Sorbus* and *Malus* are identifiable. However, it is possible that they are included in the Rosaceae arboreal undiff. (as well as *Prunus* and *Rubus*) if diagnostic features were unclear.

Prior to settlement occupation, cereals were almost absent in the pollen record (with the exception of *Triticum* (wheat) pollen in OHR-3, c. 6500 cal BCE). A few cereal and *Triticum*

pollen grains were present in OHR-4b which broadly corresponds to the Middle Neolithic phase in the archaeobotanical record, after which *Cerealia*, *Triticum* and *Hordeum* (barley) pollen increased. Cereal pollen counts (particularly *Triticum*) peaked during the Late Neolithic phase. However, *Hordeum* pollen counts were low during the main Late Neolithic phase. A single *Linum usitatissimum* pollen grain was identified in the OHR-3 zone (c. 6500 cal BCE); none were identified in the either the Middle Neolithic or Late Neolithic settlement phases (Brechbühl et al. 2023).

Table 1: Comparison between the palynological and archaeobotanical results for crops, arboreal and fruit shrub taxa. Similar taxonomic categories between the two datasets are aligned. For each, trends in pollen numbers increasing (▲), decreasing (▼) or fluctuating (▲▼) before, during and after the Late Neolithic occupation are indicated. **X** *signals taxa that were not present or in very low numbers. Grey shading shows less pronounced/uncertain changes. For the trends before occupation, the pollen numbers before and after the earlier (Middle Neolithic) settlement phase are taken into consideration.*

Palaeoecological taxa	Archaeobotanical taxa	Wooden piles	Pollen dynamics		
			Before	During	After
Pinus	*Pinus* (needles, cone scales and seed)	*Pinus* sp.	▲	▼	▲
Abies	*Abies alba* (needles)		▲	▼	▲
Quercus frainetto type *Quercus cerris* type *Quercus ilex* type	*Quercus* sp. nutshell fragments	*Quercus* sp.	▲	▼	▲

Alnus glutinosa type	*Alnus glutinosa* (seeds and cone)	*Alnus* sp. (rare)	▲	▼	▲
Corylus	*Corylus avellana* nutshell		▲	▼	▼
Ostrya type	*Ostrya carpinifolia* seeds	*Ostrya carpinifolia /Carpinus betulus /orientalis*	▲▼	▲▼	▲
Juniperus type	*Juniperus* cf. *oxycedrus*	*Juniperus excelsa/ foetedissima*	▲▼	▼	▲
Pistacia	*Pistacia terebinthus*		▲▼	▲	▼
Vitis vinifera	*Vitis vinifera* subsp. *sylvestris*		▲▼	▲	▼
Rosaceae arboreal undiff.	*Rosa* spp. *Malus* sp. *Pyrus/Sorbus* *Prunus amygdalus* *Rubus fruticosus agg.* *Rubus idaeus*		x	▲	▼
Sorbus	*Pyrus/Sorbus*		x	x	x
Prunus	*Prunus amygdalus*		x	▲	▼
Rubus	*Rubus fruticosus* agg.		x	▲	▼

	Rubus idaeus				
Cerealia type	*As for Hordeum and Triticum*		x	▲	▼
Triticum type	*Triticum monococcum* *Triticum dicoccum* *Triticum timopheevii* *Triticum durum/aestivum* *Triticum aestivum*		x	▲	▼
Hordeum type	*Hordeum vulgare* *Hordeum distichon*		x	▲	▼
Linum usitatissimum	*Linum usitatissimum*		x	x	x

2.5.2 CROP PROCESSING ANALYSIS

In order to model the agrosystem of Ploča Mičov Grad, it is first necessary to better understand the taphonomy of the potential 'weed' seed assemblage. Crop processing analysis (Jones, 1984, 1985) can be used to explore the relationship between possible 'weed' seeds and crop material to assess the likelihood that these seeds are in fact arable weeds and as such compatible with associated crop remains in terms of processing stage. As such, the Ploča Mičov Grad 'weed' seed assemblage (Figure 5) was investigated using crop processing analysis. Weed seeds were only included if identified to sufficient resolution to characterise their size, aerodynamics and headedness. The archaeological samples are added as cases to be classified after the model is created, classifying the samples as one of four groups – fine-

sieving by-product, fine-sieving product, winnowing by-product and coarse-sieving by-product.

To explore taphonomic biases impacting the 'weed' assemblage further, the significance of macrofossil preservation was explored. Two preliminary analyses included (1) all weed taxa and (2) only charred material. Details of these two preliminary analyses can be found in the Supplementary Materials (Figures S4-S5). The final analysis included uncharred taxa if also found in charred form (see Supplementary Materials for further details of taxa exclusion and inclusion). Such taxa were considered more closely related to human activity than the full potential weed dataset, but with larger weed seed numbers per sample (and so more reliable results) than the dataset with only charred macrofossils. The results of all three crop processing analyses were broadly similar, with the samples classified as fine-sieving or winnowing by-products.

The final dataset included 51 different taxa (excluding taxa that were only found uncharred, Supplementary Materials Table S1) and 46 samples. When adding the Ploča Mičov Grad archaeobotanical samples as unknown cases following the creating of the model (using the 'LDAcrop.pro' function in the CropPro package, Stroud et al. *in submission*), they are classified as the by-products of winnowing (n=28, c.61%) or fine sieving (n=18, c.39%). Most samples were closely grouped with no clear patterns based on depth or core (Figure 4). The analysis output can be found in the Supplementary Materials (Table S2 and S3).

The classification of the weed seeds matched the inference based on the abundance of cereal chaff that the cereal macrofossils were also primarily crop-processing by-products, suggesting that they were arable weeds. The combination of winnowing and fine-sieving by-product likely reflects the tossing of material from sieves following the pounding of glume wheat spikelets

(D'Andrea and Haile, 2002; Halstead, 2014). This combination is also known from other Neolithic assemblages with glume wheats such as the Early Neolithic site of Vaihingen (Bogaard, 2011). Given this outcome, functional weed ecology was used to characterise the cultivation practices.

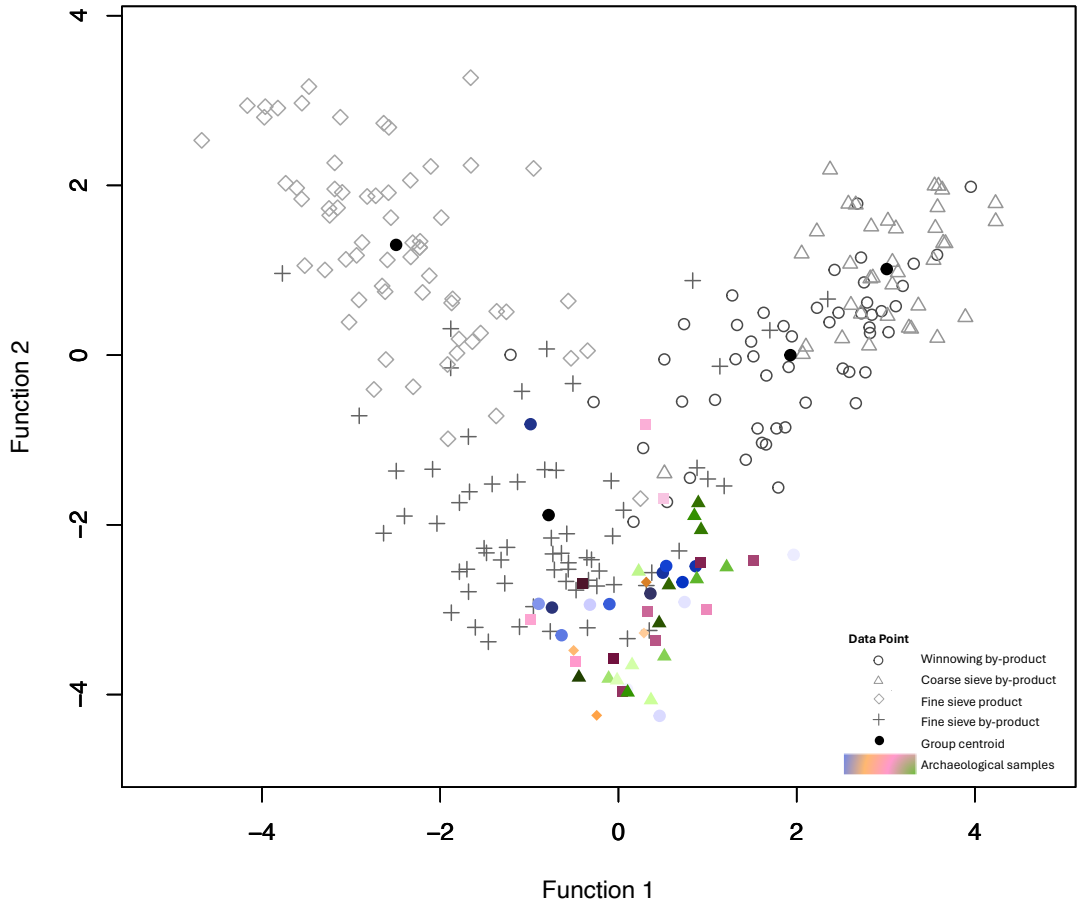


Figure 4: Crop processing analysis using including uncharred weed taxa if also found in charred form. The archaeological samples are coded with Core QLM19 0 represented by blue circles, TLM19 70 by pink squares, TLM19 0 by orange/brown diamonds and QLM19 10 by green triangles. The shade reflects the depth of the samples with the darkest colours found at the base of the sedimentary sequence. The modern data points are shown in greys. The plot of function 2 and 3 can be found in the Supplementary Materials (Figure S6).

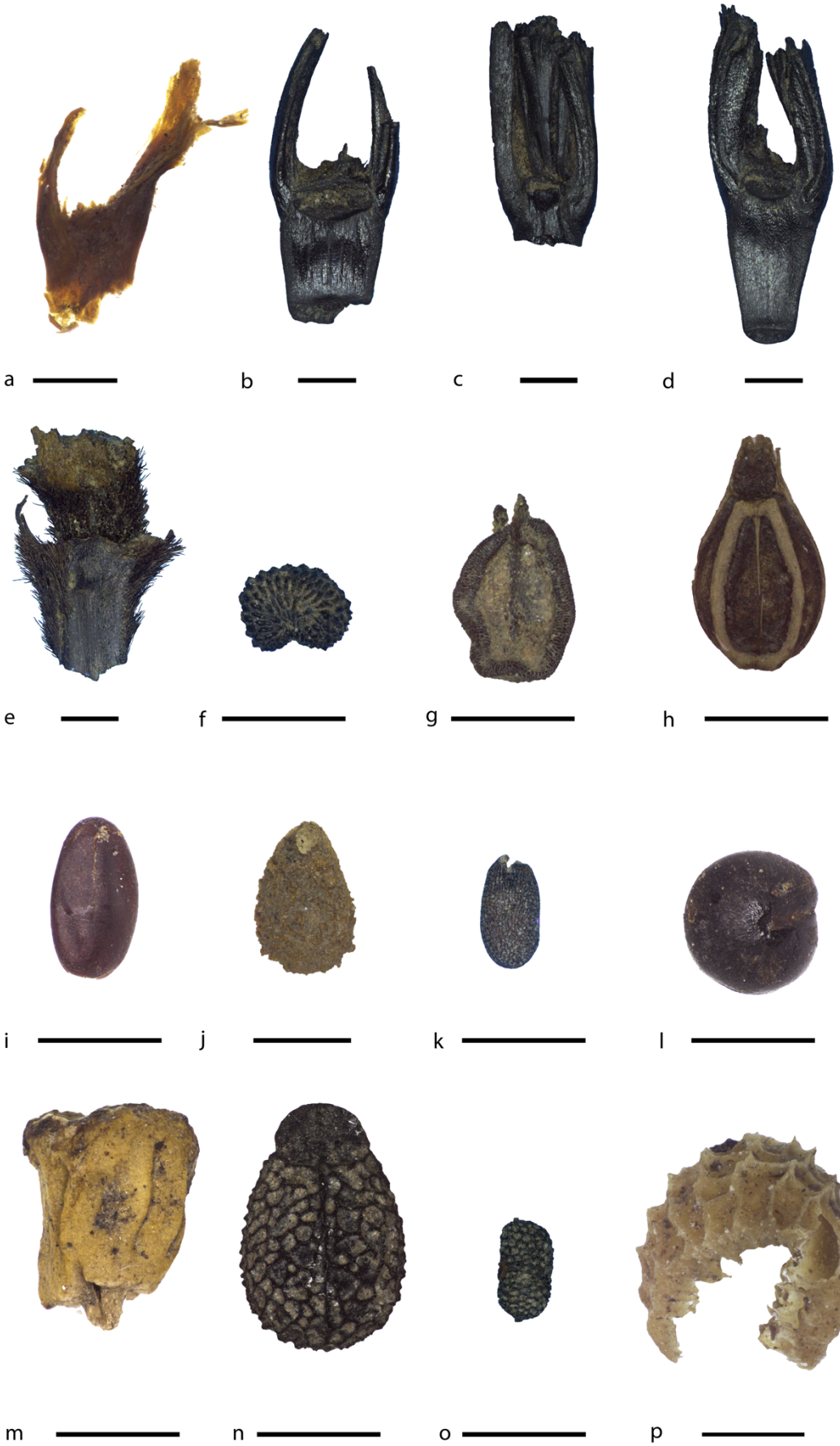

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Figure 5: Late Neolithic cereal and weed macrofossils from Ploča Mičov Grad. All macrofossils are uncharred seeds unless specified. A. glume wheat spikelet fork, b. Triticum monococcum charred spikelet fork, c. Triticum dicoccum charred spikelet fork, d. Triticum timopheevii charred spikelet fork, e. two charred rachis segments of Hordeum vulgare (hulled), f. Silene sp., g. Petrorhagia sp., h. Valeriana dentata, i. Campanula sp., j. Heliotropium europaeum, k. Capsella bursa-pastoris, l. Chenopodium album, m. Glebionis segetum, n. charred Euphorbia cf. helioscopia, o. Hypericum perforatum and p. Malva cf. sylvestris. All scale bars are 1 mm.

2.5.3 FUNCTIONAL WEED ECOLOGY

As with the crop processing analysis to further explore the taphonomic biases impacting the weed assemblage, two preliminary analyses were performed with (1) the full weed dataset and (2) only charred material. The first analysis aligned the majority of samples with high-input regimes, while the second had insufficient data (too few samples with small numbers of weed seeds; Supplementary Materials, S7 and S8). Details of the first two preliminary analyses can be found in the Supplementary Materials. The third/final analysis included all weed seeds except those taxa only preserved in an uncharred state across the assemblage (see Supplementary Materials for further details of taxa exclusion and inclusion) and is discussed here.

The final analysis excluded taxa only represented by uncharred macrofossils. This analysis included 32 weed seed types (Supplementary Materials, Table S4) and 37 sample/merged sample groups (with >30 weed seeds). The discriminant scores ranged from -0.90 to 3.06 with an average 1.00. In total, 35 of the samples were classified as ‘high-input’ and 2 as ‘low input’ (Figure 6). The analysis output can be found in the Supplementary Materials (Table S5).

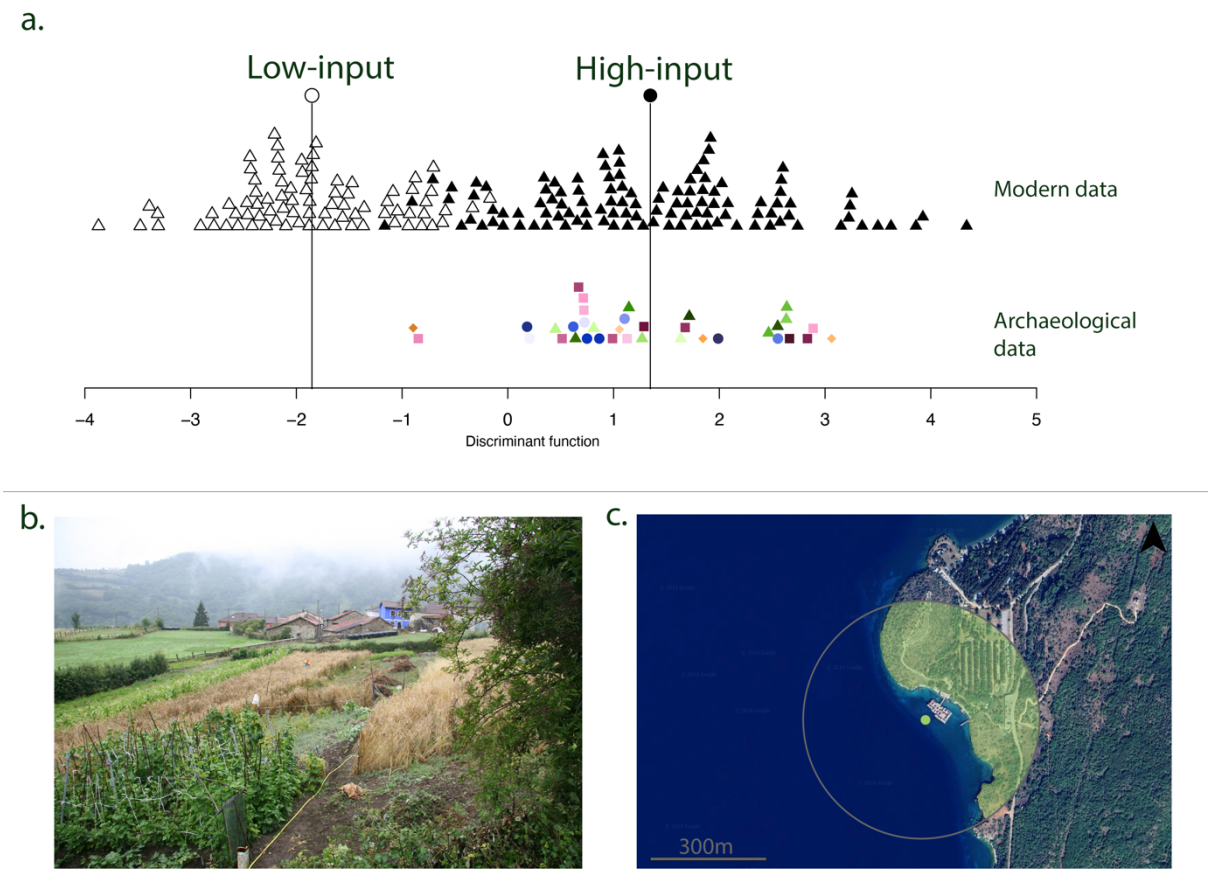


Figure 6: The agrosystems of Ploča Mičov Grad. A. The results of the functional weed ecology. The modern dataset with points classed as 'high-input' shown by black triangles and points classed as 'low-input' shown in white. The majority of the archaeological samples are classified as 'high-input'. The archaeological samples are coded as in Figure 4 with Core QLM19 0 represented by blue circles, TLM19 70 by pink squares, TLM19 0 by orange/brown diamonds and QLM19 10 by green triangles. The shade reflects the depth of the samples with the darkest colours found at the base of the sedimentary sequence. B. Modern traditional high-input agricultural system in Asturias, Spain (Photo: A. Bogaard). C. The location of arable plots (within 300 m radius of the pollen core) inferred from the magnitude of the cereal pollen.

2.6 DISCUSSION

Synthesis of the archaeobotanical and palynological records from the Bay of Bones provided a nuanced understanding of Late Neolithic human-vegetation relationships. These methods offer complementary but differing perspectives on biocultural landscapes (Edwards et al. 2015). Archaeobotanical datasets are typically biased towards cultivated or collected plants used by the prehistoric population or present in cultural landscapes (Behre and Jacomet, 1991), while pollen datasets from large lakes usually reflect regional vegetation dynamics (Jacobson and Bradshaw, 1981; Sugita, 2007). Here, the pollen core was extracted near to (10-30 m) the settlement's pile field and within a sheltered bay setting, resulting in a strong anthropic signal and showing local vegetational changes (up to c. 3-5 km) (Brechbühl et al. 2023). Other studies combining near-site pollen and on-site archaeobotanical datasets have highlighted the value in such an approach for identifying local landscape changes and for exploring the causality of correlated human and environmental trends (e.g. Rattighieri et al. 2013; Feeser et al. 2022). For instance, at the Early Neolithic lakeside pile-dwelling site of La Draga, synthesis of on-site pollen and archaeobotanical datasets provided insights into the plant resource use and management, as well as the use of space around the settlement (Revelles, 2021). As such, in combination the archaeobotanical and palynological datasets provide a stronger understanding of the lakeshore vegetational diversity and the ways the Late Neolithic population interacted with local plants.

During the Late Neolithic occupation of Ploča Mičov Grad, Brechbühl et al. (2023) observe a decrease in arboreal pollen taxa which reflects land-use and clearance activities. However, the subsequent rapid recovery of the forest following the Late Neolithic settlement episode, with a higher contribution of disturbance-adapted species, underlies the resilience of the forest to

prehistoric activity. Many arboreal pollen taxa matched types identified during analysis of the wooden piles, particularly oak (*Quercus*), pine (*Pinus*) and juniper (*Juniperus*; Hafner et al. 2021; Bolliger et al. 2023; Brechbühl et al. 2023). Similarly, many of the arboreal pollen taxa reported in Brechbühl et al. (2023). were also present as macrofossils in the archaeobotanical assemblage. However, the assemblage is interpreted as a 'midden' containing primarily the refuse of edible plant foods. As such, the number of archaeobotanical arboreal remains (excluding those with edible fruits) were low. In contrast, the Middle Neolithic assemblage (Paper 1 of this thesis) contained numerous European white fir (*Abies alba*) needles which could reflect their collection as fodder (e.g. at the Late Neolithic pile-dwelling site of Arbon Bleiche 3, Switzerland, Akeret and Rentzel, 2001). The Late Neolithic samples from Ploča Mičov Grad contained a large amount of wood charcoal, forthcoming analysis of which is expected to cast light further on the use of local arboreal taxa (Ntinou et al. *in prep*).

A large number of collected fruits and nuts are present in the archaeobotanical assemblage, many of which correspond to types seen in the pollen record (Brechbühl et al. 2023). Hazelnut (*Corylus avellana*) and acorn/oak (*Quercus*) nutshells correspond to pollen taxa (*Corylus, Quercus frainetto* type*, Q. cerris* type *and Q. ilex* type) which decline during the settlement phase. For oak (the favoured wood for piles, Bolliger et al. 2023), this is strongly associated with clearance activities. Juniper (*Juniperus* cf. *oxycedrus*) and grape (*Vitis vinifera* subsp. *sylvestris*) seeds, as well as terebinth (*Pistacia terebinthus*) nutshells are also common components of the archaeobotanical samples and match types in the pollen record (*Juniper, Vitis* and *Pistacia*). All of these species have been identified (albeit many rarely) from Mesolithic/Neolithic sites in northern Greece (e.g. hazel wood charcoal from Revenia, Kleitos and Avgi, Marinova and Ntinou, 2018; acorn kernels and grape pips and from Dikili Tash,

Valamoti, 2023; terebinth nuts, Valamoti, 2004; and juniper seeds from Theopetra cave, Kotzamani and Livarda, 2018). For these taxa, the palynological data show variable pollen counts from c. 8000 cal BCE (Brechbühl et al. 2023), and as such, the relationship between foraging practices and the local plant populations remains unclear.

In contrast, there is a clear positive correlation between the level of human activity and populations (as inferred from the pollen record) of the Rose family (Rosaceae) which thrived during human occupation. Prior to and following occupation, Rosaceae pollen percentages were low/absent. However, during the main settlement phase at Ploča Mičov Grad, there was a marked increase of pollen from members of the Rosaceae family (Brechbühl et al. 2023). The pollen type identified to *Prunus* includes wild almond (*Prunus amygdalus*), which was abundant in the archaeobotanical assemblage. Brechbühl et al. (2023) note that high Rubus pollen percentages corresponded to parts of the sedimentary sequences with *Rubus* macrofossils. Very high numbers of blackberry (*Rubus fruticosus* agg.) and raspberry (*Rubus idaeus*) were also present in the archaeobotanical assemblage. The pollen type identified to 'Rosaceae arboreal undiff.' could include any Rose family tree/shrub pollen that was not identifiable to genus. Many Rosaceae fruit seeds were identified in the archaeobotanical record including rosehip (*Rosa* spp.) and apple and pear/rowan (*Malus* sp. and *Pyrus/Sorbus* sp. collectively known as Maloideae). While pollen of these taxa can be identified to genus they could be included in the 'Rosaceae arboreal undiff.' (alongside *Prunus* and *Rubus*) if further identification was not possible. Given the archaeobotanical assemblage's anthropic, midden-like character (the first paper of this thesis), it is very likely that the abundant remains of these fruits/nuts represent collected resources.

It is challenging to discern the relationship between Rosaceae pollen numbers and human activity. Prior to the first occupation phase detected by the palaeoecological analysis, *Prunus* and *Rubus* pollen was not present palynologically. Wild almond's natural distribution is largely south-west and central Asia, and some parts of the southern Balkans (Browicz and Zohary, 1996). In southern Greece, wild almond wood charcoal (Asouti et al. 2018) and nutshell fragments (Hansen, 1991) have been identified from prehistoric sites. However, there is little Neolithic evidence of almond in northern Greece (e.g. wood charcoal, Marinova and Ntinou, 2018), with the exception of a single Late Neolithic nutshell fragment from Makri (Valamoti, 2023). As such, the coeval appearance of humans and the wild almond in the Bay of Bones could be evidence for its introduction to the area, although Lake Ohrid is within the limits of its natural distribution. Blackberry and (to a lesser extent) raspberry, while seemingly absent in the Bay of Bones prior to prehistoric occupation, are often found at Neolithic sites in Greece (Valamoti, 2023). The increase in *Rubus* pollen percentages could be due to its collection but this species also thrives in disturbed areas, commonly found near to settlements (Valamoti, 2023). It is probable that human activity encouraged the growth of rosaceous shrubs through broad habitat changes which favoured light-loving and disturbance-adapted species such as *Rubus* (Brechbühl et al. 2023).

For all of these fruit trees, there remains a question regarding whether routine collection of fruits/nuts reflects management or cultivation practices. Neolithic communities in northern Greece were certainly collecting and storing fruits as seen at Late Neolithic Dikili Tash (northern Greece) where a store of over 1,000 whole pears was identified (Valamoti, 2015; Valamoti, 2023). However, cultivation and management practices are less clear. The definition of cultivation is somewhat ambiguous (e.g. Valamoti, 2023 discussion of olive cultivation) and

is often used to reflect large scale management that could lead to domestication. At Knossos (Crete), cultivation of wild almond has been suggested due to the numbers of nutshells recovered from the Early Neolithic II levels (Sarpaki, 2013), but evidence is inconclusive (Valamoti, 2023). Research into early viticulture suggests that some form of fruit tree management occurred during the Neolithic, laying roots for domestication (Pagnoux et al. 2021). Early management practices could include pollarding, coppicing and grafting (Bathe, 2018). Archaeological evidence of coppicing includes the finds of cut young branches recovered from Late Neolithic (c. 6300-4400 cal BP) lakeshore pile-dwellings in the northern Alpine Foreland (Favre and Jacomet, 1998; Waller et al. 2012) and has been suggested at the Neolithic site in Hungary based on palynological reconstructions of *Corylus* and *Carpinus betulus* (Gardner, 2002; although with some criticism, Waller et al. 2012). In addition, the finds of *Vitis* charcoal at Late Neolithic Dikili Tash has been interpreted as incipient cultivation with management practices such as pruning (Miller, 2008; Valamoti, 2023). With current evidence from Ploča Mičov Grad, the extent to which the population were managing or cultivating fruit trees remains conjecture.

Given the highly anthropogenic character of the Late Neolithic organic layer and large amount of cereal chaff relative to grain, it was hypothesised that the "weed" seeds were arable weeds. To understand the nature of arable agriculture and how it could have impacted local vegetation, two analyses were performed using the weed flora: crop processing analysis and functional weed ecology. An ideal context for functional weed ecology would be a storage deposit, for which the weed seeds are directly associated with crops (Stroud et al. 2023). However, given the limited arboreal and wetland input, the deposit has been interpreted as largely domestic waste (Paper 1). For these analyses, weed taxa which were only found

uncharred were excluded as it was hypothesised that they were less strongly associated with human activity than those that occured (at least partly) in charred form. Crop processing analysis was undertaken to test the hypothesis that these seeds were arable weeds (Jones, 1984; 1987). If the crop composition (in this case, mostly glume bases) aligned with the weed-based classification, it was likely that the weed-like seeds came from arable plots.

Following Jones (1984; 1987), the crop processing analysis classified the archaeological samples as winnowing or fine-sieving by-products. The fine-sieving by-product matches the large quantity of cereal chaff remains, another by-product of this crop-processing stage. A high number of winnowing and fine-sieving by-products was also reported at the Early Neolithic site of Vaihingen, Germany (Bogaard, 2011). Winnowing by-products include light, fragile seeds which may not survive charring or deposition on a dryland site. As such, these seeds may be under-represented in the typical charred assemblage due to preservation factors. The tossing of material from fine-sieves is a practice known during emmer processing in highland Ethiopia (D'Andrea and Haile, 2002) and during emmer and spelt processing in Asturias, Spain, where a 'winnowing sieve' was used during coarse or fine-sieving (Halstead, 2014, p. 153). This could create a weed seed assemblage with a mixture of those typically considered as fine-sieving by-products and winnowing by-products, as was suggested for Vaihingen (Bogaard, 2011).

As the crop processing analysis supported the hypothesis that the weed-like seeds were arable weeds entering the assemblage with crop-processing by-products, the functional ecological traits of the weed seeds were analysed to model the prehistoric agrosystems. Almost all of the samples were classified as high-input (35 out of 37 samples). High-input systems are characterised by higher soil fertility and disturbance due to labour intensive activities such as

weeding, tillage and manuring of small garden-like plots (Bogaard et al. 2018; Stroud et al. 2023). The preliminary analysis of a small number of samples from Ploča Mičov Grad also suggested the agrosystem was small-scale and labour-intensive (Holguin et al. *in press*). Functional weed ecology of archaeological assemblages often produces a range of discriminant scores likely reflecting the variability of 'real' agrosystems with limited labour, flexibility and pragmatism impacting cultivation choices (Bogaard et al. 2016). Few sites in south-eastern Europe have sufficient weed assemblages for this analysis, and so at present we can make limited comparisons with contemporary sites in the region. However, this result compares very well to other models of Neolithic agrosystems across Europe and south-west Asia which favour (to varying degrees) a small-scale, intensive arable system (e.g. LBK sites in central Europe, Bogaard et al. 2016, the Körös site of Ecsegfalva, Hungary, Bogaard et al. 2007; 2016 and Neolithic Çatalhöyük, Türkiye, Green et al. 2018). While this could be in part increased by on-site crop processing, the magnitude of the cereal pollen percentages from the palaeoecological analysis suggested that this small-scale intensive cultivation likely occurred within 200-300 m of the coring site (Brechbühl et al. 2023).

Wheat (*Triticum*) was both the most common cereal pollen type (Brechbühl et al. 2023) and cereal macrofossil identified. In the archaeobotanical assemblage, einkorn (*Triticum monococcum*) and emmer (*Triticum dicoccum*) were the most important wheats. Timopheev's wheat (*Triticum timopheevii*) and bread wheat (*Triticum aestivum)* were also recovered, (Paper 1 of this thesis). Despite present in the earlier settlement phase (c. 5550-5350 cal BCE), barley (*Hordeum* type) pollen grains were scarce for the main Late Neolithic occupation phase, giving the impression that barley cultivation was largely abandoned (Brechbühl et al. 2023). While not as numerous as wheat, barley was identified throughout the archaeobotanical

assemblage, with naked (two-row and six-row) and hulled (two-row and six-row) varieties present (Paper 1 of this thesis). One possible explanation for the discrepancy between the pollen and archaeobotanical records is that barley was cultivated further away from the site and in lower amounts than wheat. Further analysis, such as stable isotopic analysis, could explore whether wheat and barley were grown under differing conditions. Other crops represented in the archaeobotanical assemblage included pulses, bitter vetch (*Vicia ervilia*), lentil (*Lens culinaris*) and pea (*Pisum sativum*), and oilseed crops, flax (*Linum usitatissimum*) and opium poppy (*Papaver somniferum*). All of these crops are poor pollen dispersers and are rarely detected in pollen records (Brechbühl et al. 2023). As such, within this small-scale cultivation, some zonation within the landscape and complexity is apparent. While it Is likely that this agrosystem served the subsistence of this community, other small lakeshore settlements are known in the Lake Ohrid basin (e.g. Hafner et al. 2021; Hafner et al. *unpublished*) which probably had similar small arable patches.

2.7 CONCLUSIONS

The integration of near-site palaeoecological and on-site archaeobotanical records, both preserved thanks to the wetland setting, provides insights into the many ways the Late Neolithic settlement of Ploča Mičov Grad interacted with local flora. Increased human activity was positively correlated with the inferred local population sizes of members of the Rose (Rosaceae) family. It is hypothesised that systematic collection of the fruits/nuts of wild almonds, apples, pears/rowans, rosehips, blackberries and raspberries (found in abundance within archaeobotanical assemblage) and land-clearance encouraged these local fruit tree populations to thrive. In addition to the fruit and nut remains, large numbers of chaff and weed seeds in the archaeobotanical assemblage imply that the rich Late Neolithic organic

layer is largely refuse from plant foods, including the by-products of crop processing. Based on the functional ecological traits of the weed flora, the Late Neolithic cultivation resembles small-scale intensive management of long-lived arable plots, which were likely positioned near to the settlement. The rare opportunity to synthesise complementary on-site and near-site datasets offers a richer view of the cultural landscape within the bay and a deeper understanding of the ways prehistoric populations interacted with the local vegetation.

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2.9 SUPPLEMENTARY MATERIALS

2.9.1 MATERIALS AND METHODS

i. Merging of macrofossil counts

As many samples were divided arbitrarily due to a lack of clear stratigraphic layers (Paper 1 of this thesis, Supplementary Materials), we explored whether the macrofossil counts of some adjacent samples should be merged. Starting with the stratigraphic sequence and identifying similar samples based on sedimentary characteristics was fundamental. However, while some stratigraphic divisions were clear, others were more ambiguous. One approach would be to recombine all samples which were divided arbitrarily but that would merge up to 30 cm of the sedimentary core (up to 5 samples), potentially losing subtle changes.

Samples separated by clear stratigraphic divisions were not merged. However, merging was considered for all samples which were divided arbitrarily or by less clear stratigraphic layers. Samples that were positioned close to one another in the correspondence analysis reported in the first paper of this thesis were considered compositionally similar. However, based on

the correspondence analysis alone, the threshold used to decide when to merge samples was relatively subjective.

A statistical approach was taken using a depth-constrained cluster analysis using the 'vegan' and 'rioja' packages in R. The dataset included all the Late Neolithic samples and 65 common taxa (those with more than 100 specimens). This is the same dataset used in the correspondence analysis in the first paper of this thesis. Dissimilarities indices were computed using the function 'vegdist' using the 'Bray' method which is favoured for discerning ecological gradients (Oksanen et al. 2022) and 'chclust' was used to perform constrained hierarchical clustering using the constrained incremental sum-of-squares cluster analysis method (or CONISS) (Juggins, 2023). Using the 'bstick' function, segmented regression (also known as the broken-stick model) provided a statistical basis for deciding the number of clusters appropriate for each core.

The broken-stick method suggested that a range of clusters was appropriate for each of the four cores (Figure S1). In general, the broken-stick method suggested that only a small number of samples should be merged as higher numbers of clusters explained more variance than random chance. The results of the depth-constrained cluster analysis broadly agreed with the correspondence analysis (details in Paper 1).

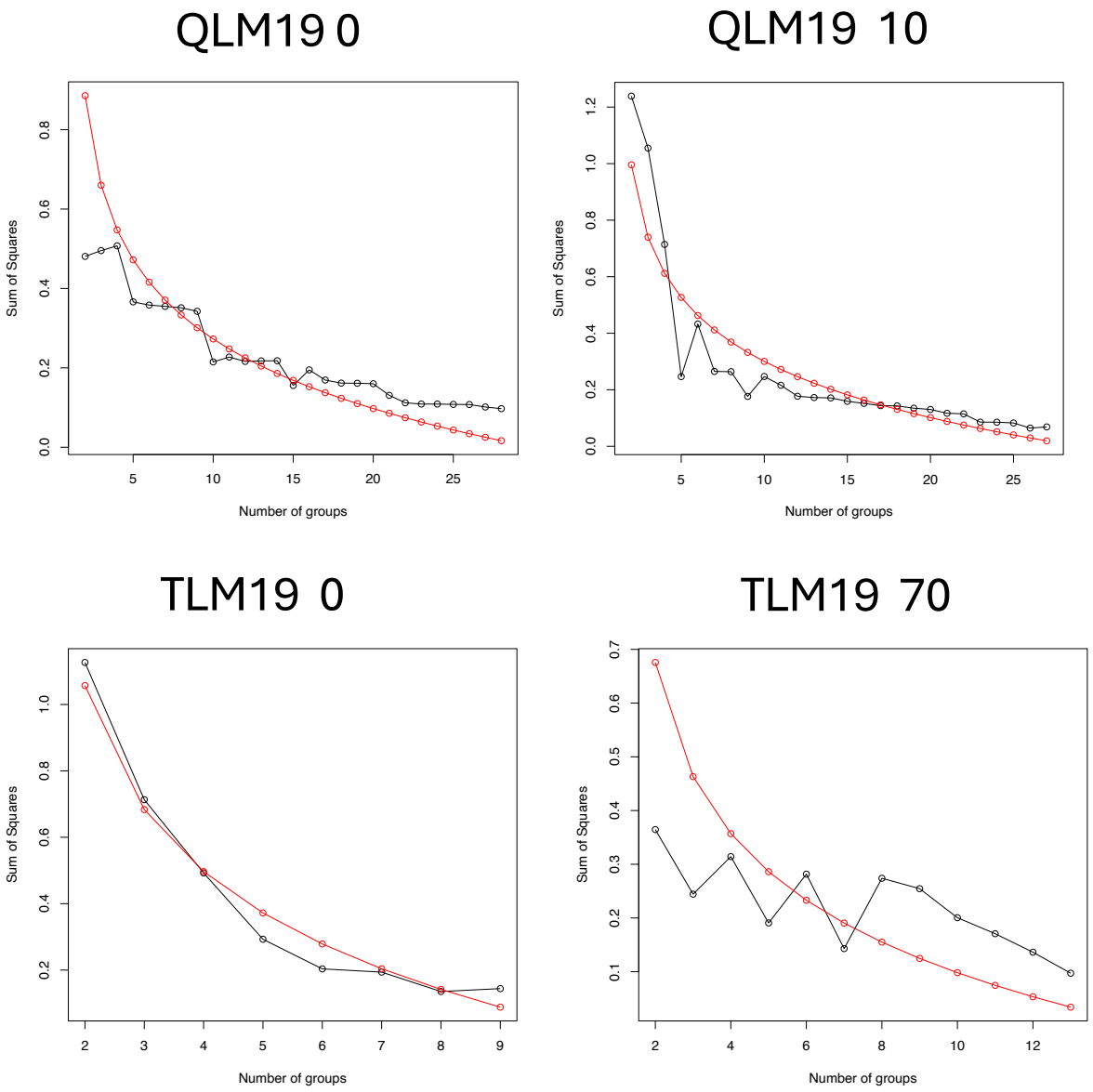


Figure S1: The broken-stick method providing a statistical basis for deciding how many samples to merge. The black line shows the amount of variance explained for each number of clusters/groups for the dataset based upon the compositional similarities. The red line shows the amount of variance explained by randomly splitting the samples into the number of clusters/groups. Any number of groups for which the black line is higher than the red line is a valid number of clusters, explaining more variance than random chance.

Together the results of the depth-constrained cluster analysis, the number of clusters recommended by segmented regression (the broken-stick method), the correspondence analysis in comparison with the visible sedimentary attributes informed the sample merging strategy (Figure S2-3). A maximum of three samples were merged (up to c. 15 cm of sediment). The 29 samples from QLM19 0 were clustered into 20 groups with a maximum merging of three samples. The 28 samples from QLM19 10 were clustered into 18 groups with a maximum merging of three samples. The 10 samples from TLM19 0 were clustered into 8 groups with two merged groups of two samples. Only two samples were merged from TLM19 70 resulting in 13 clusters for 14 samples.

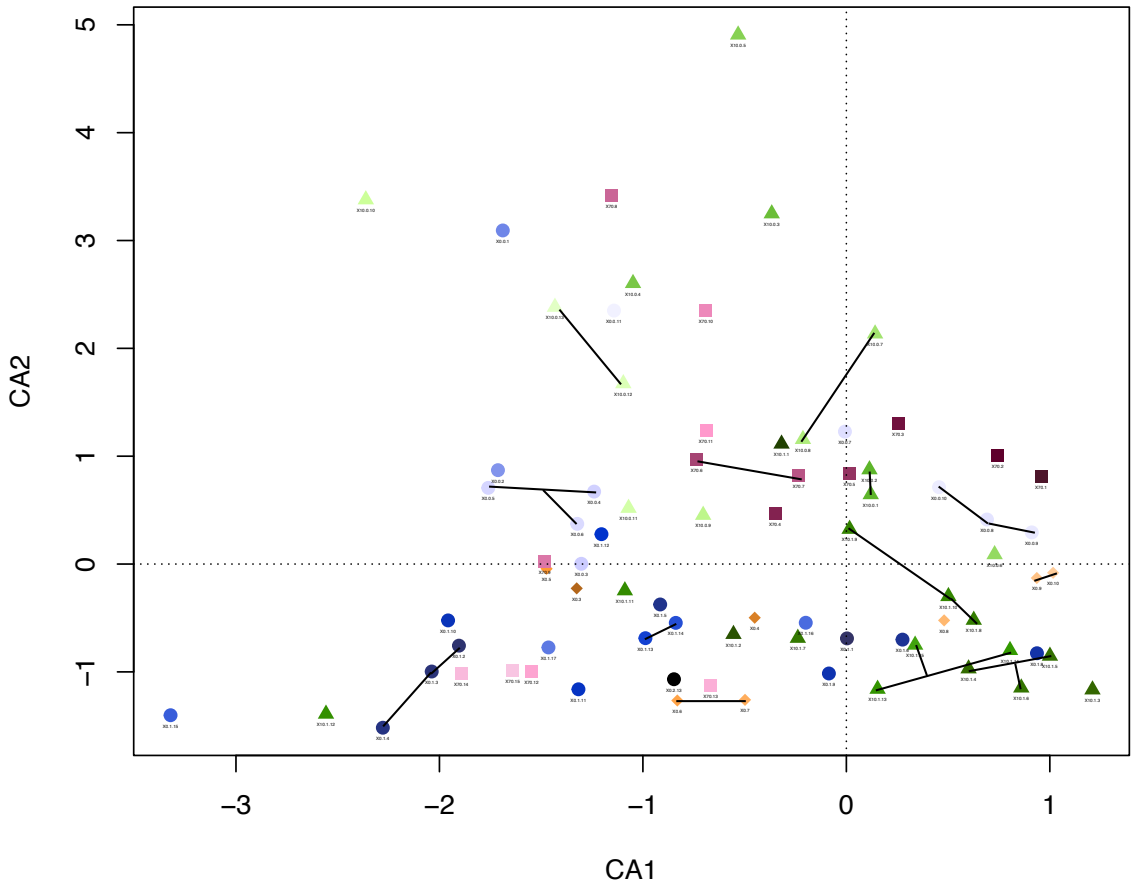


Figure S2: The merging of samples. The correspondence analysis plot from Paper 1 with adjacent samples that plotted close together and were clustered together in the cluster analysis linked with a line. These were the samples that were merged for the crop processing and the functional weed ecology analyses. Samples are coded with Core QLM19 0 in blue circles, TLM19 70 in pink squares, TLM19 0 in orange/brown diamonds and QLM19 10 in green triangles. The shade reflects the depth of the samples with the darkest colours found at the base of the sedimentary sequence. The colours match those in Figure S3 and in the crop processing and functional weed ecology figures in the main text.

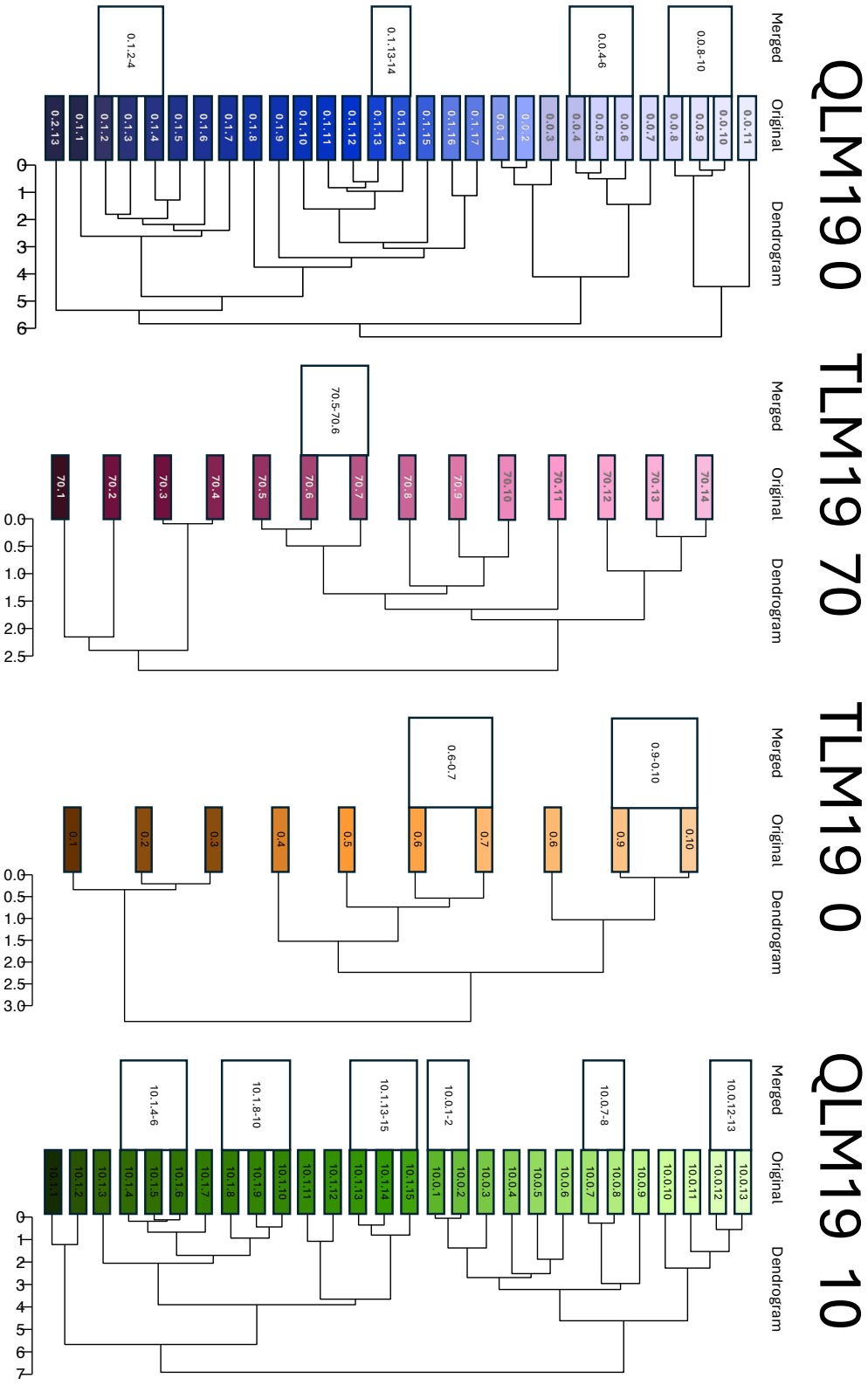

QLM19 0
Merged
Original
Dendrogram
0.1.2-4
0.1.13-14
0.0.4-6
0.0.8-10
0.2.13
0.1.1
0.1.2
0.1.3
0.1.4
0.1.5
0.1.6
0.1.7
0.1.8
0.1.9
0.1.10
0.1.11
0.1.12
0.1.13
0.1.14
0.1.15
0.1.16
0.1.17
0.0.1
0.0.2
0.0.3
0.0.4
0.0.5
0.0.6
0.0.7
0.0.8
0.0.9
0.0.10
0.0.11
0 1 2 3 4 5 6
TLM19 70
Merged
Original
Dendrogram
70.5-70.6
70.1
70.2
70.3
70.4
70.5
70.6
70.7
70.8
70.9
70.10
70.11
70.12
70.13
70.14
0.0 0.5 1.0 1.5 2.0 2.5
TLM19 0
Merged
Original
Dendrogram
0.6-0.7
0.9-0.10
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.6
0.9
0.10
0.0 0.5 1.0 1.5 2.0 2.5 3.0
QLM19 10
Merged
Original
Dendrogram
10.0.12-13
10.1.4-6
10.1.8-10
10.1.13-15
10.0.1-2
10.0.7-8
10.1.1
10.1.2
10.1.3
10.1.4
10.1.5
10.1.6
10.1.7
10.1.8
10.1.9
10.1.10
10.1.11
10.1.12
10.1.13
10.1.14
10.1.15
10.0.1
10.0.2
10.0.3
10.0.4
10.0.5
10.0.6
10.0.7
10.0.8
10.0.9
10.0.10
10.0.11
10.0.12
10.0.13
0 1 2 3 4 5 6 7

Figure S3: The merging of samples. For each of the four cores, this figure shows (a) the dendrogram produced by the cluster analysis, (b) the original sample list and (c) the samples which were merged based upon the cluster analysis and the correspondence analysis. These were the samples that were merged for the crop processing and the functional weed ecology analyses. The colours of the samples match the colours in the correspondence analysis in Figure S2 and in crop processing and functional weed ecology figures in the main text.

2.9.2 RESULTS

i. Crop processing analysis

To explore the taphonomic biases impacting the possible weed assemblage, two preliminary crop processing analyses were performed. First an analysis was run using all weed types. Overall, 90 weed seed types were included in this analysis. As low numbers of weed seeds could produce erratic results, a threshold of 30 weed seeds per sample/merged sample group was set, leaving 48 samples/merged sample groups. The archaeobotanical samples were classified as the by-products of fine-sieving (n=30, c.63%) or winnowing (n=18, c.38%; Figure S4).

The second preliminary analysis were conducted with a dataset that only included charred taxa. This dataset now had 39 weed taxa. These possible weed seeds were considered strongly related to human activities as they were charred. However, the number of weed seeds in each sample was reduced. One sample (QLM19 10.1.11) had no seeds. The samples now varied significantly in numbers of seeds (ranging from 3 to 160 with an average of 23). All samples were kept in the analysis (except 10.1.11) but samples with low numbers were treated with

particular caution. The archaeobotanical samples were classified as the by-products of fine-sieving (n=42, c.89%) or winnowing (n=5, c.11%; Figure S5).

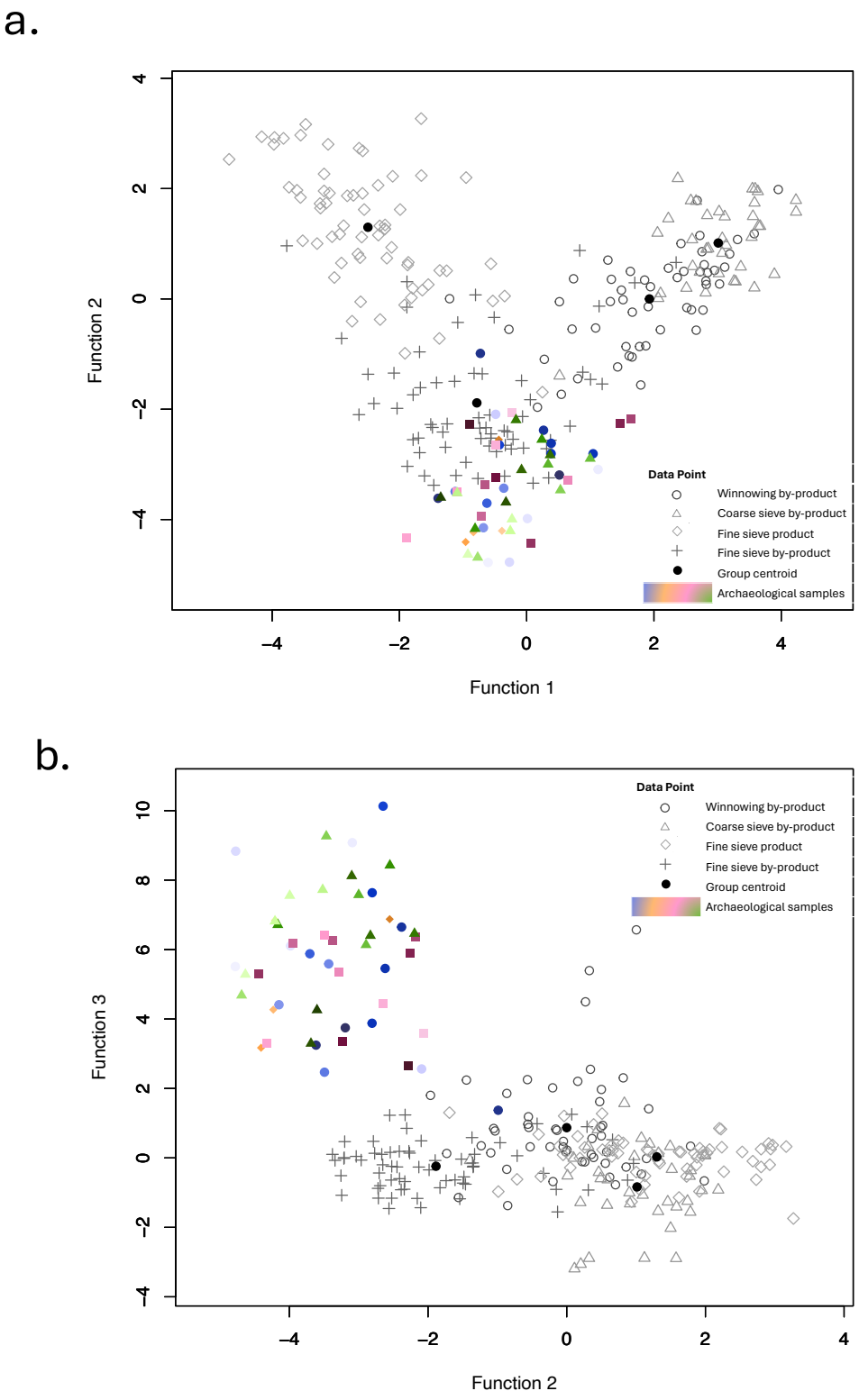


Figure S4: Crop processing analysis using all the possible weed seeds. A. the main axes (axis 1 and axis 2). B. Axis 2 and 3. For individual sample codes see Figure S3.

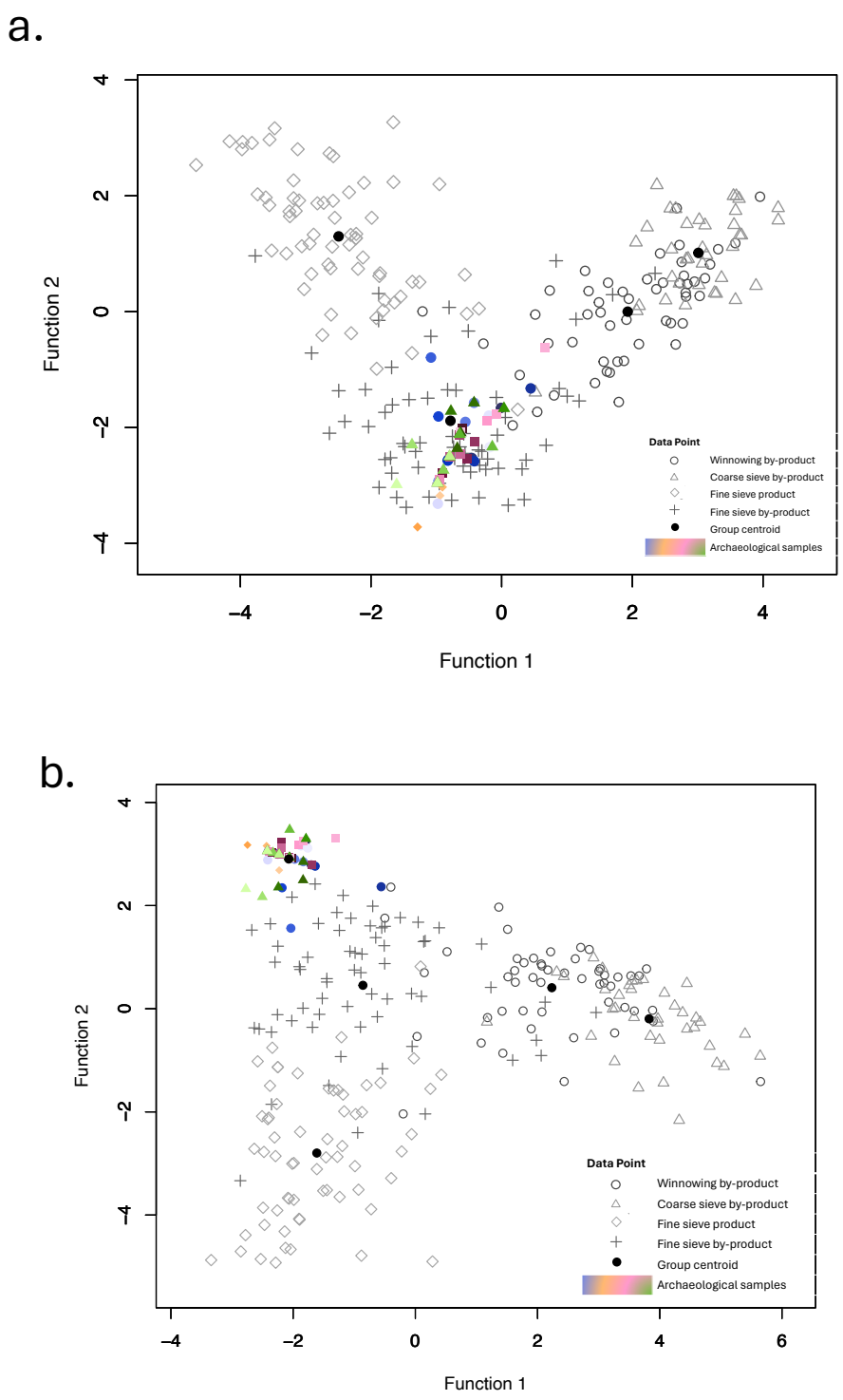


Figure S5: Crop processing analysis using all only charred weed seeds. A. the main axes (axis 1 and axis 2). B. Axis 2 and 3. For individual sample codes see Figure S3.

The final crop processing analysis included all the charred weed seeds and uncharred weed seeds if they were also found charred. As charring can inhibit identification to species of many weed types, uncharred weed seeds identified to species were included in the analysis if a charred macrofossil was identified to the same genus, provided that the species was a plausible candidate (e.g. a charred *Poa* sp. seed led to the inclusion of both *Poa annua* and *Poa* cf. *trivalis* in the analysis). This was to prevent the loss of too many taxa from the analysis. These weed types were considered strongly related to human activity, as indicated by the charring, but also had sufficient numbers to increase the reliability of the results. The results are discussed in the main text. Figure S6 shows the secondary plot with axis 2 and 3.

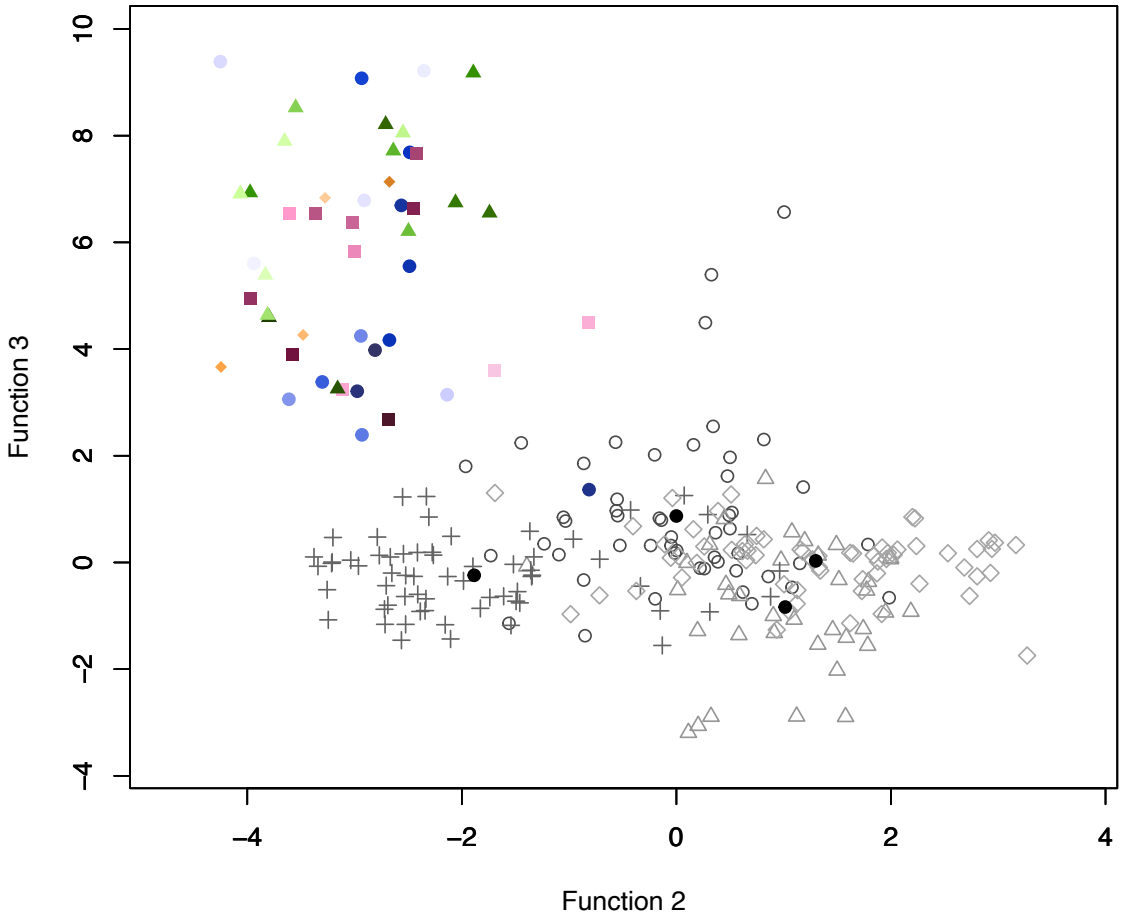


Figure S6: Crop processing analysis using uncharred weed taxa if also occurring in the assemblage in charred form. The secondary plot with axis 2 and 3. The primary plot is in the main text.

ii. Functional weed ecology

As for the crop processing analysis, two preliminary functional weed ecological analyses were undertaken to explore the taphonomic biases impacting the possible weed assemblage. The first preliminary analysis included all weed types (n=54) for which functional weed attributes were known and all samples with over 30 weed taxa (n=48). The functional weed analysis of Ploča Mičov Grad showed variability between the samples with discriminant scores ranging

from -3.2 to 2.9 (with an average 0.3). In total, 36 of the samples were classified as 'high-input' and 12 as 'low input' (Figure S7).

In the second preliminary analysis, only charred weed taxa (n=27) were included in the analysis. Many samples now had zero weed seeds and only nine samples had more than 10 weed seeds. Samples with less than 10 weed seeds were excluded from the analysis. The results were very different. Samples which had been classified as high-input were now considered low-input and vice-versa. The results were considered unreliable and the product of small sample sizes (Figure S8).

The final analysis (discussed in the text) included weed seeds that met the same criteria as set for the crop processing analysis (e.g. species were still included if a plausible charred macrofossils was identified to the same genus such as a charred *Poa* sp. leading to the inclusion of uncharred *Poa annua* and *Poa* cf. *trivalis* seeds; Table S4).

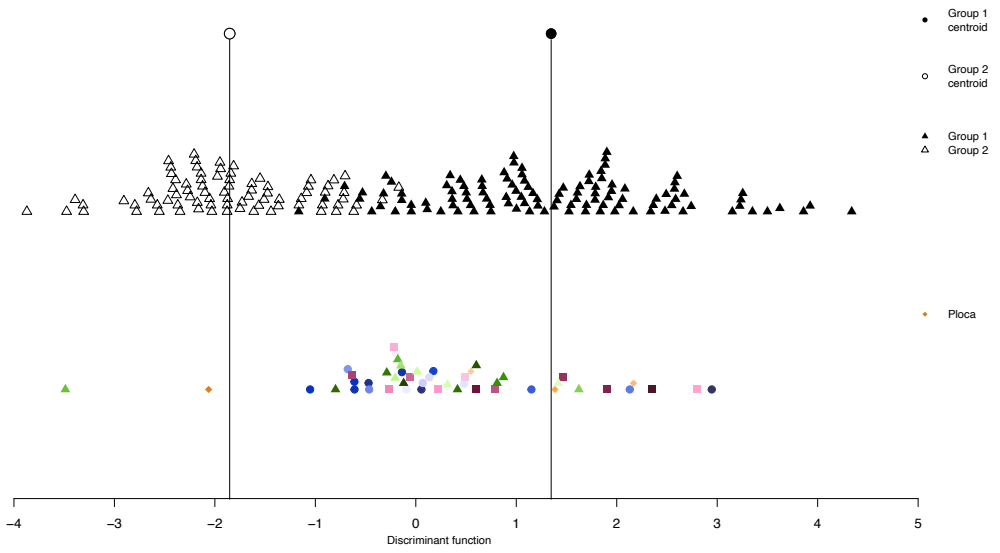


Figure S7: Functional weed ecology using all the possible weed seeds. The archaeological samples have a range of discriminant scores. The majority were classified as high-input.

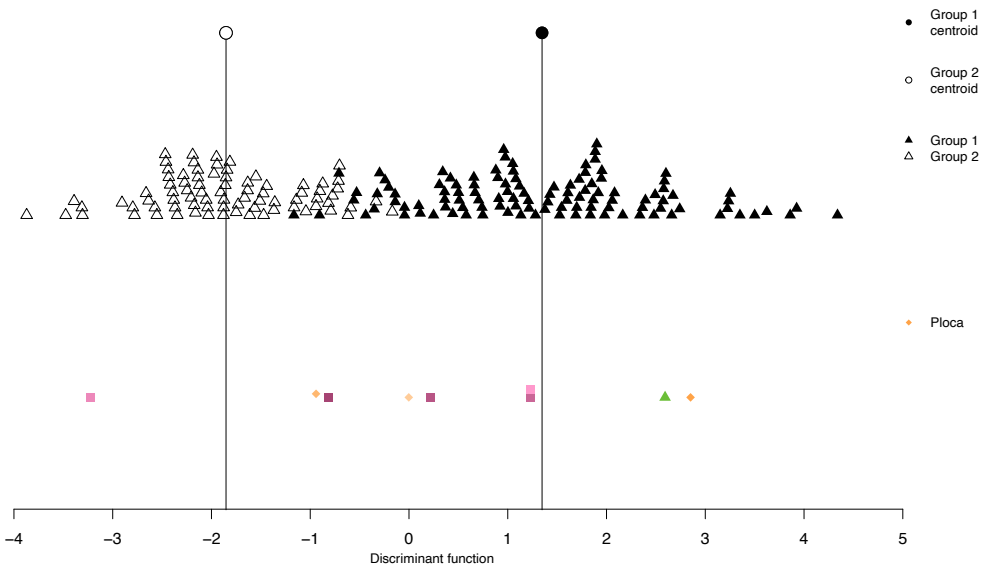


Figure S8: Functional weed ecology using only charred weed seeds. Only nine samples had more than 10 weed seeds. The archaeological samples have a range of discriminant scores. They were considered unreliable due to the sample size.

For both the crop processing analysis and the functional weed ecology, some uncharred seeds not included in the final analysis are classic arable weeds (e.g. *Agrostemma githago*). As such, by only using taxa that are represented in charred form, it is likely that some arable weeds are missing from the final analyses. However, given the total number of weed seeds in the final analysis is still high, it is hoped that the characteristics or attributes of any missing arable weeds are represented by another taxa. A limitation of this approach is that some arable weeds, particularly those that are light and fragile, are less likely to survive charring. However, it is preferable to miss a few weed taxa than to include seeds that are not arable weeds. This approach also supports more direct comparison with other archaeological applications of crop processing analysis and functional weed ecology, which has primarily been applied to charred assemblages.

Table S1: Taxa included in the crop processing analysis. All taxa were included in the first preliminary analysis and only charred taxa in the second. For the final analysis discussed in the main text, taxa that were found both uncharred and charred or only charred were included. Here uncharred includes uncharred and 'patchily charred'/'singed', while charred includes 'browed'/charred at a low temperature and fully charred. Abbreviations: sfh – small, free and heavy; bfh – big, free and heavy; shh – small, headed and heavy; bhh – big, headed and heavy; sfl – small free and light, shl – small, headed and light.

Taxa	**Category**	**Preservation**
Adonis annua/flammea	sfh	Charred
Agrostemma githago	bfh	Uncharred
Ajuga chamaepitys	sfh	Uncharred
Alchemilla/Aphanes sp.	sfh	Uncharred
Amaranthaceae	sfh	Both
Arenaria serpyllifolia	shh	Uncharred
Atriplex	sfh	Both
Avena	bfh	Both
Bifora cf. *radians*	bfh	Both
Bromus arvensis	bfh	Both
Bromus arvensis/hordaceus/secalinus	bfh	Both
Bromus hordeaceus	bfh	Both
Bromus sterilis	sfl	Both
Bromus sterilis/tectorum	sfl	Both
Bromus tectorum	sfl	Both
Campanula spp.	sfl	Both
Capsella bursa-pastoris	sfh	Uncharred
Cerastium sp.	sfh	Uncharred
Chenopodium album	sfh	Both
Chenopodium sp.	sfh	Both
Cirsium sp./*Carduus* sp.	bhh	Uncharred
Convolvulus sp.	bfh	Uncharred
Crepis sp.	shl	Uncharred
Cuscuta sp.	sfh	Both
Cf. *Daucus* sp.	bfh	Uncharred
Digitaria sp.	sfh	Uncharred
Digitaria sp./*Setaria* sp.	sfh	Uncharred
Epilobium sp.	sfl	Uncharred

Eupatorium cannabinum	sfl	Uncharred
Euphorbia cf. *exigua*	sfh	Uncharred
Euphorbia cf. *helioscopia*	sfh	Both
Fabaceae [small legume indet]	sfh	Both
Fallopia convolvulus	bfh	Both
Filipendula vulgaris	sfh	Uncharred
Fragaria sp./*Potentilla* sp.	sfh	Uncharred
Fumaria officinalis	bfh	Uncharred
Galium aparine	bfh	Both
Galium sp.	sfh	Both
G*alium spurium*	sfh	Both
Geranium cf. *purpureum*	sfh	Uncharred
Glebionis segetum	shh	Both
Heliotropium europaeum	sfh	Both
Holosteum umbellatum	shh	Uncharred
Hypericum perforatum	sfh	Both
Hypericum spp.	sfh	Both
Lapsana communis	sfh	Both
Melissa officinalis	sfl	Uncharred
Mentha aquatica	sfl	Both
Mentha longifolia	sfl	Both
Mentha sp./*Origanum* sp.	sfl	Both
Mentha spp.	sfl	Both
Origanum vulgare	sfl	Both
Papaver sp.	shl	Both
Persicaria lapathifolia	bfh	Charred
Petrorhagia spp.	sfh	Both
Petrorhagia sp./*Dianthus* sp.	sfh	Both
Picris hieracioides	sfh	Uncharred
Plantago sp.	shh	Both
Poa annua	sfh	Both
Poa cf. *trivialis*	sfh	Both
Poa sp.	sfh	Both
Poa sp./*Phleum sp.*	sfh	Uncharred
Polycnemum arvense	sfh	Both
Polygonum aviculare	sfh	Both
Potentilla sp.	sfh	Uncharred
Rumex acetosella	sfh	Uncharred
Rumex sp.	sfh	Uncharred
Silene spp.	shh	Both
Sonchus asper	sfl	Uncharred
Sonchus oleraceus	sfl	Uncharred

Stellaria media	sfh	Both
Stellaria sp.	sfh	Both
Taraxacum sp.	sfl	Both
Teucrim sp.	sfh	Uncharred
Tordylium maximum	bfh	Uncharred
Torilis sp.	sfh	Uncharred
Urtica dioica	sfh	Both
Valeriana coronata	sfh	Uncharred
Valeriana dentata	sfh	Both
Valeriana locusta	sfh	Uncharred
Valeriana rimosa	sfh	Uncharred
Valeriana sp.	sfh	Uncharred
Verbascum spp.	sfl	Both
Verbena officinalis	sfh	Uncharred
Veronica sp.	sfh	Uncharred
Viola sp. (large type)	bfh	Uncharred
Viola sp. (small type)	sfh	Uncharred

Table S2: Crop processing discriminant analysis output for the final analysis (taxa only found uncharred excluded). For each sample, the second column lists the crop-processing stage the sample was classified as with (1) being winnowing by-product, (2) coarse sieving by-product, (3) fine-sieving by-product and (4) fine-sieving product. In columns 2-5, the likelihood that the sample fits into each crop processing category is given. Columns 7-9 gives the linear discriminant scores for each function.

Sample no.	**Class_std**	**Prob.1_std**	**Prob.2_std**	**Prob.3_std***	**Prob.4_std***	**LD1***	**LD2***	**LD3***
0.5	1	0.973	0	0.027	0	0.312	-2.675	7.136
0.6 and 0.7	3	0.009	0	0.991	0	-0.244	-4.245	3.665
0.8	3	0.035	0	0.965	0	-0.503	-3.48	4.265
0.9 and 0.10	1	0.888	0	0.112	0	0.286	-3.275	6.834
0.1.1	3	0.493	0	0.507	0	0.359	-2.809	3.98
0.1.2 and 4	3	0.015	0	0.985	0	-0.746	-2.975	3.21
0.1.7	3	0.052	0	0.868	0.08	-0.986	-0.814	1.365

0.1.8	1	0.979	0	0.021	0	0.498	-2.564	6.693
0.1.10	1	0.976	0	0.024	0	0.867	-2.488	5.553
0.1.11	1	0.804	0	0.196	0	0.719	-2.675	4.169
0.1.12	1	0.994	0	0.006	0	0.536	-2.485	7.687
0.1.13 and 14	1	0.984	0	0.016	0	-0.101	-2.934	9.076
0.1.15	3	0.013	0	0.987	0	-0.638	-3.301	3.384
0.1.16	3	0.004	0	0.995	0	-0.895	-2.931	2.392
0.1.17	3	0.139	0	0.861	0	-0.32	-2.941	4.246
0.0.4.6	1	0.972	0	0.028	0	0.462	-4.251	9.388
0.0.7	1	0.981	0	0.019	0	0.742	-2.91	6.787
0.0.8 to 10	1	1	0	0	0	1.966	-2.353	9.216
0.0.11	3	0.257	0	0.743	0	0.096	-3.938	5.606
70.1	3	0.035	0	0.965	0	-0.407	-2.688	2.687
70.3	3	0.063	0	0.937	0	-0.056	-3.58	3.894
70.4	1	0.994	0	0.006	0	0.921	-2.448	6.638
70.5 and 70.6	3	0.121	0	0.879	0	0.046	-3.969	4.954
70.7	1	1	0	0	0	1.512	-2.419	7.66
70.8	1	0.871	0	0.129	0	0.414	-3.365	6.538
70.9	1	0.895	0	0.105	0	0.326	-3.024	6.38
70.10	1	0.967	0	0.033	0	0.989	-2.997	5.823
70.11	3	0.275	0	0.725	0	-0.482	-3.611	6.543
70.12	3	0.006	0	0.994	0	-0.989	-3.11	3.235
70.13	1	0.984	0	0.016	0	0.298	-0.822	4.507
70.14	1	0.888	0	0.112	0	0.511	-1.695	3.607
10.1.4 to 6	3	0.033	0	0.967	0	-0.444	-3.798	4.594
10.1.7	3	0.227	0	0.773	0	0.457	-3.158	3.256
10.1.8 to 10	1	0.996	0	0.004	0	0.566	-2.71	8.212
10.1.11	1	0.998	0	0.002	0	0.896	-1.742	6.553
10.1.12	1	0.998	0	0.002	0	0.927	-2.059	6.745
10.1.13 to 15	1	1	0	0	0	0.852	-1.893	9.179
10.0.1.2	1	0.59	0	0.41	0	0.103	-3.974	6.933
10.0.3	1	0.997	0	0.003	0	0.879	-2.639	7.717
10.0.5	1	0.995	0	0.005	0	1.214	-2.498	6.209
10.0.6	1	0.983	0	0.017	0	0.515	-3.549	8.526

10.0.7 and 8	3	0.079	0	0.921	0	-0.11	-3.811	4.636
10.0.9	1	0.99	0	0.01	0	0.227	-2.549	8.055
10.0.10	1	0.707	0	0.293	0	0.365	-4.065	6.912
10.0.11	1	0.898	0	0.102	0	0.153	-3.652	7.898
10.0.12 and 13	3	0.197	0	0.803	0	-0.015	-3.831	5.388

Table S3: The classification of samples for the final crop processing analysis (taxa only found uncharred excluded).

Classification table		
	Number of samples	Percentage of samples
Winnowing by-product (1)	28	60.87
Coarse sieve by-product (2)	0	0
Fine sieving by-product (3)	18	39.13
Fine sieving product (4)	0	0

Table S4: Taxa included in the functional weed ecological analysis. All taxa were included in the first preliminary analysis and only charred taxa in the second. For the final analysis discussed in the main text, taxa that were found both uncharred and charred or only charred were included. Here uncharred includes uncharred and 'patchily charred'/'singed', while charred includes 'browed'/charred at a low temperature and fully charred. [x]The functional traits of ecologically similar taxa were merged in three cases. The taxon codes are those given in Stroud et al. 2023.

taxon_codes	**Taxa**	**Preservation**
adonis	*Adonis annua /flammea*[x]	Charred
agrieup	*Agrimonia eupatoria*	Both
agrogit	*Agrostemma githago*	Uncharred
ajugcha	*Ajuga chamaepitys*	Uncharred
anagarv	Anagallis arvensis	Both
arenaria	*Arenaria serpyllifolia*	Uncharred

biforad	*Bifora* cf. *radians*	Both
bromarv	*Bromus arvensis*	Both
bromhorsecarv	*Bromus arvensis/hordaceus/secalinus*[x]	Both
bromhor	*Bromus hordeaceus*	Both
bromste	*Bromus sterilis*	Both
bromtecste	*Bromus sterilis/tectorum*[x]	Both
bromtec	*Bromus tectorum*	Both
camemic	*Camelina microcarpa*	Uncharred
capsbur	*Capsella bursa-pastoris*	Uncharred
chenalb	*Chenopodium album*	Both
corisat	*Coriandrum sativum*	Charred
eupacan	*Eupatorium cannabinum*	Uncharred
euphexi	*Euphorbia* cf. *exigua*	Uncharred
euphhel	*Euphorbia* cf. *helioscopia*	Both
fallcon	*Fallopia convolvulus*	Both
fumaoff	*Fumaria officinalis*	Uncharred
galiapa	*Galium aparine*	Both
galispu	*Galium spurium*	Both
gerapur	*Geranium* cf. *purpureum*	Uncharred
chryseg	*Glebionis segetum*	Both
helieur	*Heliotropium europaeum*	Both
holoumb	*Holosteum umbellatum*	Uncharred
hypeper	*Hypericum perforatum*	Both
lapscom	*Lapsana communis*	Both
malvsyl	*Malva sylvestris*	Uncharred
mentaqar	*Mentha aquatica*	Both
mentlon	*Mentha longifolia*	Both
neslpan	*Neslia paniculata*	Uncharred
origvul	*Origanum vulgare*	Both
polylap	*Persicaria lapathifolia*	Charred
picrhie	*Picris hieracioides*	Uncharred
poa_ann	*Poa annua*	Both
poa_tri	*Poa* cf. *trivialis*	Both
polyavi	*Polygonum aviculare*	Both
rumeacl	*Rumex acetosella*	Uncharred
sangmin	*Sanguisorba minor*	Both
scleann	*Scleranthus annuus*	Uncharred
soncasp	*Sonchus asper*	Uncharred
soncole	*Sonchus oleraceus*	Uncharred
stelmed	*Stellaria media*	Both
thlaarv	*Thlaspi arvense*	Both
tordmax	*Tordylium maximum*	Uncharred

urtidio	*Urtica dioica*	Both
valecor	*Valeriana coronata*	Uncharred
valeden	*Valeriana dentata*	Both
valeloc	*Valeriana locusta*	Uncharred
valerim	*Valeriana rimosa*	Uncharred
verboff	*Verbena officinalis*	Uncharred

Table S5: Output of the final functional weed ecology analysis (taxa only found uncharred excluded). For each sample, the second column lists the model the sample was classified as with (1) being high-input and (2) being low-input. Column 3 and 4 gives the likelihood that the sample was classified as high-input (Prob.1_st) and low-input (Prob.2_st*). Column 5 gives the linear discriminant scores for the function.*

Results and linear discriminant scores:				
Sample no.	**CLASS_std***	**Prob.1_std***	**Prob.2_std***	**LD1***
0.5	2	0.113	0.887	-0.895
0.6 to 0.7	1	0.999	0.001	1.845
0.8	1	1	0	3.062
0.9 and 0.10	1	0.985	0.015	1.055
0.1.2 to 4	1	0.999	0.001	1.989
0.1.8	1	0.801	0.199	0.182
0.1.11	1	0.973	0.027	0.865
0.1.12	1	0.961	0.039	0.749
0.1.13 and 14	1	0.942	0.058	0.619
0.1.15	1	1	0	2.554
0.0.4 to 6	1	0.987	0.013	1.104
0.0.8 to 10	1	0.958	0.042	0.725
0.0.11	1	0.813	0.187	0.206
70.1	1	1	0	2.664
70.3	1	0.993	0.007	1.287
70.4	1	1	0	2.833
70.5 and 70.6	1	0.998	0.002	1.677
70.7	1	0.95	0.05	0.669
70.8	1	0.982	0.018	0.99
70.9	1	0.921	0.079	0.513
70.1	2	0.13	0.87	-0.847
70.10	1	0.957	0.043	0.714

70.12	1	1	0	2.887
70.13	1	0.957	0.043	0.719
70.14	1	0.988	0.012	1.128
10.1.4 to 6	1	0.998	0.002	1.716
10.1.7	1	1	0	2.552
10.1.8 to 10	1	0.946	0.054	0.64
10.1.12	1	0.989	0.011	1.145
10.1.13 to 15	1	1	0	2.466
10.0.1 and 2	1	1	0	2.638
10.0.6	1	1	0	2.633
10.0.7-8	1	0.992	0.008	1.27
10.0.9	1	0.904	0.096	0.45
10.0.10	1	0.968	0.032	0.812
10.0.12 and 13	1	0.998	0.002	1.635

3.0 CHECKING FOR A PULSE: EVIDENCE FOR PROCESSING AND INFESTATION OF BITTER VETCH (*VICIA ERVILIA* (L.) WILLD.) AT LATE NEOLITHIC PLOČA MIČOV GRAD, LAKE OHRID, NORTH MACEDONIA

Holguin, A.[1]; Charles, M.[1]; Panagiotakopulu, E.[2] and A. Bogaard[1]

[1]School of Archaeology, University of Oxford, Oxford, OX1 2PG, UK.

[2]School of GeoSciences, University of Edinburgh, Edinburgh, EH8 9XP, UK

3.1 ABSTRACT

In times of global change and uncertainty, the future of our food systems depends upon diversifying crops. Archaeobotany offers insights into the past use of different plant foods, including lost or neglected crops. Bitter vetch (*Vicia ervilia* (L.) Willd.) is an ancient crop that was once widespread in parts of prehistoric south-eastern Europe and south-western Asia, commonly considered part of the region's Neolithic 'founder crop' package. Within Europe, bitter vetch is particularly common at many Late Neolithic sites in the northern Balkans. Despite its drought-tolerance and low soil fertility requirements, it is now widely neglected and underutilised. Based on its mild toxicity and current limited use as livestock fodder or as a famine food, routine human consumption of bitter vetch by prehistoric communities is open to question. However, processing by leaching, boiling and/or removing the seed coat (dehulling) of bitter vetch can reduce the toxin concentration, enhancing human edibility of

the crop. We present rare evidence for dehulling of bitter vetch seeds for detoxification from the Late Neolithic (c. 4697-4500 to 4436-4257 cal BCE) pile-dwelling site of Ploča Mičov Grad, Lake Ohrid, North Macedonia. We find evidence for the cultivation of bitter vetch, including its infestation by pulse pests attested through damage to seeds and pods, and the earliest published record of the bean weevil, *Bruchus rufipes* Hbst. An abundance of charred bitter vetch seed coats (testa) alongside relatively low numbers of charred seeds suggests that the lakeshore community routinely processed bitter vetch seeds for human consumption. This proposed strategy of detoxification attests to the Late Neolithic community's eco-literacy and resilience to manipulate the properties of a plant food, transforming it from a toxic plant to a safe and nourishing crop. The prehistoric value placed on this now underutilised climate-resilient pulse suggests that bitter vetch should be a focus of further scientific research and public interest, for conservation and cultivation in efforts to diversify food systems.

3.2 KEYWORDS

Ancient crops; archaeobotany; bitter vetch; crop processing; detoxification; pulse crops; pulse pests; bruchids

3.3 INTRODUCTION

Our world is changing and with it, we must change our food systems, looking towards sustainable, climate-resilient, and nutritious food resources, to address increasing food insecurity and protect ecosystem diversity. The FAO reports that, while there are an estimated 30,000 edible plants on earth, three crops (rice, maize and wheat) constitute over 40% of global carbohydrate intakes (FAO, 2018). Over-reliance on a small number of crops increases the fragility of our food systems (Jägermeyr et al. 2021). Widening our food networks to

include a range of valuable crops will increase the stability and security of food production (Massawe et al. 2016). One avenue of this is the revival of 'minor', 'ancient' or 'lost' crops: plant foods which were historically incorporated into human diets, but are now neglected and underutilised, inaccessible or unknown, to consumers on a global scale. Many of these minor or underutilised crops are highly nutritious and can thrive in a range of environments, offering stability in the face of climatic change (Azam-Ali, 2007; Mayes et al. 2012; Massawe et al. 2016; Mustafa et al. 2019).

Archaeobotany provides direct evidence of the viability of different plants as food, offering deep-time evidence of resilience, adaptation or even failure, countering or supporting our current perception of different plant foods. It can also increase and safeguard the genetic diversity of wild and domesticated plant populations in seed collections and gene banks (cf. Goal A of the 2022 COP-15 Biodiversity agreement). Health movements such as the 'Paleo-diet' (regardless of its evidence-basis, Fenton and Fenton 2016; Cambeses-Franco et al. 2021) demonstrate that notions of traditional or (pre-)historic diets have the power to transform public perceptions of different foods and food preparation methods (Chang and Nowell, 2016). Quinoa is a case in point; perceptions of this ancient crop shifted within the last few decades from a 'peasant food' to a global 'superfood', commercialised as 'the Lost Crop of the Inca' (McDonell, 2021), with problematic ecological and social consequences in the Andes (Alandia et al. 2020; Angeli et al. 2020).

Interest in 'lost' and underutilised crops has primarily concentrated upon cereals and pseudo-cereals, such as quinoa, amaranth and millet, which, until recently, were not globally known crops (Massawe et al. 2016). Less attention has been granted to neglected pulse or legume crops. Pulses have been an important part of human diets for millennia, with Neanderthal

dental calculus from Shanidar Cave (Zagros Mountains) demonstrating that pulses featured in diets 50,000 years ago (Henry et al. 2011). They provide a reliable source of protein, energy and fibre, and offer a plethora of health benefits (Hall et al. 2017). In addition to their nutritional properties, pulses are also valued by farmers thanks to their benefits to agricultural eco-systems such as their role within intercropping or rotation systems (Rubiales and Mikić, 2015) and their suitability as a cover crop (Asghar and Kataoka, 2022) due to their nitrogen-fixing abilities (Cho et al. 2003). Owing to their drought tolerance, low soil fertility requirements, disease resistance and health benefits, neglected ancient pulse grains such as vetches are increasingly attracting the attention of researchers working on issues relating to climate change and global food security (Francis et al. 2000; Nguyen et al. 2020). Indeed, Arslan (2019) identified bitter vetch (*Vicia ervilia* (L.) Willd.), along with grass pea (*Lathyrus sativus* L.) as a particularly promising crop due to its climate resilience. As projections of agricultural yields suggests that many major crops (especially maize, soybean and rice) will decline due to increasing aridity, drought-resistant crops are becoming increasingly important (Jägermeyr et al. 2021).

Bitter vetch (*Vicia ervilia* (L.) Willd., Figure 1) has high resistance to drought, tolerates low temperatures and can grow in a range of environments, including on shallow, calcareous, nutrient-poor soils (Enneking et al. 1995; Francis et al. 2000). This pulse is an ancient crop, once part of the Neolithic 'founder crop' package and identified at many prehistoric sites in southeastern Europe and in southwestern Asia (Renfrew, 1973; Kislev and Bar-Yosef, 1988; Zohary and Hopf, 1994; Mikić et al. 2015; Liber et al. 2021; Ljuština and Mikić 2010; Mikić, 2016). Within Europe, bitter vetch became prominent during the Late Neolithic in the northern Balkans (Filipović et al. 2022; de Vareilles et al. 2022). Despite its widespread prehistoric cultivation, nowadays limited bitter vetch cultivation occurs in areas of northern

Africa, the Mediterranean and Turkey, primarily as livestock fodder (Abdullah et al. 2010). Its current absence from human diets may relate to its harmful properties; bitter vetch is a mildly toxic pulse with concentrations of the toxin canavanine ranging from 0.04-0.11% (Berger et al. 2003: 201). The toxicity of bitter vetch is relatively low, compared to many other *Vicia* species (Table 1; Francis et al. 2000). While ruminant livestock are largely unaffected by this toxin when consumed in moderation, consumption by monogastric livestock can be fatal (e.g. pigs Southall, 1879; Werner, 1934; Jean-Blain, 1949). Human consumption of unprocessed (or insufficiently processed) bitter vetch can cause sickness, such as vomiting, bowel problems and headaches (Enneking, 1994). However, unlike incurable conditions such as lathyrism caused by toxins in the genus *Lathyrus* (Khazaei et al. 2019), the symptoms of moderate bitter vetch consumption by humans, while unpleasant, are generally short-term (Enneking et al. 1995).

Table 1: Comparison of the toxicity and uses of different vetches adapted from Francis et al. (Tables 2-4, pgs. 3, 5 and 6; 2000). Abbreviations: CAN = canavanine, V-C = vicine-convicine, GEC = gamma glutamyl-S ethenyl-cysteine. [1]Khazaei et al. (2019). [2]V. faba can be dangerous (even fatal) for individuals who are G6PD-deficient (Khazaei et al. 2019).

***Vicia* species**	**English name**	**Toxin**	**Seed toxin level**	**Known uses**
V. articulata	One-flowered vetch	CAN	Low-moderate	Grain; Fodder
V. benghalensis	Purple vetch		High	Fodder
V. ervilia	Bitter vetch	CAN	Low-moderate	Grain; Fodder
V. faba	Broad bean	V-C[1]	Low-high[2]	Grain
V. hybrida			Low-moderate	
V. monantha		CAN	Moderate-high	Grain
V. narbonensis	Narbonne vetch	GEC	Low?	Grain; Fodder
V. pannonica	Hungarian vetch		Low	Grain; Fodder
V. sativa	Common vetch	BCNA	Moderate-high	Grain; Fodder
V. villosa	Hairy vetch	GEC, CAN	High	Fodder

The prevalence of bitter vetch at Late Neolithic sites in south-eastern Europe raises the question of how this crop was viewed and used in prehistory. Due to its toxicity and current neglect as a human food, it could be inferred that bitter vetch was grown as livestock fodder or consumed only as a last resort in the past (Zohary et al. 2012; Valamoti, 2023). For example, de Vareilles et al. (2022) hypothesised that bitter vetch's prevalence in the northern Balkans related (at least in part) to its use as a fodder, which they link to an increase in cattle and pig husbandry. However, its abundance at many prehistoric sites (e.g. at Late Neolithic Dikili Tash), has led other researchers to argue that bitter vetch was consumed by human populations after detoxification processes (e.g. van Zeist, 1988; Valamoti et al. 2011; Valamoti, 2023) Indeed, the consumption of plants by humans and animals need not be mutually exclusive (Jones, 1998).

Methods such as leaching in water, boiling and/or roasting are mentioned in historic texts as methods to reduce toxins and render bitter vetch seeds edible (Southall, 1879; Flint-Hamiliton, 1999; Enneking, 1994). Such methods have been experimentally proven to be an effective way to reduce toxins in pulses (Kumar et al. 2022). Sarma and Padmanaban (1980) report that practices including boiling, soaking and drying can remove up to 80% of toxins from pulses. The detoxification of bitter vetch has been historically and ethnographically documented. For example, bitter vetch has been occasionally consumed during times of food shortage in Afghanistan (Fitzherbert, 2014) and (in the 1950s) in Morocco (Enneking et al. 1995). In both cases, bitter vetch was first treated with water to remove toxins. In Morocco, the seeds were also dehulled by hand-rubbing to remove the toxin-rich seed coat (Enneking et al. 1995). El Fatehi and Ater (2017) list numerous references to the use of bitter vetch in Morocco and Spain as an ingredient in porridges, soups, breads, and mashes dating from the medieval period to modern times, with references to detoxification practices including

soaking and dehulling. At present, there is little archaeological evidence for the detoxification of bitter vetch. Experimental work has suggested that the inner cotyledon morphology of bitter vetch seeds can be used to infer whether the seeds were processed with water. This could provide evidence of detoxification, as was argued in the case of the Early Bronze Age site of Agios Athanasios, Greece (Valamoti et al. 2011).

At the Late Neolithic pile-dwelling settlement of Ploča Mičov Grad (Lake Ohrid, North Macedonia), three pulses have been recovered: bitter vetch, lentil and pea. More than three times as many charred pulse seed coats with the hilum (the attachment point, Figure 1) were identified than charred pulse seeds. The majority (122 of the detached seed coats with hilum) were identified as bitter vetch, while only 14 bitter vetch seeds were recovered (Figure 1). As pulse seed coats are more fragile than the robust pulse seed, this ratio is highly unusual and unexpected. We have found only one record of such a disparity in archaeological publications, regarding desiccated (uncharred) pulse remains from pre-Hispanic Gran Canaria (Morales et al. 2014). At this site, Morales et al. (2014) suggest that insects and animal pests were responsible for the abundance of pulse seed coats and the lack of pulse seeds, based on evidence for cereal pests in the same assemblage. As such, this paper tests two hypothesises to explain the abundance of pulse seed coats.

Hypothesis 1: The large numbers of charred pulse seed coats with hila relative to the charred pulse seeds relates to pest infestation. Pulse pests consumed the pulse seed leaving only the pulse seed coats.

Hypothesis 2: The large numbers of charred pulse seed coats with hila relative to the charred pulse seeds relates to food preparation and detoxification. The toxin-rich pulse seed

coat was removed and discarded, while the pulse seed was consumed by the Late Neolithic population.

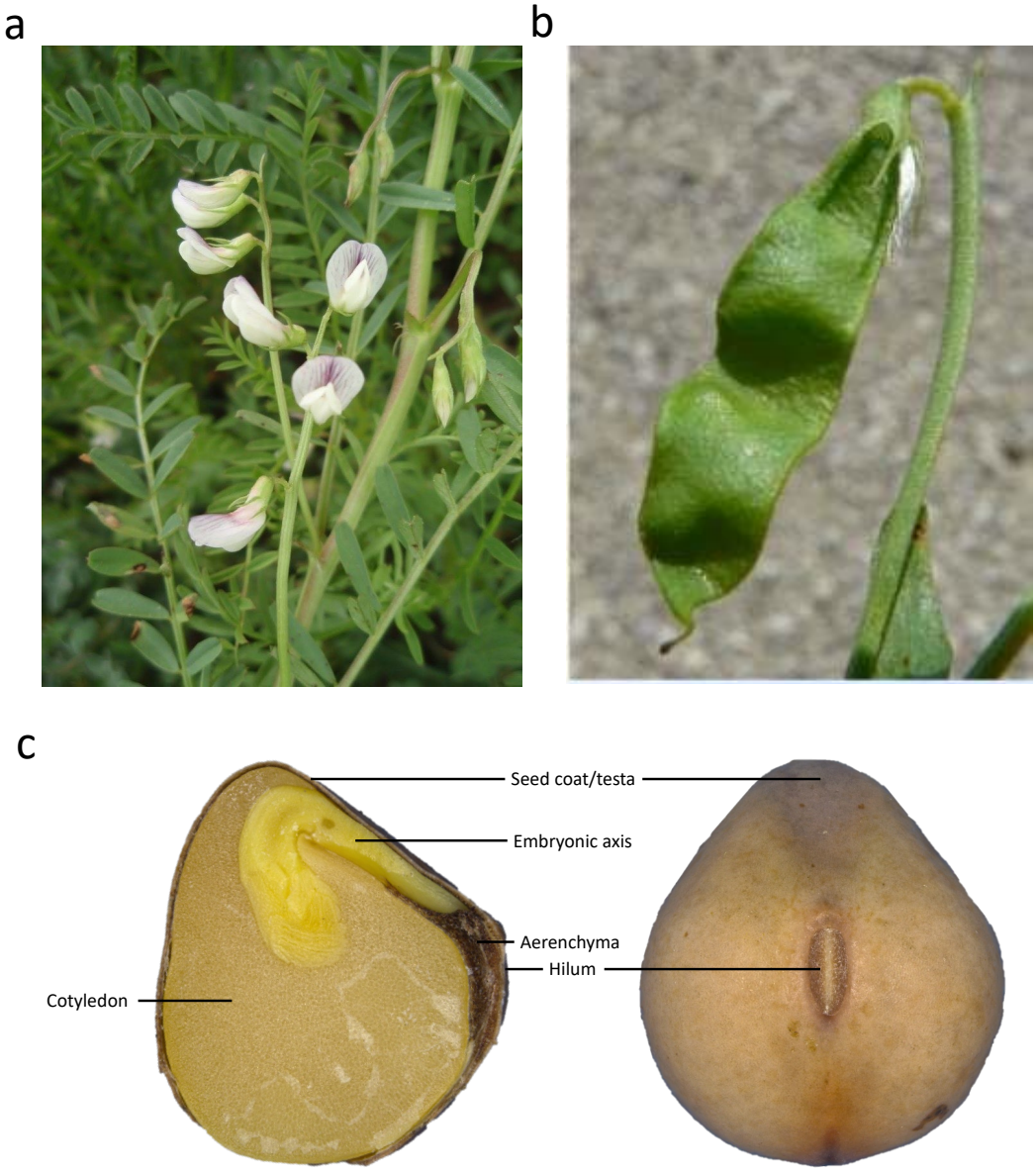


Figure 1: Bitter vetch. A. A bitter vetch plant and b. a bitter vetch green pod (photos: Alchetron, The Free Social Encyclopedia, 2023). C. labelled diagram of the longitudinal cross-section (left) and ventral view (right) of a modern bitter vetch seed showing key anatomical features (A. Holguin).

3.4 . ARCHAEOLOGICAL CONTEXT

First identified by local fisherman in the 1970s, the submerged pile-dwelling site of Ploča Mičov Grad (the eastern shore of Lake Ohrid, North Macedonia; Figure 2) has been the subject of archaeological enquiry since the late 1990s (Kuzman, 2013; Hafner et al. 2021). From 2019, this pile-dwelling site has been under investigation as part of the ERC Synergy EXPLO project, designed to explore the early agricultural settlements in wetland areas of the southwest Balkans (Hafner et al. 2021). Sediment cores were extracted from the settlement area by the project's palaeoecological team from the University of Bern. Four cores were the focus of the archaeobotanical analysis. These cores contained a rich organic cultural layer, extending up to 1.5 m thick, with well-preserved waterlogged macroscopic botanical remains (Paper 1 of this thesis). Radiocarbon analysis of short-lived botanical remains from the sediment cores indicated that the organic layer accumulated between c. 4697-4500 to 4436-4257 cal BCE. The radiocarbon chronology is refined further by dendrochronological dating of the vertical wooden piles, which suggests continuous settlement activity for at least 87 years based on the approximated tree-felling dates with a median end-date of 4350 cal BCE (Bolliger et al. 2023). A Middle Neolithic phase and a later Bronze Age phase have also been identified at the site. However, all material discussed in this paper dates to the Late Neolithic settlement phase in the mid-5th millennium cal BCE. Details of coring, sampling and sample processing can be found in Paper 1 of this thesis.

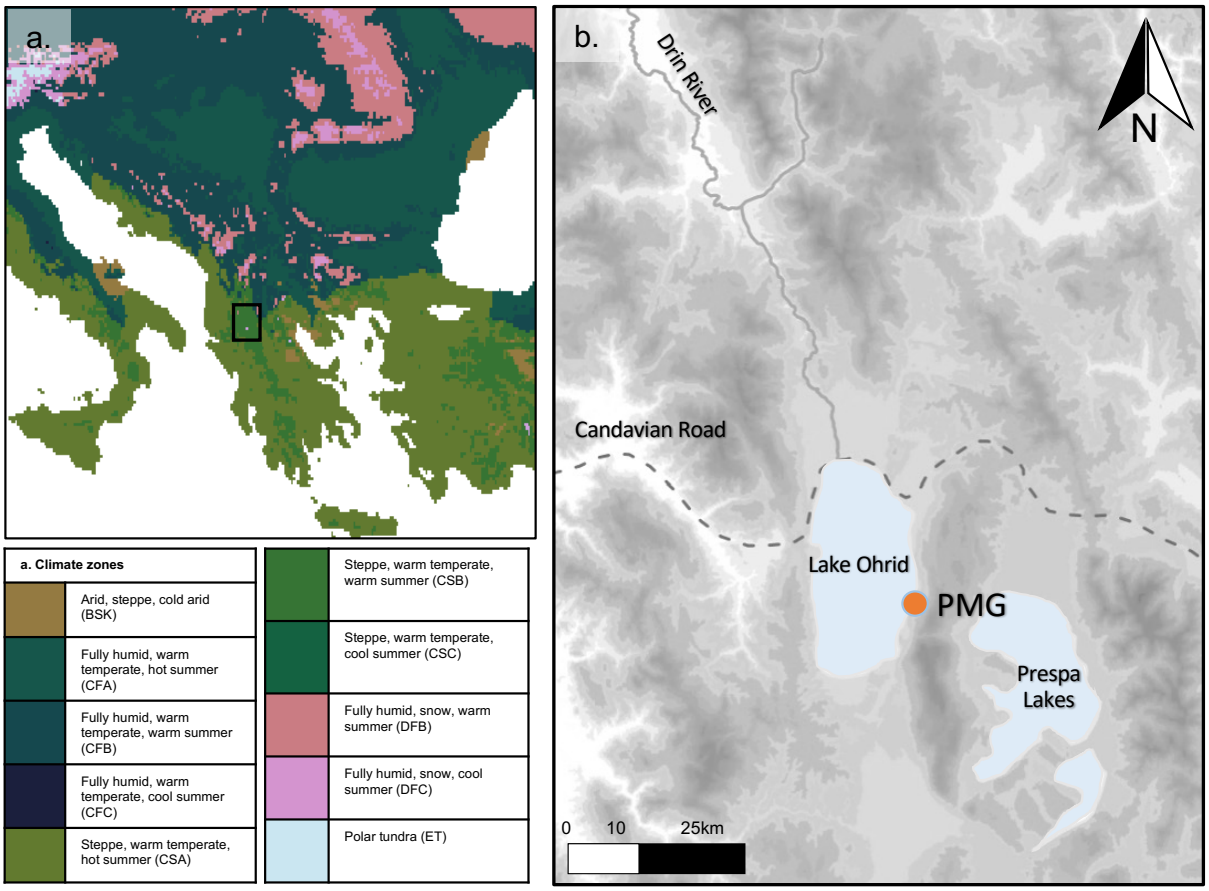


*Figure 2: The site of Ploča Mičov Grad lies on the eastern shore of Lake Ohrid, North Macedonia. (*b*), located within the steppe, warm temperate, warm summer Köppen-Geiger climate zone (*a*). Köppen-Geiger climate classification after Kottek et al. (2006) downscaling after Rubel et al. (2017) © Climate Change & Infectious Diseases Group, Institute for Veterinary Public Health, Vetmeduni Vienna, Austria. Elevation data from USGS Global Multi-resolution Terrain Elevation Data.*

As the site is fully submerged, all organic material had been preserved in anaerobic waterlogged conditions. Most botanical remains were uncharred. However, some partially charred, and fully charred plant remains were also recovered. The pulse remains included an abundance of uncharred (and some charred) pulse pod fragments and a small number of charred pulse seeds identified as bitter vetch (*Vicia ervilia* (L.) Willd.), lentil (*Lens culinaris*

Medik) and pea (*Pisum sativum* L.), as well as many charred pulse seed coat fragments with diagnostic hila (attachment points). Some uncharred or partially charred (n=225) pulse hila were also recovered from Ploča Mičov Grad. However, without charring the starch-rich pulse seeds rarely survive in anaerobic waterlogging conditions (Vandorpe and Wick, 2015). Thus, an abundance of uncharred seed coat fragments relative to (uncharred/partially charred) pulse seeds is an expected consequence of the waterlogging of uncharred pulses. Therefore, in this paper only pulse seeds and seed coats are considered that had become charred prior to waterlogging.

3.5 MATERIALS AND METHODS

3.5.1 ARCHAEOBOTANICAL PULSE REMAINS:

All pulse macrofossils were examined using a low-powered microscope (x6.3-50). Pulse remains were identified through comparison with the seed reference collection in the Archaeobotany Laboratory at the Institute of Archaeology, University of Oxford, and aided by images and descriptions in reference publications (Butler, 1990; Bojňanský and Fargašová, 2007). The pulse macrofossil counts can be found in Table 2.

i. Charred pulse seeds

Bitter vetch seeds (*Vicia* ervilia (L.) Willd.) were identified based on their angular/triangular shape and (if present) small oval hilum (Butler, 1990, Figure 3 a). The hila attached to the bitter vetch seeds were small and oval in shape with an average length of 0.66±0.08mm and an average width of 0.41±0.07mm. This was comparatively small but broadly within the range known for archaeological bitter vetch hila (e.g. c. 1.2±0.5mm in length; Caracuta et al. 2017, p.10). All of these charred seeds had a shiny or glassy, dense appearance to the parenchyma

matrix, sometimes with a bubbly appearance. Some single cotyledons of bitter vetch were also identified based on their triangular shape.

A small number of pea seeds (cf. *Pisum sativum* L.) were tentatively made. These were spherical in shape but were poorly preserved preventing confident identifications (Figure 3 b). None of the pea seeds had a preserved hilum.

Lentil seeds (*Lens culinaris* Medik) were identified based on their lenticular shape (Butler, 1990; Figure 3 c). When present, the hilum was longer (1.07mm) and narrower (0.33mm) than those identified as bitter vetch. These were similar to other archaeological specimens (e.g. *Lens* sp. identified in Caracuta et al. (2017, p.7) had an average length of 0.9±0.1 mm).

Some pulse seeds fragmented preventing identification to genus/species. These were identified as indeterminate pulses. They were relatively large and so it is likely that these remains are of a pulse crop such as bitter vetch, lentil or pea.



Figure 3: Late Neolithic charred pulse macrofossils from Ploča Mičov Grad. A. Vicia ervilia seed with hilum intact, b. broken cf. Pisum sativum seed without hilum, c. Lens culinaris seed with hilum intact, d. detached Vicia ervilia seed coat with hilum, e. detached cf. Pisum sativum seed coat with hilum, f. detached Lens culinaris seed coat with hilum, g. cross-section of Vicia ervilia

hilum showing triangular aerenchyma layer and h. cross-section of cf. Pisum sativum hilum showing curved aerenchyma layer.

ii. Charred detached pulse seed coats with hila

Identification of the charred detached pulse seed coats with hila was based on the size and shape of the hila and the shape of the aerenchyma directly underlying the hila. Some hila could not be identified to genus/species due to preservation. The elongated size and shape of lentil hila were easy to distinguish from the hila of pea and bitter vetch (Figure 3 f). Informed by the description of bitter vetch seeds in Butler (1990) and comparison with modern reference material, the aerenchyma tissue directly below the hilum was determined to be diagnostic, with an angularity/triangularity distinctive of bitter vetch (Figure 3 g) and a rounded appearance in pea (Figure 3 h). Based on the width and length of the archaeological detached hila, a correlation was observed between the size of the hila and shape of the aerenchyma tissue, with smaller hila having a triangular aerenchyma layer.

The size and shape of the archaeological detached hila was compared to the archaeological seeds (with intact hila and identified to species). The detached hila with a triangular back matched the size and shape of the hila still attached to the archaeological bitter vetch seeds (further details in Supplementary Materials). This supported the identification of the smaller, triangular-backed hila as bitter vetch (Figure 3 d) and the larger, curved-backed hila as pea (Figure 3 e).

Some detached pulse seed coats without hila were also identified based on the presence of the two key layers (the outermost layer of palisade cells and the innermost hyperdermis of thick-walled osteosclereids cells, Braadbaart et al. 2004). These two cell layers could be seen in cross-section at higher magnifications using a low-powered microscope.

All photos of pulse seeds and pulse hila were taken using a Leica Z6 AP0 camera and LAS Core software. All pulse hila were measured using this camera and software.

While a number of detached hila were identified as probably pea, only one seed compared well with pea. As such, the focus of this paper will be on the more numerous and confidently identified finds of bitter vetch. The significance of pea is briefly considered in the discussion.

Table 2: Numbers and totals of pulse macrofossils identified in each of the four cores.

Taxa	**Part**	**Totals**	**Core TLM190 total**	**Core QLM190 total**	**Core QLM1910 total**	**Core TLM1970 total**
Detached seed coat with hilum						
Vicia ervilia (L.) Willd.	Hilum	122	47	14	22	39
cf. *Pisum sativum* L.	Hilum	41	32	3	3	3
Lens culinaris Medik.	Hilum	9	0	2	1	6
Unidentified	Unidentified hilum	54	28	4	9	13
	All detached hilum	**226**	**107**	**23**	**35**	**61**
Seeds						
Vicia ervilia (L.) Willd.	Whole seed with hilum	6	1	1	3	1
	Whole seed without hilum	3	1	1	0	1
	Whole cotyledon	5	3	1	0	1
	All *V. ervilia* seed	14	5	3	3	3
cf. *Pisum sativum* L.	Whole seed without hilum	4	0	0	4	0
	All cf. *P. sativum* seed	4	0	0	4	0
Lens culinaris Medik.	Whole seed with hilum	1	0	0	1	0
	Whole seed without hilum	4	1	0	2	1
	Whole cotyledon	0	0	0	0	0
	Fragment	4	0	2	4	1

	All *L. culinaris* seed	12	1	2	7	2
	Unidentified pulse seed fragments	38	9	12	11	6
	All pulse seed	**68**	**15**	**17**	**25**	**13**

3.5.2 ENTOMOLOGICAL REMAINS

Entomological remains were recovered from one core (QLM19 0). Conspicuous large insect remains were picked out during archaeobotanical sorting. The samples were then processed using paraffin flotation to recover all insect remains in the School of GeoSciences at the University of Edinburgh by E. Panagiotakopulu. Insect remains were identified in comparison with reference material held at the School of GeoSciences.

3.5.3 MODERN SPECIMENS

Three accessions of bitter vetch seeds (*Vicia ervilia* (L.) Willd.), three of common pea (*Pisum sativum* L.) and three of lentil (*Lens culinaris* Medik.) were examined (Table 3). These accessions had been collected by researchers and kept in storage at the School of Archaeology, University of Oxford. The authors of this paper verified their identifications through comparison with reference material held at the School of Archaeology and relevant publications (Butler, 1990; Bojňanský and Fargašová, 2007).

Table 3: The modern accessions used in this study.

	Origin	**Plant items**	**Notes**
Bitter vetch (*Vicia ervilia* (L.) Willd.*)*	Bellota, Morocco	Seeds	Some seeds with insect damage. Bean weevils in with seeds. Used in the dehulling experiments
	Jordan	Seeds, pod, stem	

	Archaeobotany Lab reference collection	Seeds, pod, stem	
Common pea (*Pisum sativum* L.)	Evvia, Greece	Seeds, pod, stem	
	Asturias, Spain	Seeds, pod, stem	
	Archaeobotany Lab reference collection	Seeds, pod, stem	Some seeds with insect damage. Bean weevils in with seeds.
Lentil (*Lens culinaris* Medik.)	Archaeobotany Lab reference collection	Seeds, pod, stem	Some seeds and pods with insect damage. No bean weevils still present.
	Sakha Agri	Seeds, pod, stem	
	Archaeobotany Lab reference collection	Seeds, pod, stem	

3.5.4 DEHULLING EXPERIMENTS

Modern bitter vetch seeds from Bellota, Morocco, were dehulled and charred to compare with the archaeological charred seeds and detached seed coats. The parameters were chosen based on the bitter vetch dehulling method from 1950s Morocco described by Enneking et al. (1995), charring studies (Charles et al. 2015; Nitsch et al. 2015) and feasibility. Three different experiments were performed. In Experiment A, the seeds were soaked for 24 hours in tap water. This directly followed Enneking et al.'s (1995) observations. The seed coats were then removed by rubbing the seeds by hand. Hand-rubbing of seeds was described by Enneking et al. While some methods dry seeds prior to this stage (e.g. in Enneking et al. 1995), the seeds were not dried prior to hand-rubbing as the seed coats proved exceedingly easy to remove while still wet. The seeds and detached seed coats were patted dry and then heated to 25°C for 10 hours in a high-precision Gallenkamp oven at the School of Archaeology, University of Oxford. This mimicked the sun-drying described in Enneking et al. The seeds and detached seed coats were charred in glass beakers placed centrally in the oven pre-heated to 260°C for

two hours. The temperature and time were selected based on experience of temperature-time conditions to generate experimental material that compares well with archaeological remains. The temperature of the oven was monitored using a Thermosense thermocouple datalogger with four sensors to ensure it was consistent. In Experiment B, the experimental procedure was the same as Experiment A, except after soaking and dehulling, the seeds were not 'sundried' (by heating to 25°C for 10 hours). In Experiment C, the seeds were charred after soaking for 24 hours without being dehulled or dried.

Table 4: Details of the three experiments on modern bitter vetch seeds.

Experiment	Number of seeds	Soaking (24 hours)	Dehulling	Drying (10 hours, 25° C)	Charring (2 hours, 260° C)
A	10	Yes	Yes	Yes	Yes
B	10	Yes	Yes		Yes
C	10	Yes			Yes

3.6 RESULTS

In total, 226 archaeological charred seed coats of pulse with hila were present relative to 68 charred pulse seeds, a ratio greater than 3:1. These macrofossils were distributed across all four sediment cores extracted from the settlement vicinity and analysed for archaeobotanical research. Many detached seed coats with hila (n=122) were identified to bitter vetch, compared to a small number (n=14) of bitter vetch seeds. Even when the unidentified seeds are considered, there were far more bitter vetch seed coats with hila than seeds (Figure 4). In some samples, bitter vetch seed coats with hila were recovered, in the absence of bitter vetch

or unidentified pulse seeds. The frequency of the seed coats suggests that they reflect a recurrent activity across the settlement's Late Neolithic occupation.

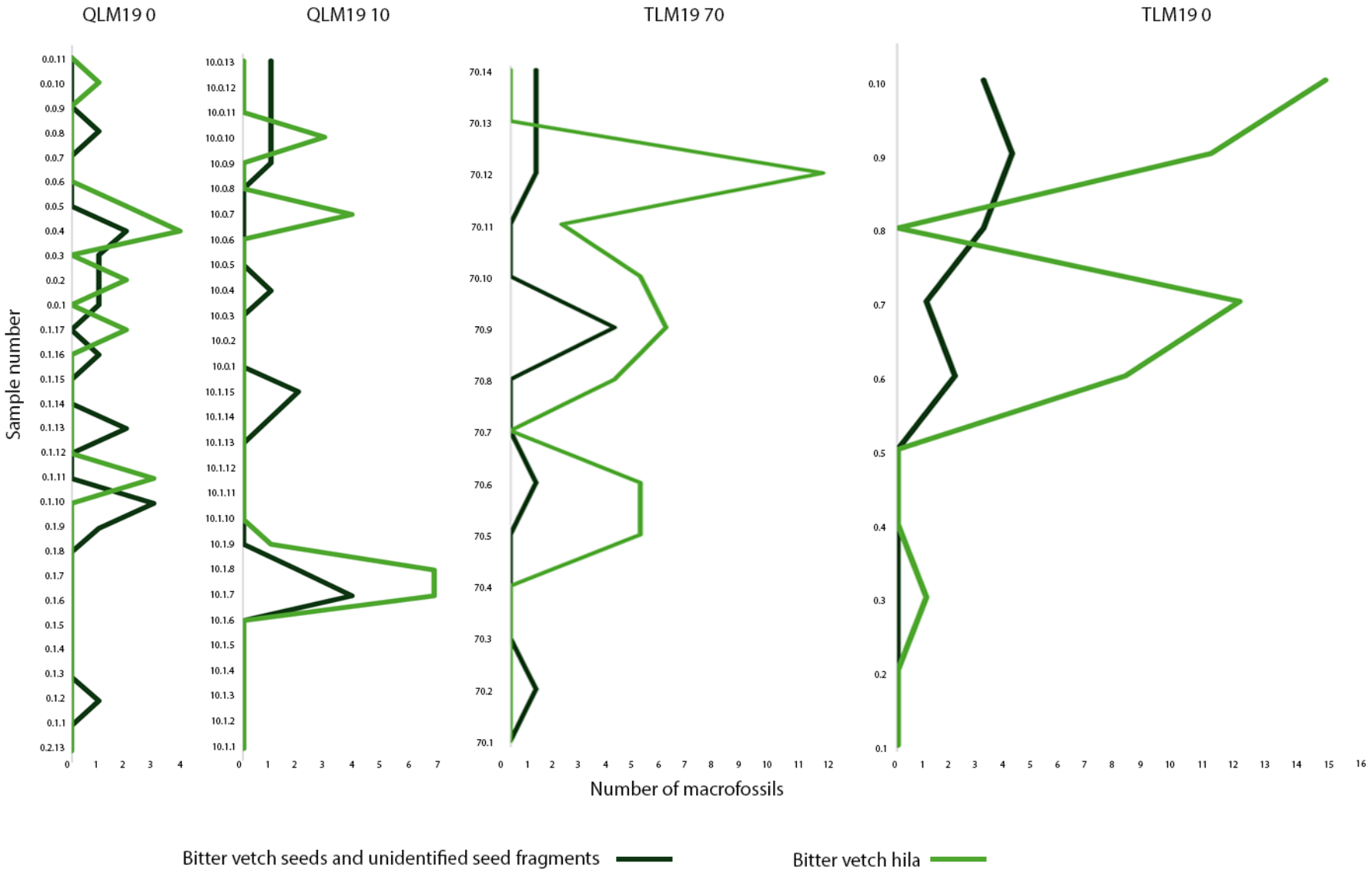

QLM19 0
QLM19 10
TLM19 70
TLM19 0
Sample number
Number of macrofossils
Bitter vetch seeds and unidentified seed fragments
Bitter vetch hila

Figure 4: Line graph of charred bitter vetch seeds and charred bitter vetch hila counts. The number of bitter vetch seeds and unidentified seeds (dark green) compared to the number of detached bitter vetch hila (light green) in each sample for each of the four sediment cores subject to archaeobotanical analysis. The samples are ordered by depth with lower samples on the y-axis pertaining to samples lower in the sedimentary sequence.

3.6.1 RESULTS ADDRESSING HYPOTHESIS 1: PEST INFESTATION

i. Archaeological macrofossils

For Core QLM19 0, several elytra were recovered that were identified to the bean weevil genus (*Bruchus* sp.). One thorax was identified as *Bruchus rufipes* Hbst (Figure 5 c). This is a preliminary result. Full quantification of the insect remains is forthcoming. One bitter vetch cotyledon was partly hollowed out in what appears to be a borehole made by an insect pest (Figure 5 f). Archaeological uncharred pulse pod was recovered from almost every sample (>12 mm^2, n=921, Paper 1 of this thesis). Two fragments of pulse pod from the same sample (70.11) in core TLM19 70 had sub-circular holes measuring c. 0.15 mm in diameter, with a ring of discolouration (Figure 5 h and i).

ii. Modern comparative material

Many of the bitter vetch seeds from Bellota, Morocco had boreholes due to insect damage. These seeds were collected as part of field surveys to generate baseline data on arable weed compositions and crop stable carbon and nitrogen isotopic values (Bogaard et al. 2018). Infested seeds were not intentionally collected. Fifteen bruchid beetles were accidentally collected with the seeds (Figure 5 b). Subsequent to their collection, some of these bruchids remained buried within the bitter vetch seeds (Figure 5 a). Fifteen of the seeds had a single

large borehole and the bruchid 'exit' holes in all of these seeds were positioned approximately 2 mm below the hilum (Figure 5 a, d and e). Approximately 50% of the starch-rich cotyledon had been consumed by the bean weevil. Excluding the 'exit' hole, a thick border of parenchyma was left unconsumed at the cotyledon's edge. The seed coat was not consumed by the bruchids. Circles of seed coat were found matching the size and shape of the exit hole. This fits with descriptions and images of bean weevils 'chiselling' a window of seed coat through which they then push to leave the seed (Teshome et al. 2015).

Several pulse pods in one of the modern lentil accessions had small (0.1-0.2 mm) holes (Figure 5 g). In these accessions, there was also clear evidence for pest infestation with many seeds having boreholes. These holes were likely caused by the bruchid larvae burrowing through the pod into the seed, matching descriptions in Laserna-Ruiz et al. (2012) of a c. 0.1-0.2 mm round hole, and images in Teshome et al. (2015).

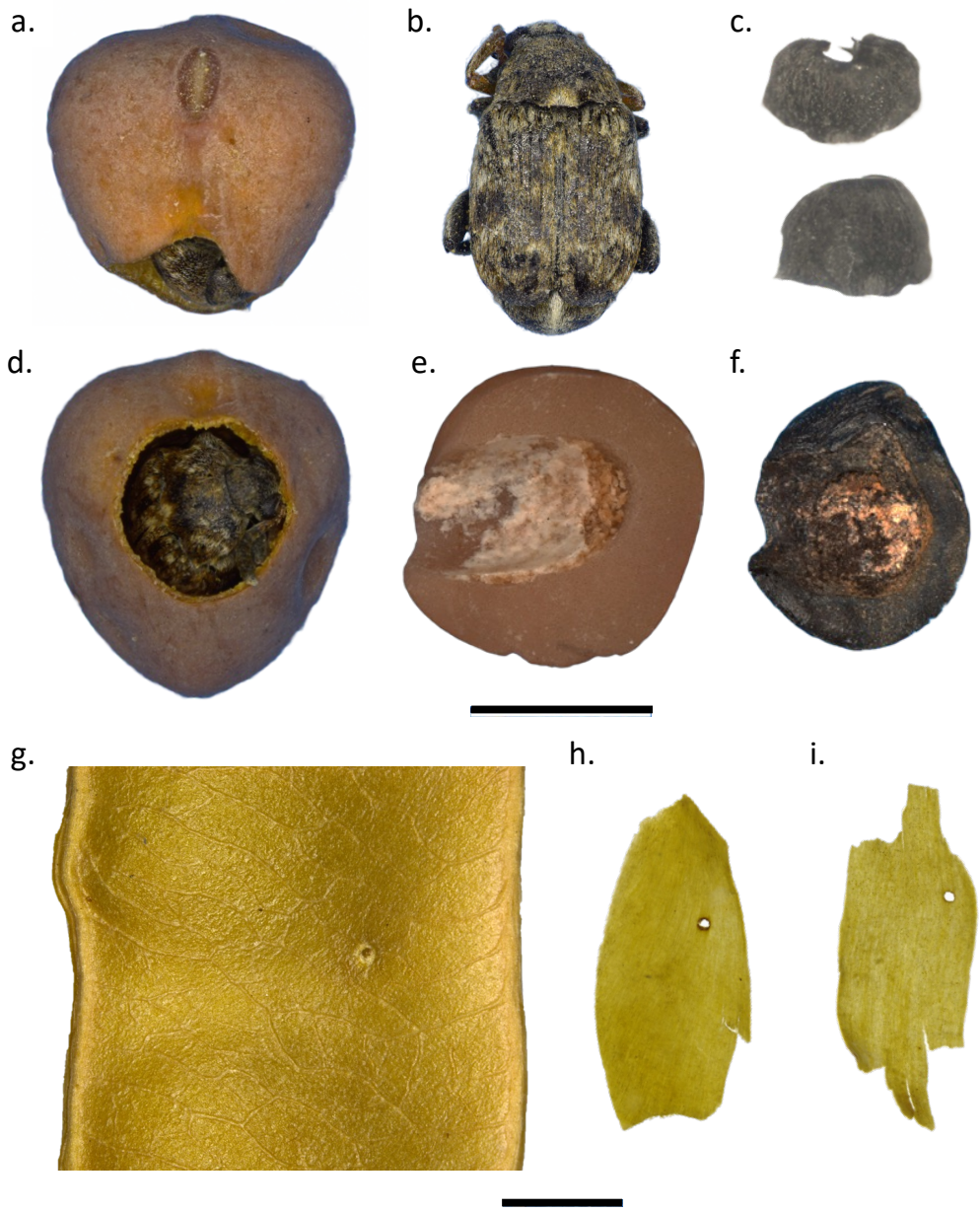


Figure 5: Pulse pests in bitter vetch. A. and D. two views of a modern bitter vetch seed with a bruchid within the seed. B. a modern bruchid. C. two views of the archaeological thorax of Bruchus rufipes Hbst. from Ploča Mičov Grad. E. a modern cotyledon with a borehole from a bruchid. F. an archaeological charred cotyledon with borehole from a bruchid from Ploča Mičov Grad. Scale bar is 2 mm. G. modern lentil pod with a pest entrance hole. H. and I. two fragments of archaeological pulse pod from Ploča Mičov Grad showing c. 0.15 mm sub-circular holes. Scale bar is 2 mm. (A. Holguin and E. Panagiotakopulu).

3.6.2 RESULTS ADDRESSING TO HYPOTHESIS 2: PULSE PROCESSING

i. Archaeological macrofossils

Some of the archaeological charred detached seed coats with hila were curled inwards, some were curled outwards, and some showed no or minimal curling or undulation (Figure 6 a). The majority of pieces of seed coat without hila were small and flat. However, some were curled outwards and others curled inwards. Some pieces were curled inwards to the extent that they almost formed a cylinder (Figure 6 e).

ii. Modern comparative material

Observations at each stage of the three experiments can be found in Table 5. The results of Experiments A and B were indistinguishable. The detached bitter vetch seed coats in Experiment A and B were easily removed following soaking for 24 hours and rubbing by hand. It took less than 3 minutes to remove the seed coats of all twenty seeds. The two cotyledons often separated during this process (Figure 6 d and h). The pieces of detached seed coat curled upon re-drying at room temperature (in Experiment A) or after charring (in Experiment A and B). Some fragments curled to the extent that they became cylindrical (Figure 6 f). In some detached fragments, the seed coat around the hilum had an undulating appearance (Figure 6 b). In some seeds in experiment C (not dehulled), the seed coat cracked and curled outwards. The seed coats (still attached to seeds) in Experiment C remained flat and did not curl inwards.

Table 5: Observations at each stage of the three processing experiments. Steps not included for certain analyses are labelled N/A.

Experiment	**Soaking**	**Dehulling**	**Re-drying (10 hours, 25° C)**	**Charring (2 hours, 260° C)**
A	Seeds expanded in size	Seed coats were quick and easy to remove (<3 minutes for 20 seeds). Some seeds split into cotyledons.	The detached seed coat curled inwards.	The detached seed coat curled inwards. Some seeds appeared glassy.
B	Seeds expanded in size	Seed coats were quick and easy to remove (<3 minutes for 20 seeds). Some seeds split into cotyledons.	N/A	The detached seed coat curled inwards. Some seeds appeared glassy.
C	Seeds expanded in size	N/A	N/A	Some seed coats cracked. Some seed coats curled outwards.

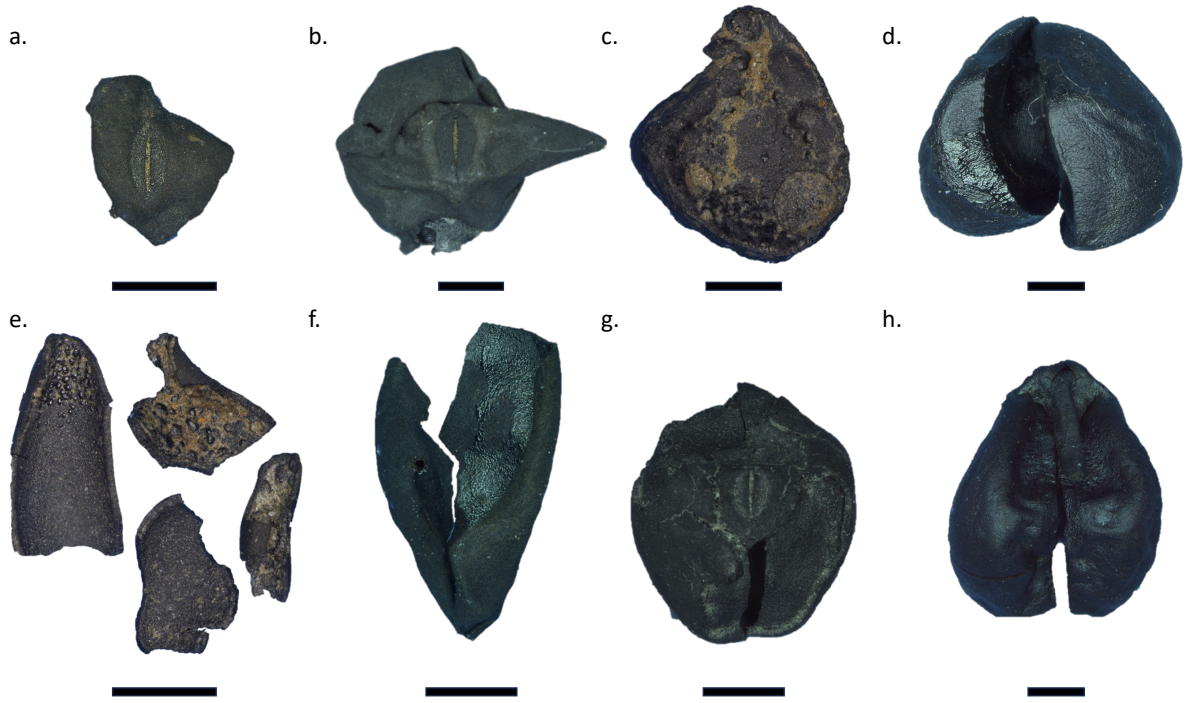


Figure 6: Bitter vetch detoxification. Images a., c. e. and g. are of archaeological specimens from Ploča Mičov Grad. Images b., d., f. and h. are of modern experimentally dehulled specimens. A. archaeological hilum with some curling and undulating of seed coat, b. modern experimentally dehulled dried seed coat, c. archaeological single bitter vetch cotyledon, d. and h. modern experimentally dehulled bitter vetch seed separating into two cotyledons, e. four inwardly curled pieces of archaeological pulse seed coat, f. inwardly curled piece of modern experimentally dehulled seed coat, g. archaeological bitter vetch seed with seed coat still attached but with cotyledons separating. All scale bars are 1 mm.

3.7 DISCUSSION

The high number of fragile charred pulse seed coats (with hila) relative to the more robust seeds (a ratio greater than 3:1) at Ploča Mičov Grad is an unusual find. The majority of the charred seed coats with hila have been identified as bitter vetch. Their presence across the

four sediment cores analysed in Paper 1 suggests that they represent a recurrent activity. Two hypotheses were considered to explain this observation.

Hypothesis 1: The large numbers of charred pulse seed coats with hila relative to the charred pulse seeds relates to pest infestation. Pulse pests consumed the pulse seed leaving only the pulse seed coats.

We find evidence for pulse pests at Ploča Mičov Grad. Elytra and thorax from bruchids (*Bruchus* sp.) show that pulse pests were present. The thorax has been identified as belonging to *Bruchus rufipes* Hbst., a bruchid associated with vetches (*Vicia* spp., Borowiec, 1987; Delobel and Delobel, 2006) and grass peas (*Lathyrus* spp.; Anton et al. 1997). This is the earliest published record of *Bruchus rufipes* Hbst. The earliest previously reported find of *Bruchus rufipes* Hbst. comes from Akrotiri, Santorini dating to c. 3200-2300 BCE (Panagiotakopulu et al. 2013). A borehole in a charred single cotyledon of bitter vetch from Ploča Mičov Grad supports the inference that pests were targeting the pulse crops at the site. Approximately 50% of the seed cotyledon has been consumed by the bruchid larva. An exit hole shows that the bruchid larva successfully developed into a mature beetle and left the seed. McDonald (1995, cited in Teshome et al. 2015) suggests that it takes two to three months following harvest for more than 50% of the seed to be consumed. The mature beetle may then exit the seed or over-winter inside the seed (Antolín and Schäfer, 2020.) This perhaps suggests then that the bitter vetch seed had been stored for at least two to three months before charring.

The extent of archaeological pest infestation is hard to assess. As infestation takes place in the field and as infested pods are more likely to shatter dropping their seeds in the field, it is likely that many infested seeds are not harvested and so do not become charred (Teshome et al.

2015). A small entrance hole on pulse pods (as found on modern infested lentil pods in this study) is evidence of infestation (Laserna-Ruiz et al. 2012; Teshome et al. 2015). On two pieces of pulse pod from Ploča Mičov Grad small (c. 0.15 mm) sub-circular holes were found in otherwise relatively well-preserved pulse pod fragments. These holes appear to be cut-out, rather than the result of a puncture with a ring of discolouration (Figure 5 h and I) and compare well to modern infested pods (Figure 5 g). It is possible that these holes are entrance points, offering rare evidence for an early step in the pest infestation process.

The abundance of pulse pod at the site suggests that pulse crops were likely harvested and possibly, at least for a time, stored in their pods. Altogether the bruchid remains, the borehole in a bitter vetch cotyledon and possible entrance holes on pods strongly suggest that bruchid pulse pests were present and perhaps a challenge to Late Neolithic communities. As such, we can start to consider the ways that Late Neolithic populations may have addressed this, perhaps using repellents, trap crops and processing methods such as panning to reduce the number of infested seeds in store (Antolín and Schäfer, 2020). Alternatively, it is possible that pulse pests were not viewed as a problem to Late Neolithic populations, and instead infested seeds may have been consumed indiscriminately offering additional protein (Panagiotakopulu and Buckland, 1991).

That considered, it appears unlikely that pulse pests account for the abundance of pulse seed coats relative to pulse seeds at this site. The archaeological bitter vetch cotyledon with a borehole shows that the bruchid left the seed after consuming about 50% of the starch-rich cotyledon. The same observations regarding largely intact seeds/cotyledons were made in modern bitter vetch seeds with bruchid infestation collected during weed and isotopes survey in northern Morocco. A thick border of parenchyma remained surrounding the central cavity.

The seed coat had over c. 0.5 mm of parenchyma left directly below it and at all parts except the exit hole. This finding fits well the modern infested bitter vetch seeds. As such, it appears implausible that pulse pests consumed the archaeological pulse seeds in their entirety or majority. Altogether it seems unlikely that infestation from bruchid pulse pests can explain the relative abundance of pulse seed coats at Ploča Mičov Grad.

Hypothesis 2: The large numbers of charred pulse seed coats with hila relative to the charred pulse seeds relates to food preparation and detoxification. The toxin-rich pulse seed coat was removed.

Experimental dehulling of modern dried bitter vetch seeds by hand-rubbing, following soaking, found that the seed coat was easy to remove. The seed coat curled inwards following redrying and/or charring. This was also seen in some of the detached pulse seed coats with hilum from Ploča Mičov Grad which showed curling inwards at the edges (Figure 6 a). These archaeological seed coats were fully charred showing that this curling occurred before/during charring, strongly suggesting that there was not a seed present during the heating event, which would have prevented inward curling. Several fragments of charred pulse seed coat (not identifiable to species) were similarly curled inwards, a few of which were curled to the extent that they are almost cylindrical (Figure 6 e). As such, the archaeological charred detached hila closely resembled the experimentally dehulled seed coats.

The dehulling of bitter vetch seeds by hand-rubbing frequently resulted in the cotyledons splitting apart. This has also been noted in ethnographic and experimental accounts of seed coat removal from pulses using light grinding (Bofill et al. 2020; Kreuz and Feth, 202; Valamoti, 2023) and interpreted as evidence of processing at some sites (e.g. Late Bronze Age celtic bean (*Vicia faba* L.) single cotyledons from Thebes, central Greece; Jones and Halstead 1993). At

Ploča Mičov Grad, we have both whole bitter vetch seeds and single cotyledons. The small number of seeds restricts the inferences we can make about the charred bitter vetch seeds. However, Valamoti (2023) reports that breaking whole charred bitter vetch seeds from Dikili Tash into cotyledons was difficult, resulting in irregular fragments. As such the finds of bitter vetch cotyledons at Ploča Mičov Grad also supports the dehulling hypothesis.

Altogether, we find the second hypothesis, interpreting the charred pulse seed coats as the by-product of processing, a more convincing explanation for the abundance of charred pulse seed coats relative to robust seeds, as the pulse macrofossils compared well the experimentally dehulled bitter vetch seeds. Dehulling of bitter vetch would have facilitated human consumption of the seeds. Other detoxification steps, such as leaching, boiling and/or roasting, may also have been necessary to further reduce the toxicity of the seeds. As the toxicity of the plant varies between populations (Berger et al. 2003), the efficacy of different detoxification processes is difficult to estimate. Detoxification practices have also been suggested at Early Bronze Age Agios Athanasios (northern Greece, Valamoti et al. 2011) and at Late Bronze Age Wöllstadt (northern Germany, Kreuz and Feth, 2021). At both sites, large numbers of bitter vetch cotyledons were recovered without their seed coat, interpreted as the product of for detoxification. Together with these sites, the evidence for detoxification at Ploča Mičov Grad suggests that this practice was been widespread in prehistory.

Wider relevance: prehistoric pulse preferences

Bitter vetch has been found at many Neolithic sites across the southern Balkans. Sites closest to Ploča Mičov Grad with finds of bitter vetch include Late Neolithic Maliq, eastern Albania (Xhuveli and Schultze-Motel, 1995), Early Neolithic Vrbjanska Čuka, central North Macedonia (Antolín et al. 2020), and Early Neolithic Paliambela and Revenia, northern Greece (Kotzamani

and Livarda, 2018). In rare instances, large numbers of bitter vetch have been recovered such as a "cache" of bitter vetch seeds found within a 6th millennium child burial at Tumba Madžari (northern North Macedonia) (Stojanova-Kanzurova and Rujak, 2013). In general, the low numbers of bitter vetch seeds recovered from Early Neolithic contexts in this region has cautioned interpretations. For example, in a synthesis of crops recovered from Early Neolithic sites in the Pelagonia Valley of North Macedonia, Sabanov et al. (2024) consider bitter vetch a likely weed of other crops fields, accidentally collected with the target crop. In contrast, lentil and pea have been identified in much larger numbers in this region during the Early Neolithic (Allen and Gjipali, 2014; Antolín et al. 2020; Kotzamani and Livarda, 2018; Sabanov et al. 2024).

However, larger numbers of bitter vetch have been recovered from some later sites, such as Late Neolithic contexts at Dikili Tash, northern Greece (Valamoti, 2023) and Early Bronze Age Agios Athanasios (Valamoti et al. 2011). Filipović et al. (2022) observe that, by the Late Neolithic, large numbers of bitter vetch are particularly common in the northern Balkans (extending to the southernmost points of Kosovo and Serbia) such as at Vinča-Belo Brdo, northern Serbia (where 1400 seeds were recovered; Filipović et al. 2022). Similarly, de Vareilles et al. (2022, p.21) consider bitter vetch "a success" for Late Neolithic (c. mid-5th to mid-4th millennium BCE) Vinča, Butmir and Sopot communities across the central and western parts of the Balkans based on its ubiquity in archaeobotanical assemblages. The number of bitter vetch macrofossils recovered from Ploča Mičov Grad suggests that bitter vetch was also valued further south. It is plausible that Late Neolithic sites across the region had some degree of interaction. The similarities between material culture from sites in the Lake Ohrid basin and those northwards along the Black Drin River valley (Kuzman, 2017; Weissová et al. 2018), southwards into the Korče basin (Kuzman, 2017) and eastwards along the Pelagonia Valley (Kuzman, 2013; Naumov, 2020) imply an interconnected region. Further, a prehistoric trade

route (the ‘Candavian Road’ or Kandaviski Pat, Figure 2) ran to the north of the Lake Ohrid basin and is thought to be the most accessible lowland pathway linking regions to the west and east (Lolos, 2007; Jovanova, 2013; Mitrevski, 2015; Weissová et al., 2018). As such, similar crop preferences could reflect convergent cultural choices, however, it is also probable that contemporary sites were connected by trade or population movement to some degree.

The results of this study suggest that bitter vetch’s mild toxicity need not have prevented human consumption. Detoxification of pulses may appear to require high labour costs for a pulse which is described as “bitter” and the toxicity of bitter vetch is documented in ancient texts (e.g. in Pliny, HN 22.153, and Hippocrates, Stockman, 1931). Yet, that does not mean it was avoided altogether for human consumption. Bitter vetch has frequently been credited with a host of medicinal qualities. Pliny the Elder wrote that the Roman Emperor Augustus believed it to have cured his illness in his *Natural History* (Flint-Hamiliton, 1999) and that it had some twenty medicinal properties or applications, including the treatment of snake bites (Southall, 1879). It is also occasionally mentioned in Classical texts as a component of human diets (e.g. Pliny describes the addition of ground bitter vetch to bread (Plin. HN 18.103)). The Roman senator, Cato, even suggests adding vetch flour as a sweetener to wine (Agr. 109; Flint-Hamiliton, 1999). In the present day, Kreuz and Feth (2021) describes bitter vetch’s “nutty taste…[as] very pleasant” emphasising that some bitter vetch varieties may be more palatable than others and highlighting that tastes are not universally experienced.

Dehulling (the removal of seed coat) is a major part of pulse processing in modern times (Malcolmson and Han, 2019). Pulse seeds high in toxins or with undesirable seed coat taste or texture may be dehulled to increase palatability. Equally, pulse seeds with seed coats that are regularly consumed, such as chickpea, lentil and pea, may still be dehulled for particularly

recipes (e.g. to produce smooth dhals; Singh, 1995). This could explain why at Ploča Mičov Grad, several detached hila of pea were also found, representing dehulling for food processing unrelated to detoxification.

3.8 CONCLUSIONS

The mildly toxic pulse, bitter vetch (*Vicia ervilia* (L.) Willd.) is a common feature of prehistoric archaeobotanical assemblages from south-eastern Europe and south-west Asia. It is particularly ubiquitous and abundant from the Late Neolithic in the northern Balkans. At the Late Neolithic pile-dwelling lakeshore site of Ploča Mičov Grad, North Macedonia, bitter vetch is the most common pulse recovered from the site suggesting this cultural preference extended further south. We find clear evidence for pulse pests at the site, through the remains of bruchids, a borehole in a bitter vetch seed and insect damage to pulse pod fragments. We report the earliest known remains of the bruchid, *Bruchus rufipes* Hbst. This suggests pulse pests were present and likely a challenge to Late Neolithic farmers. The unusual abundance of fragile charred pulse seed coats relative to robust charred pulse seeds is interpreted as evidence for food preparation with the dehulling of seeds to reduce toxicity. The plant knowledge, resilience and skill of the Late Neolithic occupants of Ploča Mičov Grad enabled them to transform a toxic plant into safe and nutritious food. Given its drought-tolerance, evidence for bitter vetch processing and consumption by prehistoric populations could help to generate scientific interest, encouraging further research, and change public perceptions of this neglected and underutilised, but nutritious and climate-resilient, crop.

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3.10 SUPPLEMENTARY MATERIALS

3.10.1 MATERIALS AND METHODS

i. Identification of the pulse hila

Identification of the lentil pulse hila was straight-forward as these hila were more elongated than the bitter vetch and pea hila which were both oval. Within the oval hila group, some hila were smaller with a triangular aerenchyma layer, while others were larger with a curved aerenchyma layer (Figure 3 in the main text). Based on comparison with modern reference material, it was hypothesised that the triangular-backed hila were bitter vetch. However, we wanted to test whether the size of the hila was also diagnostic. As pulse sizes vary between varieties and have changed over time, comparison between the sizes of modern accessions hila and the archaeological detached seed coats with hila was not a reliable identification

method. Instead, the size of the hila on the detached seed coats was compared to the archaeological seeds with intact hila.

The length and width of the detached hila were compared to the archaeological bitter vetch seeds' hila using cluster analysis. The analysis 'clusters' samples based on their similarity. The measurements of (a) the hila from the detached seed coats and (b) the seeds with intact hila were included, in order to compare sizes. The packages 'factoextra' (Kassambara and Mundt, 2020), 'cluster' (Maechler et al. 2022) and 'dendextend' (Galili, 2015) were used to perform and visualise the analyses using R Statistical Software (v.4.1.2, R Core Team, 2021). Lentil hila were not included as these were few in number and easy to identify. The number of clusters was set as two in the k-means cluster analysis as the aim was to distinguish between two taxa (bitter vetch and pea).

The cluster analysis clustered all of the small hila were a triangular back with the bitter vetch seeds in Cluster 1 (Figure S1). One hilum with a curved back was also assigned to this cluster. Cluster 2 only included larger hila with a curved back. Two poorly preserved hila (indeterminate curved/angular back) were also clustered with the triangular-backed hila and the bitter vetch seeds. This matched the hypothesis that bitter vetch has a more triangular aerenchyma layer. As such, 122 detached hila were identified as bitter vetch and 41 as pea. Some hila (54) were left unidentified due to preservation.

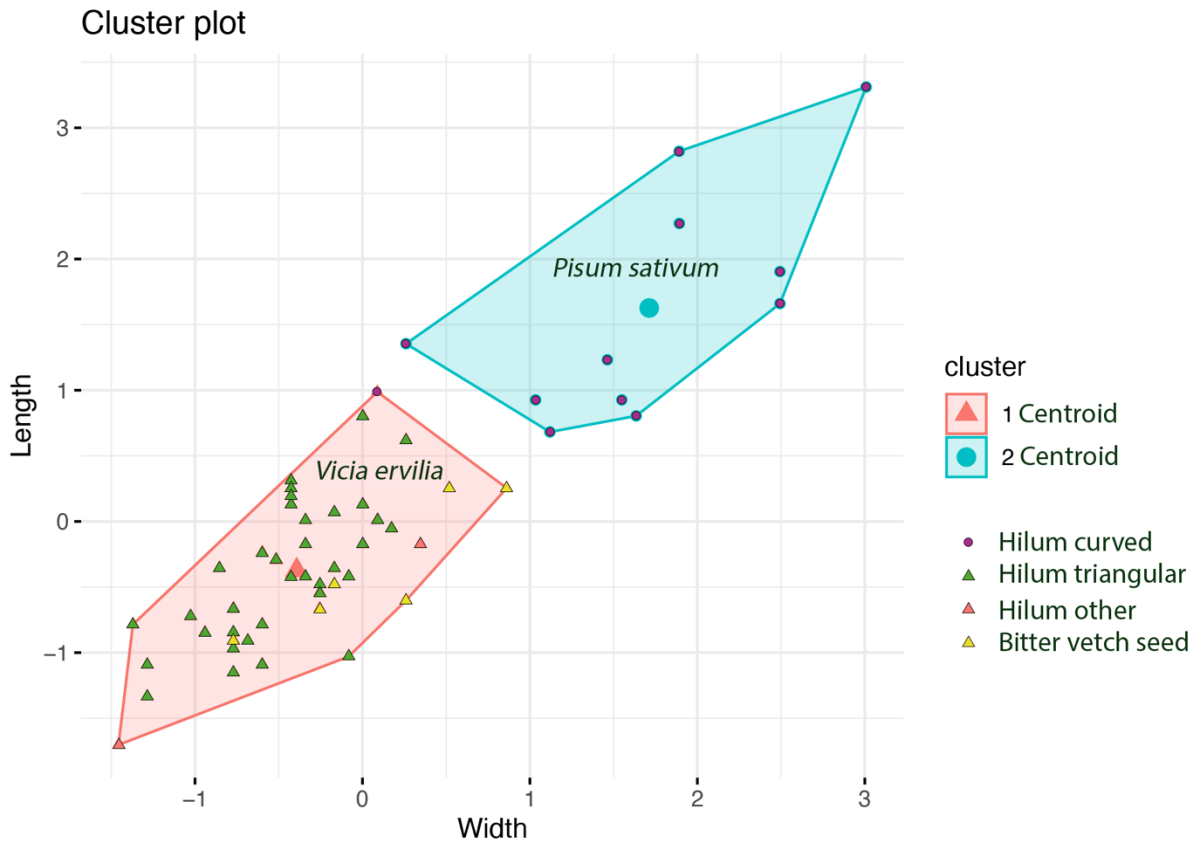


Figure S1: Cluster analysis of the pulse hila measurements. The smaller detached hila, with an angular aerenchyma layer, are grouped with the hila of seeds identified as bitter vetch (Vicia ervilia). The larger detached hila, with a curved aerenchyma layer, are grouped separately. These are identified as pea (cf. Pisum sativum). Only one hilum with a curved aerenchyma layer was grouped in the 1st cluster (on the outer limits) with the bitter vetch seeds and hilum with a triangular aerenchyma layer. The data is scaled to increase the separation between samples.

4.0 DISCUSSION

4.1 DIVERSE FOOD SYSTEMS IN UPLAND WETLAND SETTINGS:

The well-preserved waterlogged Late Neolithic archaeobotanical assemblage reflected high levels of biodiversity within the Lake Ohrid basin.

Wetland ecosystems are home to a rich array of plants and animals, often providing habitat to some of the rarest species on the globe (Denny, 1994; Walsh, 2008). The Lake Ohrid basin is no exception, being one of Europe's key biodiversity hotspots with more than 1,200 native and at least 212 endemic species of flora and fauna (Albrecht and Wilke, 2008). Anaerobic waterlogged preservation of archaeological deposits can preserve a range of plant parts (including leaves and flowers) and plant types (such as oil-rich and seasonal plant foods), which would not typically survive within dryland assemblages (Brombacher and Jacomet, 1997; Jacomet, 2004; Jacomet, 2012; Colledge and Conolly, 2014). Therefore, with suitable preservation conditions, waterlogged assemblages are expected to preserve a broad range of plants used by the prehistoric population and present in the local landscape.

In the first paper in this thesis, the density of the plant remains in the Late Neolithic organic layer at Ploča Mičov Grad compared well with well-preserved organic layers from the circum-Alpine region (c. 10,000 plant remains per litre of sediment e.g. the Late Neolithic Swiss sites of Arbon Bleiche 3, Jacomet et al. 2004; and Horgen Scheller, Favre, 2002). The presence of fragile organic remains (indicators of limited erosion/corrosion processes) further underlined the high preservation levels of the assemblage (Antolín et al. 2017). Macrofossils from 48 different families and 111 genera were identified, with a wide range of woodland, wetland and grassland taxa, alongside cultivated crops, reflecting a mosaic environment across the

cultural landscape of the site. Collected fruits and nuts included both Mediterranean (e.g. terebinth, grape and fig) and temperate (e.g. acorn, hazelnut and apple) components, reflecting the site's location at the interface of biogeographic zones and that foraging was a flexible practice adapting to different settings to incorporate locally available taxa (Ivanova et al. 2018). With such a well-preserved organic sequence, it is not surprising that the Late Neolithic archaeobotanical assemblage was particularly diverse. However, this finding reinforces the value of waterlogged wetland assemblages for understanding prehistoric landscapes, in a region where most archaeobotanical assemblages come from dryland sites (Kotzamani and Livarda, 2018; Valamoti, 2023; Sabanov et al. 2024).

Combining the near-site palynological and on-site archaeobotanical records improved our understanding of the diversity of plant taxa present in the Bay of Bones. These complementary approaches identified plant types to different taxonomic resolutions and spatial scales, enriching our grasp of the range of genera and species present in the local landscape (Paper 2 of this thesis). Biodiversity indices based on the pollen record suggested that local biodiversity levels since the onset of the Holocene were high within the Lake Ohrid basin. While some plant types (e.g. arboreal taxa) declined during the settlement period, Late Neolithic activity increased overall biodiversity levels within the Bay of Bones as land-clearance created patchwork environments and new niches (Brechbühl et al. 2023). Pollen production of several members of the Rose family increased markedly during human occupation, likely due to the creation of open and woodland edge habitats supporting light-loving species. Analysis of the archaeobotanical assemblage highlighted that many of these fruits and nuts (including wild almond, apple and blackberry) were routinely collected by the prehistoric community. Systematic foraging for wild resources, alongside possible fruit tree

management (such as pruning and coppicing), may have enhanced these plant populations. The introduction of non-native livestock and non-native plants such as cereals and pulses, as well as their pests (e.g. Paper 3 of this thesis) did not measurably negatively impact local biodiversity levels. At the other end of Europe, another study integrating wetland archaeological and palaeoecological datasets similarly concluded that early cultivation (c. 4700-4000 cal BCE) only minimally impacted local ecosystems in the north-western Netherlands (Verhagen et al. 2021). While this example is broadly contemporary with the Late Neolithic settlement phase at Ploča Mičov Grad in the 5th millennium BCE, in the Netherlands this period corresponds to the Early Neolithic. This suggests that while agricultural practices likely differed across over 2000 km and between initial cultivation and matured agriculture in the regions, neither had a significant impact upon local biodiversity levels.

The Late Neolithic food system incorporated a broad range of non-native plant foods, despite its upland and temperate setting.

While high biodiversity levels are to be expected in this wetland environment, a key question was whether the upland and relatively temperate setting restricted the range of non-native plants that could be cultivated. Most research regarding Neolithic plant foods in the southern Balkans relates to lowland dryland sites (Kotzamani and Livarda, 2018; Valamoti, 2023; Sabanov et al. 2024). A reduction in the crop spectrum is broadly observed in prehistoric archaeological assemblages with increasing latitude (particularly moving from Mediterranean to temperate biogeographic regions) and decreasing longitude (Krauß et al. 2018; Ivanova et al. 2018; Ivanova, 2020; de Vareilles et al. 2022). This has been attributed to climatic parameters (e.g. cooler summer and winter frosts) inhibiting the growth of south-west Asian crops without genetic adaptations and cultural changes (Krauß et al. 2018; Ivanova, 2020;

Gutaker and Purugganan, 2023). For example, chickpea notably disappears from Neolithic archaeobotanical assemblages in the western Balkans, while bitter vetch seems to have reduced importance at sites in the northern Balkans, prior to the Late Neolithic (Ivanova et al. 2018; de Vareilles et al. 2020). Situated in a temperate, upland lake basin at the interface between Alpine, Continental and Mediterranean biogeographic regions (European Environment Agency, 2017), the nature of prehistoric food systems within the Lake Ohrid basin offers a useful case study in early crop adaption in regions of colder winters and wetter summers. As such, this thesis aimed to investigate whether climate and altitude impacted plant food systems and reduced crop breadth at Ploča Mičov Grad.

The diversity of the Late Neolithic archaeobotanical assemblage at Ploča Mičov Grad demonstrates that a range of cereal and pulse crops were cultivated, and that many edible wild plants (of typically Mediterranean as well as continental biogeography) were also used routinely in this environment. Paper 1 explored the diversity of the Late Neolithic cultivated crops and so the suitability of the Lake Ohrid basin for cultivation. The range of cereals was notably diverse including einkorn, emmer, Timopheev's wheat, bread wheat and multiple varieties of barley (naked two- and six-row and hulled two- and six-row). This crop diversity is comparable to Late Neolithic dry lowland sites in northern Greece (Valamoti, 2023) and Early Neolithic dry upland sites in Pelagonia (Sabanov et al. 2024). No single species dominated the assemblage. Instead, there were roughly equal proportions of einkorn and emmer wheats. Cultivating a range of cereals is a risk-buffering strategy, preventing food shortages, as has been suggested for many prehistoric sites in the southern Balkans (e.g. Bogaard and Halstead, 2015; Valamoti, 2023; Sabanov et al. 2024) and is ethnographically attested approach in Greece (Halstead, 2014). It would have also offered a varied cuisine (Forbes, 1976; Valamoti,

2023). The frequency of each cereal type varied between samples. Yet, there is not a clear site-wide trend to suggest a change in the relative importance of different crops or significant crop failures. Instead, these cereals were consistently present throughout the cultural layer reflecting recurrent patterns of cultivation across the roughly century-long settlement phase (c. 4697-4500 to 4436-4257 cal BCE).

Three pulses (bitter vetch, lentil and pea) broadened the Late Neolithic crop spectrum further and offered a source of plant protein to complement the carbohydrate-rich cereals. Fragments of pulse pod were abundant throughout the Late Neolithic samples, demonstrating that pulse cultivation was routine (Paper 1). This inference is supported by the analysis in Paper 3, which showed that while charred pulse seed numbers were low, large numbers of fragile (uncharred and charred) fragments of pulse seed coat were present. The importance of pulses and pulse processing is likely underestimated at dryland sites, as it is plausible that these fragile charred testa fragments would not survive in dryland assemblages (cf. Fuller and Harvey, 2006; Melamed et al. 2008). Lentil and pea are common components of Neolithic assemblages in the region (Valamoti, 2023; Sabanov et al. 2024). Abundance of bitter vetch, on the other hand, is more unusual. Its increased rarity at Early Neolithic sites in the central and northern Balkans has been linked to climate (Ivanova et al. 2018; Sabanov et al. 2024). The numerous charred bitter vetch remains at Ploča Mičov Grad suggests that bitter vetch could be a valuable component of the plant food spectrum in this region. More widely in the Late Neolithic, bitter vetch seems to be a resurgent crop in the central and western Balkans, particularly for the Vinča culture (Ivanova et al. 2018; Filipović et al. 2022; de Varielles et al. 2022). Finds of bitter vetch further south at Ploča Mičov Grad suggests contemporary and convergent cultural preferences valuing bitter vetch by the mid-5th millennium BCE. It also helps to situate rare

sites in northern Greece with abundant finds of bitter vetch such as Late Neolithic Dikili Tash (Valamoti, 2023) within regional narratives.

The large numbers of remains of flax and opium poppy show that these oil-crops were important parts of Late Neolithic food systems. Opium poppy can be used for oil, medicine or as a narcotic, and as a flavouring in other food stuff such as baked goods (Valamoti et al. 2022; Valamoti, 2023). The seeds of flax are similarly valued for oil, as well as in food and medicine, while the fibrous stem can be used for textiles or construction (Valamoti, 2023). Macrofossils of flax and opium poppy (while a common feature of western and central European archaeobotanical assemblages, Herbig and Maier, 2011; Salavert et al. 2018) are rare in south-east Europe (Valamoti, 2023). Small numbers of opium poppy were recovered from the Early Neolithic sites of Vrbjanska Čuka, Veluška Tumba and Vlaho in North Macedonia (Sabanov et al. 2024). In Greece, a small number of opium poppy seeds were identified at Late Neolithic Makriyalos and Final Neolithic Mandalo (Valamoti, 2001; Valamoti and Jones, 2003; Valamoti, 2023). It is likely that poppy seeds are underrepresented/absent at dryland sites in south-east Europe due to taphonomic biases, as fragile oil-rich seeds rarely survive charring (Märkle and Rösch, 2008). Due to its limited presence in Neolithic Greece, Valamoti (2023) suggests that opium poppy was primarily a Bronze Age crop for this region with earlier finds being representative of some earlier use or intrusions. The abundance of poppy seeds in the Late Neolithic assemblage at Ploča Mičov Grad confirms that this crop was known and used prior to the Bronze Age.

Flax remains are similarly rare from Early and Middle Neolithic Greek sites, becoming slightly more common during the Late Neolithic with large numbers at sites such as at Makriyalos, Arkadikos, Mandalo and Dikili Tash, northern Greece (Valamoti, 2004; Valamoti and Jones,

2003; Valamoti, 2011; Valamoti, 2023). Even low numbers of flax seeds are sufficient to suggest cultivation by prehistoric populations, as (like with opium poppy seeds) oil-rich flax seeds are less likely to survive charring (Kroll, 1993; Valamoti, 2023). Further, Valamoti (2023) notes that (as of publication) no stem or capsule remains of flax had been recovered from Greek prehistoric sites, likely due to their low likelihood of becoming charred. As such, the numerous flax seeds and capsule remains at Ploča Mičov Grad likely reflects routine and regional cultivation practices which are underrepresented at typical charred assemblages in the southern Balkans. Together, abundant evidence of flax and opium poppy use at Ploča Mičov Grad is an unusual find for the region. However, this is likely due to preservation biases underrepresenting the role of these crops, rather than their being absent. While unlikely cultivated during the Neolithic, terebinth nutlets are abundant in the archaeobotanical record at Ploča Mičov Grad and could have been collected as another source of oil (Paper 1). Oil-yielding plants would have been a valuable addition to the crop spectrum contributing plant-based fats to diets and playing a significant culinary role.

Cultivation practices of this upland wetland settlement were similar to those across prehistoric Europe.

It is clear that a rich array of crops was cultivated by the Late Neolithic population of Ploča Mičov Grad. However, another primary research question of this thesis was *how* they were cultivated. The nature of prehistoric cultivation has been the subject of debate (particularly in central and northern Europe). Off-site evidence has been used to suggest that Neolithic cultivation in temperate areas was characterised by slash-and-burn shifting cultivation (Rösch, 1992). However, on-site evidence from weed flora and stable isotopic analysis of crop remains from across Europe and south-west Asia suggests that cultivation during the Neolithic was

largely akin to ‘garden agriculture’ with small-scale long-lived plots, rather than shifting of extensive regimes, (Bogaard, 2002; Vaiglova et al. 2014; 2021; Jacomet et al. 2016; Bogaard and Halstead, 2015; Halstead, 2018). For example, stable carbon and nitrogen isotopic analysis of cereals (alongside other plants and animals) from the Middle-Late Neolithic tell of Kouphovouno (southern Greece) suggested small-scale intensive agricultural practices (Vaiglova et al. 2014; 2020; 2021). Approaches such as functional weed ecology are often not possible in the southern Balkans, as excavated dryland sites rarely yield enough weed-rich crop samples. Moreover, most excavated sites in the southern Balkans are lowland and dryland (Valamoti, 2023). While it was hypothesised that Late Neolithic cultivation practices in the Bay of Bones were also small-scale and labour-intensive, it was unclear how the upland wetland setting of Ploča Mičov Grad impacted the nature of cultivation.

In Paper 2, functional weed ecology was used to model the nature of the Late Neolithic agrosystems. The intensity of the cereal pollen in the near-site record (in contrast with its invisibility in pollen cores taken further away in the lake, Wagner et al. 2009; Brechbühl et al. 2023) and the analysis of the weed flora from Ploča Mičov Grad suggests that the prehistoric agrosystem resembled traditional, small-scale and labour-intensive cultivation of long-lived plots, located close to the settlement. High-input systems are characterised by high soil fertility and high levels of disturbance, through activities such as weeding and fertilising (Bogaard et al. 2018; Stroud et al. 2023). As such, the agrosystem of Ploča Mičov Grad appears broadly similar to LBK sites in central Europe (Bogaard et al. 2016) the Körös site of Ecsegfalva, Hungary (Bogaard et al. 2007; 2016) and Neolithic Çatalhöyük, Türkiye, (Green et al. 2018), suggesting that the upland wetland setting did not significantly alter this general approach to cultivation practices. As part of the EXPLO project, analysis of other wetlands sites in the Lake

Ohrid basin and on Lake Kastorias with sufficient weed flora (Ballantyne et al. *in prep*; Ergun et al. *in prep*) alongside stable isotopic evidence from crops (Vidas et al. *in prep*) will enable comparisons and further understanding of cultivation practices for upland lakeshore sites in the region.

The magnitude of the wheat pollen percentages suggests that wheat cultivation likely occurred near to the settlement (within c. 200-300 m) (Paper 2; Brechbühl et al. 2023). In the archaeobotanical assemblage, barley was recovered in far small numbers than wheat (Paper 1) which could (in part) explain its absence in the pollen record. Another possibility is that barley was grown further away from the settlement than wheat. Barley is particularly well suited to areas with low soil fertility (Weiss and Zohary, 2011) and so separate cultivation of wheat and barley could relate to physiological properties as well as cultural priorities. At the Middle-Late Neolithic site of Kouphovouno, stable nitrogen isotopic ratios from hulled barley were notably lower than free-threshing wheat, which is interpreted as evidence for separate cultivation on soils with differing fertility levels (Vaiglova et al. 2014). Pulses are poor pollen-dispersers and are similarly absent in the pollen record (Brechbühl et al. 2023). Possible differences in cultivation practices between barley, wheat, and pulses, as well as changes over time, could be explored in further work through stable isotopic analysis, providing another proxy through which to compare upland and lowland agrosystems in the southern Balkans.

In north-western Europe, early agricultural practices have been similarly described as intensive and small-scale (Colledge et al. 2019). Here, the seeming 'success' of small-scale, intensive, agricultural production has been associated with rapid population expansion from c. 4,000 cal BCE. However, this was followed by a stark population decline from c. 3,600 cal BCE, connected with reduced crop yield (Colledge et al. 2019). This "boom and bust" trend

from the early to matured (Middle/Late) Neolithic was identified in several parts of central and western Europe (e.g. Hinz et al. 2012; Shennan, 2013, Timpson et al. 2014), particularly prominently in Ireland, Scotland and England (e.g. Stevens and Fuller, 2012; Whitehouse et al. 2014; Colledge et al. 2019). While some look to social factors to explain population declines in this period (e.g. Hinz et al. 2012), others favour hypotheses that highlight the impact of climatic deteriorations (Whitehouse et al. 2014; Warden et al. 2017; Bevan et al. 2019) and the use of less fertile soils (Colledge et al. 2019). In the case of the latter, this could suggest that early agricultural practices were unsustainable, inevitably leading to changes in small-scale systems, as agricultural practices matured, and land became exhausted. A climatic explanation could suggest that agricultural practices were fragile, unable to adapt to environmental changes (Bevan et al. 2019). Comparisons between prehistoric agricultural systems in north-western Europe and south-eastern Europe are limited due to their geographical distance (different soil conditions and climates) and temporally disparity (e.g. unlike during the late-5th millennium in north-western Europe, climatic conditions were seemingly stable during the mid-5th millennium BCE). Equally, it is unclear how similar these agrosystems may have been as terms such as 'intensive' and 'extensive' are loosely defined (see McClatchie, 2014) and used to describe models based on different datasets. That considered, our results suggest that during the Late Neolithic settlement phase at Ploča Mičov Grad, the agrosystems was small-scale with high-labour inputs suggesting that such practices were not increasingly unsustainable as agriculture matured. The breadth of crops that can be cultivated in southeast Europe perhaps provided greater resilience, buffering crop failure, than the more limited range suited to the temperate climates of northwest Europe.

4.2 FROM PLANTS TO FOODS

The Late Neolithic waterlogged assemblage provides insights into the processing of cereals and pulses.

How plants became food is the focus of interdisciplinary projects such as 'PlantCult' exploring crop processing and food preparation and situated within discussions of the culinary prehistoric significance of different plants (Valamoti et al. 2017; Valamoti, et al. 2020). The site of Ploča Mičov Grad offered many insights into the *chaîne opératoire* of plant foods, from cultivation/collection and crop processing to food preparation.

Following cultivation of cereals in small-scale, garden-like plots (Paper 2), crops would have been harvested and processed. The abundance of cereal chaff relative to cereal grains (Paper 1) and the characteristics of the weed component (Paper 2) suggests that the assemblage is dominated by crop-processing by-products. The weed flora aligned with the winnowing and fine-sieving by-products. This combination is interpreted as evidence for late-stage crop-processing, separating the grain from the chaff with fine-sieving and the tossing of material from sieves (a practice recorded ethnographically for glume wheats in Spain, Halstead, 2014; and Ethiopia, D'Andrea and Haile, 2002) (Paper 2). Another cereal processing step potentially captured by the waterlogged assemblage is the scorching or singeing of cereal awns prior to or during dehusking (as is ethnographically known in Asturias, Spain, Peña-Chocarro, 1999; Peña-Chocarro and Zapata, 2003). Many 'patchily' charred glume bases (recorded as 'singed') were recovered throughout the Late Neolithic archaeobotanical assemblage, suggesting that this crop material briefly encountered high temperatures (Paper 1). Further work on these partially charred glume wheat chaff could link this material to crop processing practices such

as dehusking (Holguin et al. *in press* – Appendix 3). Such inferences could not be made from dryland sites alone where partially charred cereal chaff would not be preserved.

Pulse pods are another by-product of crop processing. This likely happened close to or in the settlement, given the abundance of pulse pod in the cultural midden at Ploča Mičov Grad (Paper 1). Such a finding is known for waterlogged assemblages such as at Late Neolithic Hornstaad-Hörnle IA (Germany, Maier, 2001). However, identification of fragments of pulse pod is difficult, requiring good levels of waterlogged preservation. It is, therefore, suggested that the importance of pulse crops is often underestimated at wetland sites (Brombacher and Jacomet, 1997; Jacomet, 2009). As such, the high numbers of pulse pod recovered from Ploča Mičov Grad attests to the importance of pulses and the high preservation levels at the site (Paper 1). Further processing of pulse crops was explored in Paper 3, in which detoxification of bitter vetch is inferred from the high number of toxin-rich (charred) pulse seed coats relative to the pulse seeds. Historic and ethnographic reports suggest that the removal of bitter vetch's seed coat (through soaking and hand-rubbing or roasting) reduces the canavanine levels of this mildly toxic pulse rendering it edible (Enneking et al. 1995; Kreuz and Feth, 2021; Valamoti, 2023). The large numbers of detached pulse seed coats (many identified to bitter vetch based on the diagnostic hilum) are interpreted as a detoxification by-product. Evidence for the detoxification of bitter vetch also comes from Early Bronze Age Agios Athanasios (northern Greece, Valamoti et al. 2011) and Late Bronze Age Wöllstadt (northern Germany; Kreuz and Feth, 2021), where numerous bitter vetch seeds were found without the toxin-rich seed coat, suggesting that this practice was widespread during prehistory (Paper 3). These fragile pulse remains also emphasise the value of the charred remains preserved within

waterlogged assemblages, many of which likely would not survive the burial environment of a dryland site.

Evidence for Late Neolithic plant food preparation at Ploča Mičov Grad reflects regional practices.

Indications of food preparation can be observed in the presence of cereal grain fragments with pre-charring breaks at Ploča Mičov Grad (identified through the bulging of the fracture surface, following Valamoti et al. 2021). Many of these cereal grain fragments were of barley or einkorn. This could suggest differential food preparation between the three glume wheats (einkorn, emmer and Timopheev's wheat), though numbers of identified grains were low (Paper 1). The frequent occurrence of cereal grains with pre-charring breaks suggests that they were deliberately broken during the early stages of grinding or with coarse processing to produce food types akin to 'bulgur'. Cracked grains have culinary advantages such as a shorter cooking time (Valamoti, 2023). Grains with pre-charring breaks have been identified at many prehistoric sites (Valamoti, 2002; Valamoti et al. 2021; Valamoti, 2023). For example, many grains appeared to have been cracked at Late Neolithic Dikili Tash (northern Greece, Kokkidou, 2018) and Early Bronze Age site of Mesimeriani Toumba (northern Greece, Valamoti et al. 2021). Numerous grains with pre-charring breaks at Ploča Mičov Grad reflect convergent culinary choices or shared cultural traditions within the region.

Numerous 'amorphous' charred remains were also recovered from Ploča Mičov Grad (Paper 1). These macrofossils appear to be composites of various botanical materials. Some pieces were shiny/glassy in appearance, suggesting charring at very high temperatures and/or oil-rich materials, while others had fragments of fish scale imbedded within the matrix. It is likely

that some of the amorphous remains are processed foods, as has been identified at many other sites (from Natufian Jordan, Arranz-Otaegui et al. 2018 to Roman England, González Carretero, 2023). For instance, high magnification (Scanning Electron Microscopy) analysis of amorphous macrofossils from the Late Neolithic pile-dwelling site of Parkhaus Opéra in Zurich (Switzerland), revealed a bread-like morphology with inclusions of barley and wheat tissues. The size of the cereal particles in the bread-like macrofossils suggested they had been milled and sieved, while the presence of celery suggests flavouring (Heiss et al. 2017). Further analysis of these well-preserved macrofossils could offer insights into Late Neolithic 'recipes' with possible ingredients including cultivated or collected plants, alongside fish from the lake.

At Ploča Mičov Grad, grape is another taxon that merits further research in relation to food preparation. Many grape pips were recovered partially charred from the Late Neolithic assemblage. These macrofossils were dark brown in colour suggesting that they were exposed to low temperatures, changing the colour of the pips and resulting in a macrofossil harder than uncharred but softer than charred remains (Paper 1). Contact with low-temperate fires could relate to the cooking or processing of grapes such as drying out for raisins. Grape collection and storage is known at other Late Neolithic sites such as over 2400 pips at the site of Dikili Tash (northern Greece) dating to approximately 4300 BCE, contemporary with Ploča Mičov Grad (Valamoti et al. 2007; Valamoti, 2023). Many grape remains at Dikili Tash showed evidence of pressing which, coupled with biomarkers for fermentation and grapes in residue analysis of ceramics, suggests Late Neolithic wine production (Garnier and Valamoti, 2016). Grape could also have been collected to be cooked for all sorts of meals and baked goods. Further work on the partially charred grape pips could connect these macrofossils to food preparation.

4.3 THE MIDDLE NEOLITHIC EVIDENCE AT PLOČA MIČOV GRAD

Cultural macrofossils suggesting a Middle Neolithic presence in the Bay of Bones are among the earliest evidence for human activity in the Lake Ohrid basin.

The Late Neolithic phase accounted for the main organic layer (c. 1.5 m thick) at Ploča Mičov Grad. However, at the bottom of one sediment core, organic lenses (totally c. 45 cm thick) were dated to the Middle Neolithic (c. 5790-5722 to 5755-5714 cal BCE). Paper 1 detailed the components of this assemblage. Some cultural indicators such as uncharred and charred glume wheat and barley chaff and fragments of uncharred cereal bran (with the ventral groove) were present, alongside fully charred grape pips and uncharred terebinth pistachio nutshells. Together, these cultural indicators implied human activity in the local area during the 57th century BCE, with similar cultivation practices and use of collected fruits and nuts to the Late Neolithic. Many wild taxa (e.g. wild almond and cornelian cherry) were absent in the Middle Neolithic assemblage. This could reflect differing wild resource usage or be a product of the low Middle Neolithic sample numbers. The Middle Neolithic lenses had large numbers of silver fir needles. Numbers of silver fir needles were low in both the Late Neolithic and the later Bronze Age phases, as well as in the layers underlying the Middle Neolithic phase. This suggests that fir could have been collected by the prehistoric population, possibly as animal fodder (as suggested at the Late Neolithic pile-dwelling site of Arbon Bleiche 3, Switzerland, Akeret and Rentzel, 2001) or for bedding (Brockmann-Jerosch 1918).

The presence (but limited number) of cultural plant indicators suggests that the Middle Neolithic settlement was close to the coring site, possibly inland, but its location differed somewhat from the Late Neolithic and later Bronze Age pile-dwelling. Currently, no Middle

Neolithic material culture has been excavated at the site (Hafner et al. 2021; Bolliger et al. 2023). However, an earlier cultural phase was detected during the palaeoecological analysis based on cultural indicators such as cereal pollen and microcharcoal suggesting human activity at c. 5550-4850 cal BCE within 3-5km of the Ploča Mičov Grad (Brechbühl et al. 2023). The archaeobotanical Middle Neolithic lenses correspond to the start of this earliest anthropogenic phase in the pollen sequence.

The oldest known pile-dwelling, Lin 3, is situated on the western shore of Lake Ohrid where radiocarbon analysis of the wooden piles has dated the site to 6000-5800 BCE with further dating underway (Hafner et al. *in prep*). Archaeobotanical analysis from Lin 3 is forthcoming (Ballantyne et al. *in prep*). Comparison between the small number of Middle Neolithic cultural macrofossils from Ploča Mičov Grad and numerous samples from contemporary layers at Lin 3 will offer insights into early prehistoric practices across the Lake Ohrid basin. Further comparison with the Middle Neolithic archaeobotanical results from the pile-dwelling site of Dispilio (early-late 6th millennium BCE) on the southern shore of Lake Kastorias (Greece) (Ergun et al. *in prep*) would contextualise patterns within the Lake Ohrid basin within regional narratives.

The site chronologies (Bolliger et al. 2023; Maczkowski et al. 2023; Hafner et al. *in prep*) connect the wetland settlements in the southern Balkans to known climate change events. Pile-dwellings (e.g. Dispilio and Lin 3) appear in the region not long after the 8.2K BP (c. 6200 BCE). The 8.2K BP event saw a marked decrease in global temperatures and decrease in moisture with seasonal variability causing significant biome shifts (Pál et al. 2016; Gassner et al. 2020). The earliest plant material from Ploča Mičov Grad dated to not long after (c. 5790-5722 to 5755-5714 cal BCE) belongs to the subsequent phase following this cold/dry episode.

Comparison with other pile-dwellings from the southern Balkans (Ballantyne et al. *in prep*; Ergun et al. *in prep*) as well as high-resolution climatic records (Schlaefli et al. *in prep*) in the near future will be beneficial to disentangle regional or temporal phenomena in relation to climatic or cultural factors with the creation and abandonment of the pile-dwellings.

4.4 THE LATER BRONZE AGE EVIDENCE AT PLOČA MIČOV GRAD

Later Bronze Age food systems were broadly similar to those of the Late Neolithic, but with a new crop and more domesticated varieties.

A significant proportion of the wooden piles and excavated material culture from the pile-field of Ploča Mičov Grad was dated to the later Bronze Age (Hafner et al. 2021; Bolliger et al. 2023). However, it was thought that the majority of the later Bronze Age material had been eroded from the top of the organic layer. Indeed, Bronze Age deposits were completely missing from the palaeoecological sediment cores taken (10-30 m from the pile-field, Brechbühl et al. 2023; Paper 2). Fortunately, a later Bronze Age phase (c. 24 cm thick) was preserved at the top of one of the sediment cores in the archaeobotanical analysis, providing insights into food system continuity and change between different periods of prehistory (Paper 1).

The spectrum of cultivated cereals appeared similar between the Late Neolithic and later Bronze Age samples. Both periods cultivated the glume wheats, einkorn, emmer and Timopheev's wheat, as well as some barley (although preservation of the later Bronze Age material inhibited the identification of the barley chaff to variety.) Fragments of pulse pod and single finds of bitter vetch and lentil seeds suggest that pulses were also a component of later Bronze Age food systems, and the presence of flax and opium poppy shows their continued importance since the Late Neolithic. Some differences were present between the two

assemblages. Free-threshing wheat and pea were absent in the later Bronze Age assemblage, but this could be a product of the small sample size. Some Bronze Age sites in northern Greece show a narrowing of the pulse spectrum (e.g. only bitter vetch at Kastanas, Kroll, 1983; and Agios Athanasios, Moniaki, 2009; and lentil and bitter vetch at Assiros, Jones et al. 1986; Valamoti, 2023). Free-threshing wheat is generally more common in Bronze Age assemblages in the region than in the Neolithic (Valamoti, 2023). An additional crop, spelt wheat, was identified in the later Bronze Age assemblage. This reflects regional trends which see an introduction of spelt to food systems during the Bronze Age such as at the Greek sites of Archondiko (late 3rd millennium BCE; Papaefthymiou-Papanthimou et al. 2013) and Assiros Toumba (1350 BCE; Jones et al. 1986). Altogether, there is notable continuity between cultivation practices in the Late Neolithic and later Bronze Age periods. The significance of absent taxa in the later Bronze Age assemblage is challenging to interpret as it could be due to the small number of samples. However, the addition of spelt to the assemblage certainly shows some diversification and adjustment of cereal cultivation practices.

Recent studies have suggested that cultivation (particularly at large sites) becomes slightly more extensive during the Bronze Age, particularly at large sites such as Bronze Age Knossos, but this process is highly dependent upon the size of the settlements and populations, with extensification observed, for example, at urban Late Bronze Age Knossos but not at the small Late Bronze Age tell settlement of Thessaloniki Toumba (Styring et al. 2022). The size of the later Bronze Age Ploča Mičov Grad was still comparatively small (c. 80 m; Hafner et al. 2021) and so it is hypothesised that later Bronze Age cultivation at Ploča Mičov Grad would be similar to the Late Neolithic agrosystems or characterised as slightly more low-input (Paper 2). However, both the weed flora and the number of samples dating to the later Bronze Age is

too restricted to permit analyses such as functional weed ecology. The later Bronze Age is also missing from the palaeoecological record, and so we cannot estimate the impact of settlement activity on the local vegetation nor the proximity of cultivation plots (Brechbühl et al. 2023). More later Bronze Age material may be preserved at the top of some of the nine other sediment cores extracted within the pile-field which remain currently unanalysed. This could enable investigation into the nature of later Bronze Age cultivation and add more statistical weight to comparisons between the two periods.

Opium poppy seeds were particularly abundant in the later Bronze Age archaeobotanical assemblage. These seeds were generally larger (resembling the domestic morphotype, *Papaver somniferum* subsp*. somniferum*) than the size of those in the Late Neolithic assemblage (resembling the wild morphotype *Papaver somniferum* subsp. *setigerum*, Jesus et al. 2023). Similarly, some grape pips in the later Bronze Age were elongated and resembled domesticated types in comparison to the wild morphotype found in the Late Neolithic layer (Paper 1). Unlike the opium poppy seeds, the number of grape pips is too low to sufficiently explore this further (Pagnoux et al. 2015). The contrast between smaller Late Neolithic and larger later Bronze Age opium poppy seeds from the same site prompts discussions of when, where and how domestication processes took place. Opium poppy seeds are thought to originate from western Europe (Salavert et al. 2018), but when and where opium poppy seeds experienced domestication processes is still the subject of investigation (e.g. Antolín et al.'s "The Poppy Project"). The observed shift in seed size at Ploča Mičov Grad could reflect domestication processes and selection for expanding grain size under favourable growing conditions. Alternatively intensive practices already undertaken in the Late Neolithic could

have initiated gradual morphological changes resulting in a larger size by the later Bronze Age. Geometric morphometric analysis of the seeds is forthcoming (Antolín et al. *in prep*).

As in the Late Neolithic assemblage, the later Bronze Age assemblage included evidence of plant food preparation such as cereal grains with pre-charring breaks, which could be signs of early stages of grinding or coarse cereal processing to produce “bulgur”-like food (Paper 1). Many Bronze Age sites in Greece have similar evidence, prompting Valamoti et al. (2021, p.) to describe ‘bulgur’ as a “Bronze Age ‘fast food’”. This shows continuities in cereal food preparation between the Late Neolithic and later Bronze Age occupations of the settlement. In contrast, no pulse seed coats with hila were identified in the later Bronze Age layer, unlike the abundant remains in the Late Neolithic assemblage (Paper 3). While this assemblage is small and comes from a single 6cm-wide core, this could reflect different practices relating to bitter vetch. While the Late Neolithic population appears to have processed bitter vetch seeds by removing the outer seed coat as a form of detoxification (Paper 3), it is possible that the later Bronze Age population used a different detoxification method, had a bitter vetch variety with a lower toxin concentration, or did not need to detoxify bitter vetch (e.g. if it was grown as livestock fodder). With only one bitter vetch seed recovered from in the later Bronze Age assemblage, it is possible that bitter vetch was not an important crop.

4.5 SUMMARY

Numerous wetland sites are known in the southern Balkans, yet few have been the focus of systematic archaeobotanical analysis. High levels of waterlogged preservation of an organic layer (c. 1.5 m thick) at the lakeshore pile-dwelling site of Ploča Mičov Grad provides insights into Late Neolithic (c. 4697-4500 to 4436-4257 cal BCE) food systems. This rich, midden-like

deposit reflected high levels of biodiversity in the Lake Ohrid basin with woodland, wetland and grassland taxa attesting to a diverse, mosaic landscape. A broad range of cereal (including einkorn, emmer, Timopheev's wheat, barley and bread wheat), pulse (bitter vetch, lentil and pea) and oilseed (flax and opium poppy) crops were complemented by a diverse variety of collected wild fruits and nuts. Synthesis between the on-site archaeobotanical and near-site palynological datasets provided insights into how the Late Neolithic population interacted with local vegetation. Cultivation practices were likely centred upon small-scale, long-lived plots near to the settlement, like other Neolithic sites in Europe. The Late Neolithic assemblage contained many crop processing by-products relating to both cereals and pulses. Evidence for Late Neolithic plant food preparation reflects regional practices suggesting convergent strategies or interconnected sites with shared cultural traditions. Similarities with the Middle Neolithic (c. 5790-5722 to 5755-5714 cal BCE) and later Bronze Age (c. 1878-1688 cal BCE) phases at the Ploča Mičov Grad broadly show continuity of plant use. The archaeobotanical results from this thesis demonstrate that high waterlogged preservation is not unique to the prehistoric sites in the Alps, or isolated areas of central and western Europe. Instead, wetland sites in the southern Balkans are an exceptional but under-researched resource, which deserve further research and the global recognition alongside lakeshore sites of the circum-Alpine region.

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5.0 Appendix 1: The archaeobotanical dataset

Abbreviations:

Api.-end – Apical end

Bro. – Brown

Cha. – Charred

Emb.-end – Embryo end

Frag. – Fragment

GB – Glume base

LBA – Later Bronze Age

LN – Late Neolithic

MN – Middle Neolithic

Pres. – Preservation

Sin. – Singed

Sp. – [following genus] one species of the genus

SPK – Spikelet fork

Spp. – [following genus [two species of the genus

UnC. – Uncharred

For counting and identification criteria see Appendix 2. For radiocarbon dates see Paper 1 of this thesis. Volumes measured using water displacement.

Table 1: Archaeobotanical dataset for Core TLM19 0. Late Neolithic samples.

Core TLM19 0											
SAMPLE CODE			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.10
PERIOD			LN	LN	LN	LN	LN	LN	LN	LN	LN	LN
VOLUME SAMPLE (ml)			150	70	70	100	260	610	290	630	510	600
TAXA	TYPE	PRES.										
CROPS												
Cerealia	Awn, straight barbed	Cha.	0	2	3	3	78	61	23	56	132	452
Cerealia	Awn, twisted	Cha.	0	0	0	0	0	8	0	1	12	0
Cerealia	Rachis segment	Bro.	0	0	0	0	5	0	0	0	0	0
Cerealia	Basal rachis segment	Cha.	0	0	0	0	5	0	4	0	0	0
Cerealia	Culm base	Cha.	0	0	0	0	0	0	0	0	0	15
Cerealia	Culm node	Cha.	0	0	0	0	0	1	0	0	0	15
Cerealia	Ear base	Cha.	0	0	0	0	0	0	4	0	0	0
Cerealia	Embryo	Cha.	0	0	1	0	5	8	8	33	22	30
Cerealia	Grain frag.	Cha.	0	0	0	0	0	2	0	11	1	0
Cerealia	Bulgur	Cha.	0	0	0	0	0	8	1	1	11	0
Cerealia	Grain frag. with emb.-end	Cha.	0	0	0	0	0	0	0	1	0	0

Cerealia	Rachis segment	UnC.	0	0	0	0	0	0	0	0	22	0
Cerealia	Testa with hilum >2mm	UnC.	3	3	0	1	46	17	7	124	948	863
Fabaceae	Pedicel	UnC.	0	0	0	0	0	0	0	0	2	1
Fabaceae	Hilum	Bro.	0	0	0	1	1	0	0	22	1	15
Fabaceae	Hilum	UnC.	0	0	0	0	0	0	0	0	22	0
Fabaceae	Hilum	Cha.	0	0	0	1	0	15	0	0	11	0
Fabaceae	Pod frag.	Sin.	0	0	0	0	0	0	0	0	0	1
Fabaceae	Pod frag.	UnC.	1	0	0	3	4	23	12	17	48	130
Fabaceae	Pod frag.	Cha.	0	0	1	0	5	0	0	0	43	61
Fabaceae [large]	Seed	Cha.	0	0	0	0	0	1	1	2	1	2
cf. Fabaceae [large]	Seed	Cha.	0	0	0	0	0	1	0	0	0	0
Hordeum distichon, hulled	Rachis segment	Cha.	0	0	0	0	0	1	0	22	0	0
H. cf. *vulgare,* hulled	Rachis segment	Cha.	0	0	0	0	0	0	0	0	1	0
H. distichon, naked	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	15
H. vulgare, hulled	Rachis segment	Bro.	0	0	0	1	0	0	0	0	0	0
H. vulgare, hulled	Rachis segment	Cha.	0	0	0	0	2	8	0	0	0	2
H. vulgare/distichon	Rachis segment	Cha.	0	0	0	0	2	0	0	0	0	0
H. vulgare/distichon	Ear base	Cha.	0	0	0	0	1	0	0	0	0	0
H. vulgare/distichon	Grain with emb.-end	Cha.	0	0	0	0	5	0	0	1	4	2

H. vulgare/distichon	Rachis segment	Sin.	0	0	1	1	0	8	11	11	0	0
H. vulgare/distichon	Rachis segment	Bro.	1	0	0	1	0	15	4	33	34	48
H. vulgare/distichon	Rachis segment	UnC.	1	0	0	9	59	46	4	86	441	300
H. vulgare/distichon	Rachis segment	Cha.	0	2	0	0	0	0	0	11	0	15
H. vulgare/distichon naked	Lemma base	Cha.	0	0	0	0	0	0	0	0	0	1
Lens culinaris	Hilum	Bro.	0	0	0	0	0	0	0	0	11	15
Lens culinaris	Seed no hilum	Cha.	0	0	0	0	0	0	0	0	0	1
cf. *Lens culinaris*	Pod frag.	Cha.	0	0	0	0	0	0	0	1	0	0
Linum usitatissimum	Seed frag.	UnC.	0	0	1	4	21	53	9	12	0	15
Linum usitatissimum	Seed with hilum	UnC.	0	0	0	1	5	15	5	2	59	61
Linum usitatissimum	Capsule segment	UnC.	2	0	3	15	17	111	41	154	241	490
Papaver somniferum	Seed	UnC.	1	0	0	5	31	15	4	55	43	105
cf. *Pisum sativum*	Hilum	Cha.	0	0	0	0	1	9	0	11	11	0
Triticum aestivum	Rachis segment	Bro.	0	0	0	0	0	0	0	0	11	15
T. aestivum	Rachis segment	UnC.	0	0	0	0	0	8	0	0	0	0
T. cf. *aestivum*	Rachis segment	Cha.	0	0	0	0	0	0	4	0	1	1
Triticum dicoccum	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	1	0
T. dicoccum	SPK/GB	Sin.	0	0	0	0	0	0	2	0	0	0
T. dicoccum	SPK/GB	Bro.	0	0	0	3	0	8	10	21	39	31

T. dicoccum	SPK/GB	Cha.	0	0	3	1	9	68	13	28	86	113
Triticum cf. *dicoccum*	SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	2
T. dicoccum	Terminal SPK/GB	Cha.	0	0	0	0	1	0	0	0	2	0
T. dicoccum/ monococcum/ timopheevii	Grain frag.	Cha.	0	0	0	0	0	0	0	1	0	0
T. dicoccum/ monococcum/timopheevii	SPK/GB	Sin.	0	0	6	22	55	137	68	364	585	753
T. dicoccum/ monococcum/timopheevii	SPK/GB	Bro.	1	0	2	12	17	3	0	29	84	181
T. dicoccum/ monococcum/timopheevii	SPK/GB	UnC.	5	0	38	128	677	2285	1196	5377	14278	17184
T. dicoccum/ monococcum/timopheevii	SPK/GB	Cha.	0	0	1	3	17	61	43	27	126	67
T. dicoccum/monococcum/ timopheevii, two-seeded	Grain frag.	Cha.	0	0	0	0	0	0	0	1	0	0
T. dicoccum/timopheevii	SPK/GB	Cha.	0	0	0	0	0	2	0	0	2	15
Triticum cf. *monococcum*	SPK/GB	Cha.	0	0	0	2	0	0	0	0	0	0
T. cf. *monococcum,* one-seeded	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	1	0
T. monococcum	SPK/GB	Cha.	0	3	1	2	43	27	38	241	94	91

T. monococcum	Ear base inserted into straw	Cha.	0	0	0	0	0	0	0	0	1	0
T. monococcum	SPK/GB	Bro.	0	0	0	0	0	0	11	23	2	19
T. monococcum, one-seeded	Grain with emb.-end	Cha.	0	0	0	0	0	1	0	0	0	15
T. timopheevii	SPK/GB	Bro.	0	0	0	0	1	0	0	0	0	0
T. timopheevii	SPK/GB	Cha.	0	0	0	0	11	0	27	37	0	0
T. cf. *timopheevii*	SPK/GB	Cha.	0	0	0	0	0	0	0	0	11	0
Triticum spp.	Ear base	Cha.	0	0	0	0	0	0	0	0	1	0
Triticum spp.	Ear base inserted into straw	Bro.	0	0	0	0	0	0	0	0	1	0
Triticum spp.	Bulgur	Cha.	0	0	0	0	0	0	4	0	0	0
Triticum spp.	Grain with emb.-end	Bro.	0	0	0	0	1	0	0	0	0	0
Triticum spp.	Grain with emb.-end	Cha.	0	0	0	0	0	1	0	2	2	2
Triticum spp.	Rachis segment	UnC.	0	0	0	0	0	0	0	0	11	0
Vicia ervilia	Seed with hilum	Cha.	0	0	0	0	0	0	0	0	1	0
Vicia ervilia	Seed no hilum	Cha.	0	0	0	0	0	0	0	1	1	0
Vicia ervilia	Cotyledon	Cha.	0	0	0	0	0	0	0	0	1	1
Vicia ervilia	Hilum	Cha.	0	0	1	0	0	8	11	0	11	15
NON-CROP PLANTS												
Abies alba	Needle	UnC.	0	0	1	0	5	0	0	12	12	0

Abies sp.	Needle	UnC.	0	0	1	2	2	1	5	1	1	1
cf. *Abies* sp.	Needle	UnC.	2	0	0	0	0	0	0	0	0	0
cf. *Abies* sp.	Needle	Cha.	0	0	1	0	0	0	0	0	0	0
cf. *Acer* sp.	Seed	UnC.	0	0	0	0	0	0	0	0	11	0
Agrimonia eupatoria	Exocarp	Cha.	0	0	0	0	0	0	0	0	1	2
Agrostemma githago	Seed	UnC.	0	0	0	0	5	0	0	0	0	0
Alchemilla / Aphanes spp.	Seed	UnC.	0	0	0	0	0	23	8	22	11	0
Alkekengi officinarum	Seed	UnC.	0	0	0	1	0	0	0	1	0	0
Alnus glutinosa	Seed	UnC.	0	0	0	2	1	0	0	0	0	0
Alnus cf. *glutinosa*	Seed	UnC.	0	0	3	0	0	0	0	0	0	0
Amarathaceae	Seed	Cha.	0	0	0	0	0	0	0	0	0	1
Amarathaceae	Seed core	UnC.	0	1	2	2	16	38	11	11	32	165
Amarathaceae	Seed core	Cha.	0	0	0	0	26	0	0	110	86	91
Apiacaeae	Seed	UnC.	0	0	0	0	0	0	0	0	1	0
Arenaria serpyllifolia	Seed	UnC.	0	1	2	4	21	53	15	44	239	90
Asteraceae	Seed	UnC.	0	0	1	0	0	0	0	12	1	0
Atriplex sp.	Seed	UnC.	0	0	0	0	0	0	0	11	0	15
Bifora cf. *radians*	Seed	Cha.	0	0	0	0	0	0	0	6	0	0
Bifora cf. *radians*	Seed	UnC.	0	0	0	0	0	0	1	3	4	4

Brassicaceae	Capsule	Cha.	0	0	0	0	0	0	0	1	0	0
Brassicaceae	Seed	UnC.	0	2	0	0	5	0	0	11	22	30
Brassicaceae	Seed	Cha.	0	0	0	0	0	8	0	0	0	0
Bromus hordeaceus	Seed	UnC.	0	0	0	0	0	0	0	0	1	0
Bromus arvensis /hordeaceus /secalinus	Seed	UnC.	0	0	0	0	1	0	0	0	2	0
Bromus spp.	Seed	UnC.	0	0	0	1	0	0	8	1	0	1
Bromus sterilis	Seed	UnC.	0	0	0	1	0	0	0	1	0	2
Bromus sterilis/tectorum	Seed	UnC.	0	0	0	0	0	0	0	0	1	30
Bromus tectorum	Seed	UnC.	0	0	0	0	0	0	4	0	3	0
Bromus tectorum	Seed	Cha.	0	0	0	0	0	0	0	0	1	0
Camelina microcarpa	Capsule	UnC.	0	0	0	0	0	1	0	0	0	1
Campanula spp.	Seed	UnC.	0	0	1	0	5	8	4	22	32	60
Capsella bursa-pastoris	Seed	UnC.	0	0	1	0	5	0	0	0	11	15
Carthamus lanatus/dentatus	Seed	UnC.	0	0	0	0	0	0	0	0	0	1
Caryophyllaceae	Seed	UnC.	0	0	0	2	0	0	0	0	0	0
Caryophyllaceae	Seed	Cha.	0	0	0	0	5	0	0	0	0	0
Caryophyllaceae	Capsule	Sin.	0	0	0	0	0	0	4	0	0	0
Caryophyllaceae	Capsule	UnC.	0	0	0	0	5	17	0	0	11	0
Cerastium sp.	Seed	UnC.	0	1	0	0	0	0	0	11	0	0

Chara spp. with calcite	Oogonium	UnC.	158	101	92	15	62	53	8	0	0	0
Chara spp. without calcite	Oogonium	UnC.	429	912	526	24	334	23	23	242	140	75
Chenopodium album	Seed	UnC.	0	0	0	0	5	23	8	0	0	15
Chenopodium sp.	Seed	UnC.	0	0	1	0	0	0	0	11	0	0
Cornus mas	Seed	UnC.	0	0	0	1	4	3	5	23	14	11
Cornus mas	Seed	Cha.	0	0	0	0	0	1	0	0	0	0
Corylus avellana	Nutshell	UnC.	0	0	0	0	0	1	1	10	7	1
Corylus avellana/Prunus amygdalus	Nutshell	UnC.	0	0	0	0	0	1	0	0	0	0
Crataegus sp.	Seed	UnC.	0	0	0	0	0	0	0	3	0	0
Cuscuta sp.	Seed	UnC.	1	0	0	1	10	4	11	22	25	30
cf. *Digitaria* sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	30
Euphorbia cf. *helioscopia*	Seed	Cha.	0	1	1	0	0	8	0	0	0	0
Fabaceae [small]	Seed	UnC.	0	0	0	0	0	0	0	0	0	15
Fabaceae [small]	Seed	Cha.	0	0	0	0	0	0	4	0	0	0
Fallopia convolvulus	Seed	UnC.	1	1	0	2	5	17	7	27	31	35
Fallopia convolvulus	Seed	Cha.	0	0	0	0	0	0	0	0	0	5
Ficus carica	Seed	UnC.	1	1	0	5	23	15	11	22	56	45
Filipendula vulgaris	Seed	UnC.	0	0	0	0	0	0	0	0	0	15
Fragaria vesca	Seed	UnC.	0	1	4	1	58	61	19	110	153	165

Fumaria officinalis	Seed	UnC.	0	0	1	1	0	8	2	0	1	3
Galium spp.	Seed	UnC.	0	0	0	1	5	0	0	1	15	15
Geranium cf. *purpureum*	Outer seed coat	UnC.	0	0	0	0	0	0	4	1	0	0
Glebionis segetum	Seed	UnC.	0	0	1	0	3	15	0	22	11	15
Heliotropium europaeum	Seed	UnC.	0	0	0	0	0	0	0	0	11	0
Holosteum umbellatum	Seed	UnC.	0	0	0	0	0	8	0	0	0	0
Hypericum perforatum	Seed	UnC.	0	1	2	3	16	9	8	66	108	60
Hypericum perforatum	Seed	Cha.	0	0	0	0	0	0	4	0	0	15
Hypericum spp.	Seed	UnC.	0	0	0	1	0	15	4	4	0	0
Hypericum spp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	15
Juncus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	0
Juniperus cf. *oxycedrus*	Seed	UnC.	0	0	0	0	0	2	2	4	5	1
Juniperus cf. *oxycedrus*	Pitch gland (if no seed)	UnC.	0	1	1	0	0	0	0	0	0	0
Juniperus cf. *oxycedrus*	Fruit	UnC.	0	0	0	0	0	8	0	0	1	0
cf. Liliaceae	Bulb	UnC.	0	0	0	0	0	0	0	0	11	0
Maloideae	Seed	UnC.	0	0	0	0	0	9	1	1	2	15
Maloideae	Seed	Cha.	0	0	0	0	0	0	1	0	0	0
Maloideae	Calyx	UnC.	0	0	0	0	0	1	1	2	3	2
Maloideae	Seed internal tissue	UnC.	1	0	0	1	6	10	2	6	5	21

Maloideae	Tissue endocarp	UnC.	0	0	0	1	0	0	4	0	2	1
Malus sp.	Seed	UnC.	0	0	0	0	6	1	1	3	4	3
Medicago sp.	Pod	UnC.	0	0	0	0	1	0	4	3	11	31
Medicago sp.	Pod	Cha.	0	0	0	0	0	0	0	1	11	0
Mentha longifolia	Seed	UnC.	0	0	0	0	5	0	4	0	0	0
Najas marina	Seed	UnC.	4	1	1	1	3	9	1	6	2	0
Najas sp.	Seed	UnC.	1	0	1	1	0	8	0	3	0	0
Origanum vulgare	Seed	UnC.	0	1	0	0	0	0	0	0	0	15
Ostrya carpinifolia	Seed	UnC.	1	0	3	2	5	9	2	0	0	15
Papaver sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	16
Petrorhagia spp.	Seed	UnC.	0	0	0	0	5	0	8	11	11	15
cf. *Petrorhagia* spp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	15
Petrorhagia sp./ *Dianthus* sp.	Seed	UnC.	0	0	1	1	0	0	0	0	0	0
Phragmites australis	Culm	UnC.	0	3	2	0	0	0	0	0	0	1
Phragmites australis	Culm	Cha.	0	0	0	0	0	0	0	0	12	168
Phragmites australis	Culm node interior	Cha.	0	0	0	0	0	0	0	0	0	16
Pinaceae	Needle	UnC.	1	0	0	0	0	0	0	0	0	0
Pinus sp.	Needle	UnC.	0	0	0	1	6	9	4	14	15	90
Pinus sp.	Needle	Cha.	0	0	0	0	0	0	0	0	0	15

Pinus sp.	Cone scale	Cha.	0	0	0	2	0	0	0	0	0	0
Pistacia terebinthus	Seed	UnC.	0	0	1	1	25	18	6	45	51	8
Pistacia terebinthus	Seed	Cha.	0	0	0	0	0	1	0	3	19	8
Pistacia terebinthus	Attachment point	UnC.	0	0	0	0	0	0	0	1	11	30
Poa cf. *annua*	Seed	UnC.	0	0	0	0	0	0	0	0	11	0
Poa cf. *trivialis*	Seed	UnC.	0	0	0	0	0	0	0	11	11	0
Poa cf. *trivialis*	Seed	Bro.	0	0	0	0	0	0	0	11	0	0
Poaceae >2mm	Seed	UnC.	0	0	0	0	0	8	4	22	11	0
Poaceae <2mm	Seed	UnC.	0	0	0	2	0	0	0	11	0	0
Polycnemum arvense	Seed	UnC.	0	0	3	0	0	0	4	0	0	15
Polygonaceae	Seed	Cha.	0	0	0	0	0	0	0	0	11	0
Polygonum aviculare	Seed	UnC.	0	0	1	0	0	0	4	0	11	0
Potamogeton sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	0
Prunus amygdalus	Nutshell frag.	UnC.	0	0	0	1	3	25	12	75	43	20
Prunus amygdalus	Nutshell frag.	Cha.	0	0	0	0	0	0	0	1	0	0
Prunus cf. *spinosa*	Seed	UnC.	1	0	0	0	0	0	0	0	0	0
Pyrus/Sorbus	Seed	UnC.	0	0	0	0	1	0	1	2	1	3
Quercus sp.	Nutshell base	UnC.	0	0	0	0	2	0	2	4	2	2
Quercus sp.	Nutshell	Cha.	0	0	0	0	0	0	0	1	11	1

Quercus sp.	Nutshell	UnC.	0	0	0	1	7	5	5	10	11	19
Ranunculus spp.	Seed	UnC.	0	0	0	0	0	0	1	0	4	1
Rosa spp.	Seed	UnC.	0	0	1	1	1	13	10	34	18	13
Rubus fruticosus agg.	Seed	UnC.	2	1	24	45	544	1070	397	524	924	982
Rubus fruticosus agg.	Seed	Sin.	0	0	1	1	0	9	1	2	2	2
Rubus fruticosus agg.	Seed	Cha.	0	0	0	0	0	1	0	0	2	0
Rubus idaeus	Seed	UnC.	0	0	0	0	0	9	4	0	1	0
Rumex cf. *acetosella*	Seed	UnC.	0	0	0	0	0	0	0	11	0	0
Rumex sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	1
Sambucus cf. *ebulus*	Seed	UnC.	0	0	0	0	0	0	0	1	1	0
Sambucus cf. *nigra*	Seed	UnC.	0	0	0	0	0	0	0	0	1	0
Sambucus spp.	Seed	UnC.	0	0	1	0	0	2	4	4	0	0
Scleranthus annuus	Exocarp	UnC.	0	0	0	0	1	8	0	11	11	45
Silene spp.	Seed	Cha.	0	0	0	0	0	0	0	0	11	0
Silene spp.	Seed	UnC.	0	0	1	1	0	0	8	11	23	30
Silene sp.	Capsule	UnC.	0	0	1	1	5	15	4	23	17	17
Stellaria media	Seed	UnC.	0	1	0	1	0	15	0	11	11	0
Stellaria sp.	Seed	UnC.	0	0	0	0	5	0	0	0	0	15
Taraxacum sp.	Seed	UnC.	0	0	0	2	3	0	0	11	3	15

Teucrim sp.	Seed	UnC.	0	0	0	0	0	8	0	0	0	0
Thlaspi arvense	Seed	UnC.	0	0	0	0	0	0	0	0	1	0
cf. *Tilia platyphyllos*	Exocarp	UnC.	0	0	0	0	0	0	0	0	1	0
Tordylium maximum	Seed	UnC.	0	0	0	0	1	8	0	0	0	3
Tordylium cf. *maximum*	Seed	UnC.	0	0	1	0	0	0	0	0	0	0
Trifolium sp.	Exocarp	UnC.	0	0	0	0	6	0	4	12	13	31
Urtica dioica	Seed	UnC.	1	1	0	0	5	8	4	0	11	45
Urtica dioica	Seed	Cha.	0	0	0	0	0	0	4	0	0	0
Valeriana dentata	Seed	UnC.	0	0	0	0	0	0	8	22	0	15
Valeriana dentata	Seed	Cha.	0	0	0	0	0	8	0	0	0	0
Valeriana locusta	Seed	UnC.	0	0	0	0	0	0	0	0	0	15
Verbascum spp.	Seed	UnC.	0	0	1	0	16	8	4	11	43	60
Verbena officinalis	Seed	UnC.	1	0	2	0	0	0	0	0	11	0
Viola sp.	Capsule	UnC.	0	0	0	0	0	0	0	0	2	1
Vitis vinifera subsp. *sylvestris*	Seed	UnC.	0	0	0	0	1	0	0	4	0	4
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	0	0	0	0	1	8	0	2	4	3
Vitis vinifera subsp. *sylvestris*	Seed	Sin.	0	0	1	1	1	1	1	1	15	0
Vitis vinifera subsp. *sylvestris*	Pedicel	UnC.	0	0	0	0	0	0	0	0	0	1
INDETERMINATE												

Indet	Capsule	UnC.	0	0	0	1	0	0	0	0	0	0
Indet	Capsule	Cha.	0	0	0	0	0	8	0	0	0	0
Indet	Cf. Lichen	UnC.	1	0	2	7	5	0	4	12	35	15
Indet	Cf. Lichen	Cha.	0	0	0	0	0	0	0	12	67	120
Indet	Cupule frag.	UnC.	0	0	0	0	5	0	0	34	1	31
Indet	Flower	UnC.	0	1	0	1	0	0	0	0	1	15
Indet	Fruit pedicel	UnC.	0	0	0	0	1	0	0	0	0	0
Indet	Nut kernel	Cha.	0	0	1	0	0	0	0	0	2	0
Indet	Nutshell	Cha.	0	0	0	0	0	0	1	0	0	0
Indet	Seed coat	Cha.	0	0	0	0	5	0	0	0	0	0
Indet	Seed/fruit	UnC.	0	0	0	6	0	8	0	0	0	0
Indet	Seed/fruit	Cha.	0	0	0	0	0	0	1	1	1	0
Indet	Seed/fruit/bud	Cha.	0	0	0	0	0	0	0	0	11	0

Table 2: Archaeobotanical dataset for Core QLM19 0. One of three tables. Middle Neolithic samples.

Core QLM19 0 (Table 1 of 3)													
SAMPLE CODE			0.2.1	0.2.2	0.2.3	0.2.4	0.2.5	0.2.6	0.2.7	0.2.8	0.2.9	0.2.10	0.2.11	0.2.12
PERIOD			MN	MN	MN	MN	MN	MN	MN	MN	MN	MN	MN/ LN	MN/ LN
VOLUME SAMPLE (ml)			27	30	40	50	30	55	35	30	35	66.5	15	20
TAXA.	TYPE	PRES.												
CROPS														
Cerealia	Testa with hilum >2mm	Unc.	0	0	1	1	0	1	0	0	1	1	3	4
Cerealia	Awn, straight barbed	Cha.	0	0	0	0	0	0	0	0	1	0	1	3
Cerealia	Awn, twisted	Cha.	0	0	0	0	0	0	0	0	0	1	0	0
Fabaceae	Pod frag.	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Pod frag.	Cha.	0	0	0	1	0	0	0	0	0	0	0	0
Fabaceae [large]	Seed frag.	Cha.	0	0	0	0	2	0	0	0	0	0	0	0
Hordeum vulgare/distichon	Rachis segment	Cha.	0	0	0	0	1	0	0	0	0	0	0	0
Hordeum vulgare/distichon	Rachis segment	Unc.	0	0	0	0	0	0	0	0	0	0	0	2
Linum usitatissimum	Capsule segment	Unc.	0	0	0	0	0	2	0	0	0	2	0	1
Linum usitatissimum	Seed frag.	Unc.	0	0	0	0	0	0	0	0	0	1	0	0

Linum usitatissimum	Seed with hilum	Unc.	0	0	0	0	0	1	0	0	0	0	0	1
Papaver somniferum	Seed	Unc.	0	0	0	0	0	2	0	0	0	0	0	1
Triticum dicoccum	SPK/GB	Cha.	0	0	0	1	0	1	0	0	0	0	0	0
T. dicoccum/ monococcum/timopheevii	SPK/GB	Unc.	0	0	0	0	6	1	1	0	0	6	0	7
T. dicoccum/ monococcum/timopheevii	SPK/GB	Sin.	0	0	0	0	0	1	0	0	0	0	0	0
T. dicoccum/ monococcum/timopheevii	SPK/GB	Bro.	0	0	0	0	0	0	0	1	0	1	3	5
T. dicoccum/ monococcum/timopheevii	SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	1	2	0
Triticum monococcum	SPK/GB	Cha.	0	0	0	0	0	1	0	0	0	0	0	0
NON-CROP PLANTS														
Abies alba	Needle	Unc.	1	3	1	134	212	77	4	27	48	336	5	2
Abies alba	Needle	Cha.	0	0	0	0	0	0	0	0	0	0	0	1
Abies alba	Needle	Bro.	0	0	0	1	0	0	0	0	0	0	0	0
Abies sp.	Needle	Unc.	1	0	2	13	33	14	1	4	10	30	4	2
Abies sp.	Needle	Bro.	0	0	0	2	0	0	0	0	0	0	1	0
Abies sp.	Needle	Cha.	0	0	0	0	0	1	0	0	0	0	0	0

Agrostemma githago	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Ajuga chamaepitys	Seed	Unc.	0	0	0	0	1	1	0	0	0	0	0	0
Alchemilla/Aphanes spp.	Seed	Unc.	0	0	1	0	0	0	0	0	0	0	0	0
Alnus glutinosa	Seed	Unc.	0	0	0	1	0	1	0	0	0	0	0	0
Amarathaceae	Seed	Unc.	0	1	0	0	0	0	0	0	0	0	0	0
Amarathaceae	Seed core	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Arenaria serpyllifolia	Seed	Unc.	0	0	0	0	1	0	0	0	1	0	0	0
Bromus spp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Campanula spp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Capsella bursa-pastoris	Seed	Unc.	0	0	0	0	0	0	0	0	0	1	0	0
Caryophyllaceae	Seed	Unc.	0	0	0	1	0	1	0	0	0	1	0	0
Caryophyllaceae	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	1
cf. *Arenaria serpyllifolia*	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Chara spp. with calcite	Oogonium	Unc.	41	445	663	656	43	102	119	69	45	43	3	2
Chara spp. without calcite	Oogonium	Unc.	54	49	464	820	189	136	46	26	52	72	9	25
Chenopodium sp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Cornus mas	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Corylus avellana	Nutshell	Unc.	0	0	0	1	0	0	0	0	0	0	1	0
Crataegus sp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0

Cuscuta sp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	1
Cyperaceae	Seed	Unc.	0	0	0	0	1	1	0	0	0	1	0	0
Euphorbia cf. *helioscopia*	Seed	Unc.	0	0	0	1	0	0	0	0	0	0	0	0
Fallopia convolvulus	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Ficus carica	Seed	Unc.	0	0	0	0	3	0	0	0	0	1	1	0
Fragaria vesca	Seed	Unc.	0	0	0	1	0	2	0	1	0	0	1	1
Fumaria officinalis	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Heliotropium europaeum	Seed	Unc.	0	0	0	0	0	1	0	0	0	0	1	0
Heliotropium europaeum	Seed	Cha.	0	0	0	0	1	1	0	1	0	0	0	0
Hypericum perforatum	Seed	Unc.	0	0	0	1	0	0	0	0	1	0	0	0
Hypericum spp.	Seed	Unc.	0	0	0	2	0	0	0	0	0	0	0	0
Juniperus cf. *communis*	Seed	Unc.	0	0	1	8	20	40	0	2	1	0	0	0
cf. *Juniperus excelsa/ foetidissima/ sabina*	Seed	Unc.	0	0	1	1	5	17	0	0	1	2	0	0
Juniperus sp.	Fruit	Unc.	0	0	0	0	1	0	0	0	0	0	0	2
Juniperus sp.	Needle/leaves	Unc.	1	0	0	1	0	0	0	0	0	2	0	0
Maloideae	Seed	Unc.	0	0	0	0	0	0	0	0	0	1	0	0
Maloideae	Seed internal tissue	Unc.	0	0	0	0	0	0	1	0	0	2	0	0
Maloideae	Tissue endocarp	Unc.	0	0	0	0	0	0	0	0	0	0	0	1

Malva cf. *sylvestris*	Mericarp	Unc.	0	0	0	1	0	0	0	0	0	1	0	0
Medicago sp.	Pod	Unc.	0	0	0	1	0	0	0	0	0	0	0	0
Melampyrum sp.	Seed	Unc.	0	0	0	0	2	0	0	0	0	0	0	0
Mentha/*Origanum* sp.	Seed	Unc.	0	0	0	1	0	0	0	0	0	0	0	0
Najas marina	Seed	Unc.	1	1	1	2	2	4	0	2	2	1	1	1
Najas sp.	Seed	Unc.	0	0	0	1	0	0	0	0	0	0	0	1
Ostrya carpinifolia	Seed	Unc.	0	1	0	1	0	2	0	0	1	0	0	1
Papaver sp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	1
Phragmites australis	Culm	Cha.	0	0	0	0	1	0	0	0	0	0	0	0
Picris hieracioides	Seed	Unc.	0	0	0	0	1	0	0	0	0	0	0	0
Pinus sp.	Needle	Unc.	1	0	1	2	6	4	0	1	4	23	1	1
Pistacia terebinthus	Seed	Unc.	0	1	0	3	4	2	4	0	0	1	0	0
Poaceae large	Seed	Unc.	0	0	0	0	0	1	0	0	2	0	0	1
Poaceae small	Seed	Unc.	0	0	1	0	2	5	1	0	0	0	0	0
Polycnemum arvense	Seed	Unc.	0	0	1	1	0	1	0	0	0	0	1	1
Potamogeton sp.	Seed	Unc.	0	0	0	0	0	1	0	0	0	0	0	0
Prunus amygdalus	Nutshell	Unc.	0	0	0	0	0	1	0	0	0	0	0	1
Quercus sp.	Nutshell base	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Nutshell	Unc.	0	0	0	0	2	1	0	1	2	3	0	1

Rosa spp.	Seed	Unc.	0	0	0	1	4	0	0	0	1	3	0	0
Rubus fruticosus agg.	Seed	Unc.	1	0	0	1	3	3	1	1	0	2	3	5
Rubus fruticosus agg.	Seed	Cha.	0	0	0	0	0	1	0	0	0	0	0	0
Rumex sp.	Seed	Unc.	0	0	0	0	1	0	0	0	0	0	0	0
Sambucus spp.	Seed	Unc.	1	0	0	0	2	0	0	0	1	0	1	1
Scleranthus annuus	Exocarp	Unc.	0	0	1	0	0	0	0	0	0	1	0	0
Silene spp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	1	0	0
Stellaria media	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Taraxacum sp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Tordylium maximum	Seed	Unc.	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium sp.	Exocarp	Unc.	0	0	0	1	0	0	0	0	0	0	0	0
Typha sp.	Seed	Unc.	0	0	0	0	0	0	0	0	0	1	0	1
Verbascum spp.	Seed	Unc.	0	0	0	0	0	1	0	0	0	0	0	1
Verbena officinalis	Seed	Unc.	0	0	0	1	1	1	0	0	0	0	3	0
Vitis vinifera subsp. *sylvestris*	Seed	Unc.	0	0	0	1	1	1	0	0	0	0	0	0
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	0	0	0	0	2	1	1	1	1	1	1	2
Vitis vinifera subsp. *sylvestris*	Seed	Sin.	0	0	0	1	2	0	0	0	0	0	0	0
INDETERMINATE														
Indet	Cf. lichen	Unc.	0	0	0	0	2	0	0	0	0	0	0	0

Indet	Flower	Unc.	0	0	0	0	2	2	0	0	0	0	0	0
Indet	Herbaceous stem	Cha.	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Pedicel	Cha.	0	0	0	0	1	0	0	0	0	0	0	0
Indet	Pedicel	Unc.	0	0	0	0	3	0	0	0	0	0	0	0
Indet	Seed/Fruit	Unc.	0	0	0	1	14	12	2	1	6	1	0	0

Table 3: Archaeobotanical dataset for Core QLM19 0. Two of three tables. Late Neolithic samples.

Core QLM19 0 (Table 2 of 3)																			
SAMPLE CODE			0.2.13	0.1.1	0.1.2	0.1.3	0.1.4	0.1.5	0.1.6	0.1.7	0.1.8	0.1.9	0.1.10	0.1.11	0.1.12	0.1.13	0.1.14	0.1.15	0.1.16	0.1.17
PERIOD			LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN
VOLUME SAMPLE (ml)			60	90	100	200	100	60	32	150	100	55	130	170	100	70	125	140	50	70
TAXA	TYPE	PRES.																		
CROPS																				
Cerealia	Awn, straight barbed	Cha.	1	2	0	0	0	0	0	0	2	0	0	0	3	2	0	0	0	4
Cerealia	Awn, twisted	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	6
Cerealia	Basal rachis	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Cerealia	Basal rachis	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerealia	Embryo	Cha.	0	0	0	0	0	0	0	0	0	0	4	5	0	0	0	0	0	0
Cerealia	Bulgur	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0
Cerealia	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Cerealia	Rachis segment	UnC.	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0

Cerealia	Rachis segment	Cha.	0	0	0	0	2	1	0	0	0	0	0	3	0	0	0	0	0	0
Cerealia	Testa with hilum >2mm	UnC.	4	2	0	0	1	1	0	2	12	0	0	10	13	14	0	3	3	8
Fabaceae	Hilum	Bro.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Fabaceae	Hilum	UnC.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0
Fabaceae	Hilum	Cha.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Fabaceae	Pod frag.	UnC.	1	14	4	1	0	3	3	127	52	3	14	6	3	19	2	2	19	30
Fabaceae	Pod frag.	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Fabaceae	Pedicel	UnC.	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0
Fabaceae [large]	Seed	Cha.	0	0	1	0	0	0	0	0	0	1	2	0	0	2	0	0	1	0
Hordeum cf. *distichon*	Rachis segment	UnC.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
H. cf. *distichon,* hulled	Rachis segment	Cha.	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
H. cf. *distichon*, naked	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
H. cf. *vulgare*, hulled	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
H. cf. *vulgare*, naked	Rachis segment	Cha.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
H. distichon	Rachis segment	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. distichon, naked	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0
H. vulgare	Rachis segment	UnC.	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0
H. vulgare, hulled	Rachis segment	Cha.	0	0	0	0	2	0	0	4	0	0	0	0	0	2	0	0	0	0

H. vulgare, naked	Rachis segment	UnC.	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0
H. vulgare, naked	Rachis segment	Cha.	0	0	1	0	0	0	0	0	4	0	2	0	0	0	0	3	1	2
H. vulgare/distichon	Grain with emb.-end	Cha.	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
H. vulgare/distichon	Rachis segment	Sin.	0	0	0	1	0	0	0	0	0	0	0	0	3	2	30	0	4	0
H. vulgare/distichon	Rachis segment	UnC.	3	12	6	1	8	5	7	21	38	0	14	10	20	6	0	10	15	8
H. vulgare/distichon	Rachis segment	Cha.	0	6	0	0	4	0	0	2	4	6	0	10	3	2	5	5	0	2
H. vulgare/distichon	Rachis segment	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. vulgare/distichon, naked	Lemma base	UnC.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Lens culinaris	Hilum	Bro.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Lens culinaris	Hilum	UnC.	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0
Lens culinaris	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Linum usitatissimum	Capsule segment	Unc.	1	9	4	1	6	0	8	2	8	1	4	10	9	10	5	21	36	62
Linum usitatissimum	Seed with hilum	UnC.	1	16	4	0	2	2	1	2	0	1	2	3	13	2	0	3	5	6
Papaver somniferum	Seed	UnC.	1	5	2	0	4	5	1	2	4	1	18	0	15	14	30	21	6	14
cf. *Pisum sativum*	Hilum	UnC.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum aestivum	Rachis segment	UnC.	0	0	0	0	0	1	0	0	4	0	0	0	0	0	0	0	1	0
T. aestivum	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	1	0
T. aestivum/durum	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

T. aestivum/durum	Rachis segment	UnC.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
T. cf. *aestivum/durum*	Rachis segment	UnC.	0	0	2	0	4	0	4	2	2	0	0	0	11	0	0	1	0	0
T. dicoccum	Grain with emb.-end	Cha.	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
T. dicoccum	SPK/GB	Sin.	0	16	14	2	12	0	0	2	33	4	2	0	0	4	34	3	4	4
T. dicoccum	SPK/GB	Cha.	0	1	8	2	11	2	4	3	9	9	14	12	12	12	15	4	4	30
T. dicoccum/ monococcum/ timopheevii	SPK/GB	Sin.	1	48	10	0	0	2	1	0	52	5	4	0	0	38	56	0	21	18
T. dicoccum/ monococcum/ timopheevii	SPK/GB	Bro.	8	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. dicoccum/ monococcum/ timopheevii	SPK/GB	UnC.	49	308	155	85	165	278	166	294	1097	178	240	528	353	409	521	236	267	318
T. dicoccum/ monococcum/ timopheevii	SPK/GB	Cha.	0	2	4	3	15	0	0	0	8	0	0	18	0	20	9	7	6	36
T. monococcum	Bulgur	Sin.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
T. monococcum	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0
T. monococcum	SPK/GB	Sin.	0	20	0	2	0	0	2	4	12	3	0	0	0	4	5	2	3	10
T. monococcum	SPK/GB	Cha.	1	12	2	11	12	5	4	6	11	5	19	25	13	19	19	31	10	28

T. timopheevii	SPK/GB	Cha.	0	0	0	3	1	0	0	0	0	0	0	0	0	0	4	0	4
T. timopheevii	SPK/GB	Sin.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T. timopheevii/dicoccum	SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	8
T. timopheevii/dicoccum	Terminal SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Triticum spp.	Basal rachis	UnC.	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0	0	0
Triticum spp.	Bulgur	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	2
Triticum spp.	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0
Vicia ervilia	Hilum	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	2
Vicia ervilia	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
NON-CROP PLANTS																				
Abies alba	Needle	UnC.	17	1	1	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0
Abies sp.	Needle	UnC.	2	2	0	3	2	1	0	2	0	0	1	4	0	0	9	0	0	0
cf. *Acer* sp.	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	0	1	0	6	0	0	1
Agrimonia eupatoria	Exocarp	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Agrostemma githago	Seed	UnC.	1	0	2	1	0	0	1	0	0	0	0	0	0	4	1	0	0	0
Alchemilla/Aphanes spp.	Seed	UnC.	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	3	0	0
Alisma sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Alnus glutinosa	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Amarathaceae	Seed	UnC.	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amarathaceae	Seed core	UnC.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apiaceae	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Arenaria serpyllifolia	Seed	UnC.	1	4	6	0	8	3	1	6	0	0	2	15	7	2	0	21	6	20
Asteraceae	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Avena sp.	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Avena sp.	Lemma base	UnC.	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Avena sp.	Lemma base	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
cf. *Bifora radians*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Brassicaceae	Capsule	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Brassicaceae	Seed	UnC.	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	1
Bromus arvensis	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0
Bromus arvensis /hordeaceus /secalinus	Seed	UnC.	0	0	0	0	0	0	0	4	0	0	0	0	5	0	0	0	0	2
Bromus spp.	Seed	UnC.	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bromus sterilis	Seed	UnC.	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus tectorum	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	2	0	0	2	0	0	0	0
Camelina microcarpa	Capsule	UnC.	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0
Campanula spp.	Seed	UnC.	1	4	2	0	0	2	0	0	18	0	0	0	3	2	0	5	0	0

Capsella bursa-pastoris	Seed	UnC.	0	2	2	2	0	1	0	2	0	1	0	0	3	0	0	7	0	0
Carex spp. 2-sided	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	9	0	0	0
Carex spp. 3-sided	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Caryophyllaceae	Capsule	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Caryophyllaceae	Seed	UnC.	1	0	2	0	0	0	3	0	0	0	0	0	0	2	0	3	0	0
Cerastium sp.	Seed	UnC.	0	0	0	0	0	1	0	4	0	2	0	0	3	4	9	7	1	2
Chara spp. without calcite	Oogonium	UnC.	41	1	0	3	6	1	1	6	0	8	12	8	7	0	13	10	1	10
Chara spp. with calcite	Oogonium	UnC.	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium album	Seed	UnC.	0	0	4	0	10	0	1	0	14	6	0	10	7	8	5	15	0	2
Chenopodium album	Seed	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium sp.	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Cirsium/Carduus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Cornus mas	Seed	UnC.	1	2	2	0	2	1	0	0	2	0	2	4	0	1	3	2	0	1
Corylus avellana	Nutshell frag.	UnC.	1	1	2	1	0	3	0	0	0	0	0	0	0	4	0	2	0	1
Crataegus sp.	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crepis sp.	Seed	UnC.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Cuscuta sp.	Seed	UnC.	0	2	10	2	0	1	0	4	2	1	4	8	5	0	9	22	12	8
Cyperus fuscus	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0

Epilobium sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Eupatorium cannabinum	Seed	UnC.		0	0	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0
Euphorbia cf. *exigua*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Fallopia convolvulus	Seed	UnC.	1	1	0	1	2	2	0	12	4	2	3	8	1	8	9	2	5	2
Ficus carica	Seed	UnC.	3	4	8	0	0	0	0	2	4	2	0	8	0	4	9	10	2	6
Filipendula vulgaris	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragaria vesca	Seed	UnC.	3	15	20	28	36	71	8	20	20	9	36	75	83	46	27	46	10	22
Fragaria vesca	Seed	Cha.	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Fumaria officinalis	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0
Galium aparine	Seed	UnC.	0	2	6	1	2	0	0	2	2	0	0	0	0	0	0	0	0	0
Galium spp.	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	2	0	3	0	5	0	1	2
Galium spp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Galium spurium	Seed	UnC.	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Glebionis segetum	Seed	UnC.	0	0	0	1	0	0	0	2	2	0	2	13	3	0	5	5	0	0
Heliotropium europaeum	Seed	UnC.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3
Hordeum sp. (wild)	Rachis segment	UnC.	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Hypericum perforatum	Seed	UnC.	0	6	6	4	4	6	4	4	6	2	8	15	22	6	13	12	6	8
Hypericum perforatum	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0

Hypericum spp.	Seed	UnC.	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Juncus sp.	Seed	UnC.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juniperus cf. *oxycedrus*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	5	3	0	0	2	1	1
Juniperus sp.	Needle	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Juniperus sp.	Pitch gland	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lamiaceae	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	2	0	0	0	5	0	0	0
Lamium spp.	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lapsana communis	Seed	UnC.	0	2	0	0	0	1	0	0	4	0	0	0	0	0	0	0	0	0
Maloideae	Calyx	UnC.	0	0	0	0	0	0	0	0	14	0	0	0	1	0	0	0	0	0
Maloideae	Inside seed tissue	UnC.	0	2	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Maloideae	Outside seed tissue	UnC.	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maloideae	Seed	UnC.	0	1	1	0	0	0	1	0	1	0	1	0	0	1	6	1	0	0
Maloideae	Seed	Cha.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Medicago sp.	Pod	UnC.	2	3	0	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0
Medicago sp.	Pod	Cha.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melissa officinalis	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2
Mentha aquatica	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	0	3	3	0	0	0	1	2
Mentha longifolia	Seed	UnC.	0	0	0	0	0	0	0	0	0	2	2	3	0	4	5	0	0	0
Mentha spp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0

Najas marina	Seed	UnC.	0	0	0	3	0	1	0	0	0	1	0	0	0	0	0	0	0	2
Origanum vulgare	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	2	0	3	2	5	0	0	0
Ostrya carpinifolia	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Papaver sp.	Seed	UnC.	0	3	0	1	0	0	0	2	0	0	0	15	0	0	0	0	0	0
Petrorhagia spp.	Seed	UnC.	0	0	0	1	2	1	0	0	0	0	0	3	0	2	5	5	1	0
Petrorhagia spp.	Seed	Cha.	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Phragmites australis	Culm	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alkekengi officinarum	Seed	UnC.	0	1	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0
Picris hieracioides	Seed	UnC.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pinus sp.	Needle	UnC.	1	2	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0
Pistacia terebinthus	Nutshell frag.	UnC.	1	11	2	1	7	6	3	5	8	1	2	16	2	11	6	5	8	47
Pistacia terebinthus	Nutshell frag.	Cha.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa annua	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Poa cf. *trivalis*	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	4
Poaceae >2mm	Seed	UnC.	0	0	2	1	4	1	0	6	6	1	0	15	3	2	0	0	0	2
Poaceae <2mm	Seed	UnC.	0	0	4	1	2	0	0	2	4	0	0	0	0	0	0	3	0	0
Polycnemum arvense	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonum aviculare	Seed	UnC.	0	0	0	1	0	0	0	2	0	1	2	3	3	0	5	0	1	0
Potentilla sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Prunus amygdalus	Nutshell frag.	UnC.	2	1	0	0	7	2	0	10	5	2	1	2	0	0	3	6	1	1
Prunus spinosa	Seed	UnC.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrus/Sorbus	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Quercus sp.	Nutshell frag.	UnC.	18	47	11	1	3	6	1	2	0	1	5	4	1	13	1	1	21	29
Quercus sp.	Nutshell base	UnC.	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Quercus sp.	Cupule frag.	UnC.	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ranunculus spp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Rosa spp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	3	3	8	8	1	2	1
Rosaceae	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Rubus fruticosus agg.	Seed	UnC.	20	61	140	62	183	94	20	158	61	29	205	267	152	187	220	548	65	229
Rubus fruticosus agg.	Seed	Cha.	0	0	0	0	2	1	0	0	2	0	2	0	0	0	0	0	0	0
Rubus fruticosus agg.	Seed	Sin.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Rubus fruticosus/idaeus	Seed	UnC.	0	9	6	2	6	3	3	0	0	1	6	0	0	10	0	3	0	22
Rubus idaeus	Seed	UnC.	0	4	4	2	0	1	2	0	9	2	10	3	0	4	0	3	5	8
Rumex sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Rumex sp.	Perianth	UnC.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus spp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	1	2	3	0	3	0	1	1	0
Schoenoplectus /Scirpus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0

Scleranthus annuus	Exocarp	UnC.	0	0	0	0	0	1	1	2	0	1	4	3	0	4	5	0	0	0
Silene sp.	Capsule	Cha.	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Silene sp.	Capsule	UnC.	0	0	2	0	0	1	0	0	0	1	3	0	0	0	5	1	0	0
Silene spp.	Seed	UnC.	0	3	0	1	0	1	1	2	2	0	2	5	3	2	9	0	0	0
Silene spp.	Seed	Cha.	0	0	0	0	2	0	0	0	4	0	2	0	0	0	0	0	0	0
Solanaceae	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae	Seed	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	Seed	UnC.	1	2	0	0	2	0	0	0	0	0	0	3	1	0	9	3	1	2
Stellaria sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Taraxacum sp.	Seed	UnC.	1	0	0	0	0	0	0	0	4	0	0	5	3	0	5	0	1	4
Teucrium spp.	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0
cf. *Tilia platyphyllos*	Exocarp	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tordylium maximum	Seed	UnC.	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
cf. *Torilis* sp.	Seed	UnC.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Trifolium sp.	Exocarp	UnC.	0	0	2	0	0	2	2	0	0	0	0	0	1	1	0	1	0	0
Trifolium sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Urtica dioica	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	5	3	0	0
Valeriana dentata	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0
Valeriana spp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Verbascum spp.	Seed	UnC.	1	0	0	0	0	0	0	6	2	1	2	3	9	2	5	12	0	2
Verbena officinalis	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0	3	0	0	5	1	0	2
Viola sp.	Capsule	UnC.	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	2
Viola sp. [small]	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	5	0	0	0	3	1	0
Vitis vinifera subsp. *sylvestris*	Seed	Sin.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Vitis vinifera subsp. *sylvestris*	Seed	UnC.	1	0	0	1	0	1	0	1	0	0	2	0	1	0	0	0	0	0
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	1	2	3	0	1	1	0	2	2	0	0	0	0	0	0	0	0	0
INDETERMINATE																				
Indet	Cupule frag.	UnC.	0	0	2	0	0	1	0	0	0	1	0	3	0	0	0	0	3	0
Indet	Flower	UnC.	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Seed/Fruit	UnC.	2	6	0	3	4	2	3	6	11	5	6	10	9	0	26	10	5	14
Indet	Seed/Fruit	Cha.	0	0	0	0	0	0	4	0	0	1	0	10	0	4	0	0	0	0
Indet	Stem	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0

Table 4: Archaeobotanical dataset for Core QLM19 0. Three of three tables. Late Neolithic samples.

Core QLM19 0 (Table 3 of 3)												
SAMPLE CODE			0.0.1	0.0.2	0.0.3	0.0.4	0.0.5	0.0.6	0.0.7	0.0.8	0.0.9	0.0.10	0.0.11
PERIOD			LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN
VOLUME SAMPLE (ml)			50	90	30	50	80	100	120	110	60	90	80
TAXA	TYPE	PRES.											
CROPS													
Cerealia	Awn, straight, barbed	Cha.	9	5	3	3	16	4	3	3	10	0	10
Cerealia	Awn, twisted	Cha.	0	2	4	0	4	0	0	0	0	1	0
Cerealia	Basal rachis segment	UnC.	0	0	0	0	0	0	0	0	0	0	1
Cerealia	Basal rachis segment	Cha.	1	0	0	0	0	0	0	0	0	1	0
Cerealia	Culm node	Bro.	1	0	0	0	0	0	0	0	0	0	0
Cerealia	Culm node	UnC.	0	0	0	0	0	0	0	0	1	0	0
Cerealia	Culm node	Cha.	0	0	0	0	1	0	1	0	0	0	0
Cerealia	Embryo	Bro.	0	0	0	0	0	1	0	0	0	0	0
Cerealia	Embryo	Cha.	1	4	0	2	9	4	1	0	1	2	0

Cerealia	Embryo, sprouted?	Cha.	1	0	0	0	0	0	0	0	0	0	0
Cerealia	Bulgur	Cha.	0	0	0	0	3	5	0	0	0	0	0
Cerealia	Grain frag. ap.-end	Cha.	0	0	0	0	0	1	0	0	0	0	0
Cerealia	Grain frag. embr-end	Cha.	0	0	0	1	2	1	0	1	0	0	0
Cerealia	Lemma/palea	UnC.	0	0	0	0	0	1	0	0	0	0	0
Cerealia	Testa with hilum (>2mm)	UnC.	1	0	0	4	0	0	0	0	0	0	0
Fabaceae	Hilum	Bro.	2	0	0	0	0	0	0	0	0	0	0
Fabaceae	Hilum	Cha.	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Nose	Cha.	1	0	0	0	0	0	0	0	0	0	0
Fabaceae	Pod frag.	UnC.	3	1	2	0	2	3	0	1	0	2	0
Fabaceae	Pod frag.	Cha.	2	3	0	0	0	0	0	0	0	1	1
Fabaceae	Pedicel	UnC.	0	0	0	0	0	2	0	0	2	0	0
Fabaceae	Pedicel	Cha.	0	0	0	0	1	0	0	0	0	0	0
Fabaceae [large]	Seed	Cha.	1	0	1	1	0	0	0	1	0	0	0
Hordeum cf. *distichon* cf. naked	Rachis segment	Cha.	1	0	0	0	0	0	0	0	0	0	0
H. cf. *vulgare*	Rachis segment	Cha.	0	0	0	0	0	1	0	1	0	1	0
H. cf. *vulgare*, hulled	Rachis segment	Cha.	0	0	0	0	0	0	0	1	0	0	0
H. cf. *distichon*	Rachis segment	Cha.	0	0	0	1	0	0	0	0	0	0	0
H. distichon	Rachis segment	Cha.	0	1	0	0	1	1	0	0	0	0	0

H. distichon, hulled	Rachis segment	Cha.	1	0	0	0	0	0	0	0	1	0	0
H. vulgare	Grain with ap.-end	Cha.	1	0	0	0	0	0	0	0	0	0	0
H. vulgare	Grain with ap.-end, straight	Cha.	0	0	0	1	0	0	0	0	0	0	0
H. vulgare, cf. nudum	Rachis segment	Cha.	2	0	0	0	0	0	0	0	0	0	0
H. vulgare, hulled	Rachis segment	Cha.	2	1	0	0	3	0	2	1	0	0	0
H. vulgare/distichon	Lemma/palea	UnC.	0	0	0	1	0	1	0	0	0	0	0
H. vulgare/distichon	Basal rachis segment	Cha.	0	0	2	0	0	0	0	0	0	0	0
H. vulgare/distichon	Rachis segment	Sin.	0	0	1	0	1	0	1	1	3	0	0
H. vulgare/distichon	Rachis segment	Bro.	0	0	0	0	0	1	0	0	0	0	0
H. vulgare/distichon	Rachis segment	UnC.	4	5	1	3	7	6	5	5	4	3	1
H. vulgare/distichon	Rachis segment	Cha.	0	0	0	0	4	2	0	0	0	0	0
H. vulgare/distichon, naked	Rachis segment	Cha.	0	0	0	0	1	0	0	0	0	0	0
Lens culinaris	Hilum	Bro.	0	0	0	0	0	0	0	0	0	1	1
Lens culinaris	Hilum	Cha.	0	0	0	0	1	0	0	0	0	0	1
Lens culinaris	Seed	Cha.	0	0	0	0	0	1	0	0	0	0	0
cf. *Lens culinaris*	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0
Linum usitatissimum	Capsule segment	Cha.	0	0	0	0	2	1	0	0	0	0	0
Linum usitatissimum	Capsule segment	UnC.	3	3	4	4	5	15	24	22	36	39	16
Linum usitatissimum	Seed frag.	UnC.	0	2	4	10	12	1	1	1	1	5	2

Linum usitatissimum	Seed with hilum	UnC.	1	1	2	2	3	4	1	0	0	0	0
Papaver somniferum	Seed	UnC.	44	17	12	18	17	18	22	19	23	19	9
Papaver somniferum	Seed	Cha.	0	0	0	0	0	0	0	0	0	1	0
cf. *Pisum sativum*	Hilum	Cha.	0	1	0	1	0	0	0	0	0	0	1
Triticum aestivum	Rachis segment	UnC.	0	0	0	0	0	1	0	0	0	0	0
T. aestivum	Rachis segment	Cha.	0	0	0	2	0	0	0	0	0	0	0
T. cf. *aestivum*	Rachis segment	UnC.	0	0	0	0	1	0	0	0	0	0	0
T. cf. *aestivum/durum*	Rachis segment	Cha.	0	0	0	0	0	1	0	0	0	0	0
T. cf. *dicoccum*	SPK/GB	Cha.	1	0	0	0	1	0	0	0	0	0	0
T. cf. *monococcum*	SPK/GB	Cha.	0	0	2	0	0	0	0	0	0	0	0
T. cf. *timopheevii*	SPK/GB	Cha.	2	0	0	0	0	0	0	0	0	0	0
T. dicoccum	SPK/GB	Sin.	5	1	0	0	1	0	2	1	0	1	0
T. dicoccum	SPK/GB	Bro.	0	1	0	2	3	3	1	2	0	2	0
T. dicoccum	SPK/GB	Cha.	5	6	7	12	12	13	0	1	1	3	2
T. dicoccum	Terminal SPK/GB	Cha.	0	0	0	0	0	1	2	0	0	0	0
T. dicoccum/ monococcum/timopheevii	SPK/GB	Sin.	23	17	34	39	36	49	46	57	49	46	20
T. dicoccum/ monococcum/timopheevii	SPK/GB	Bro.	1	2	0	3	4	5	12	15	9	5	5

T. dicoccum/ monococcum/timopheevii	SPK/GB	UnC.	80	91	105	194	119	248	234	359	598	454	136
T. dicoccum/ monococcum/timopheevii	SPK/GB	Cha.	2	2	6	2	12	2	0	0	4	2	8
T. dicoccum/monococcum/ timopheevii, two-seeded	Grain frag.	Bro.	1	0	0	0	0	0	0	0	0	0	0
T. dicoccum/timopheevii	SPK/GB	Cha.	0	1	0	1	0	0	0	0	0	0	1
T. dicoccum/timopheevii	Terminal SPK/GB	Cha.	0	1	0	0	0	0	0	0	0	0	0
T. monococcum	Bulgur	Cha.	0	0	0	0	2	0	0	0	0	0	0
T. monococcum	SPK/GB	Sin.	3	1	0	0	3	0	0	0	0	0	0
T. monococcum	SPK/GB	Bro.	3	1	0	0	0	3	0	0	1	1	0
T. monococcum	SPK/GB	Cha.	6	11	6	10	17	6	3	0	1	1	4
T. monococcum, 1-seeded	Grain with emb.-end	Cha.	0	1	0	0	0	0	0	0	0	0	0
T. timopheevii	SPK/GB	Cha.	0	0	0	1	0	0	0	0	0	0	0
Triticum spp.	Bulgur	Cha.	2	0	0	1	0	0	0	0	0	0	0
Triticum spp.	Lemma base	Cha.	0	1	0	0	1	0	0	0	0	0	0
Triticum spp.	Rachis segment	UnC.	0	0	0	0	0	1	0	0	0	0	0
Vicia ervilia	Hilum	Cha.	0	2	0	4	2	0	0	0	0	1	0
Vicia ervilia	Seed with hilum	Cha.	0	1	0	0	0	0	0	0	0	0	0

Vicia ervilia	Seed without hilum	Cha.	0	0	0	1	0	0	0	0	0	0	0
NON-CROPS													
Abies alba	Needle	UnC.	0	0	0	0	1	0	0	1	0	0	0
cf. *Abies* sp.	Needle	UnC.	1	0	0	1	0	0	2	0	0	0	0
cf. *Abies* sp.	Needle	Cha.	0	1	0	0	0	0	0	0	0	0	0
cf. *Acer* sp.	Seed	UnC.	0	0	0	1	0	1	0	0	0	0	0
cf. *Acer* sp.	Seed	Cha.	0	0	0	0	0	0	1	0	0	0	0
Adonis annua/flammea	Seed	vk	1	0	0	0	0	0	0	0	0	0	0
Agrimonia eupatoria	Exocarp	UnC.	0	0	0	0	0	1	0	1	0	0	0
Agrostemma githago	Seed	UnC.	0	1	1	1	0	0	0	0	0	0	0
Ajuga chamaepitys	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Alchemilla /Aphanes spp.	Seed	UnC.	1	1	0	0	0	1	3	0	0	2	2
Alisma sp.	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Alkekengi officinarum	Seed	UnC.	0	1	1	1	0	0	0	0	0	0	0
Alnus glutinosa	Seed	UnC.	0	0	1	0	0	0	0	0	0	1	1
Amaranthaceae	Seed Core	Bro.	2	3	8	18	26	21	17	3	3	6	13
Prunus amygdalus	Nutshell frag.	UnC.	3	4	0	9	6	0	2	0	2	1	0
Apiaceae	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Arenaria serpyllifolia	Seed	UnC.	5	3	4	6	8	7	8	5	10	27	10

Asteraceae	Seed	UnC.	0	0	0	1	0	0	0	0	1	2	0
Bifora cf. *radians*	Seed	UnC.	0	1	0	0	0	0	0	0	0	1	0
Brassicaceae	Seed	UnC.	1	0	2	3	2	0	3	2	2	6	2
Bromus cf. *sterilis*	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0
Bromus cf. *sterilis*	Seed	Cha.	0	0	0	0	0	1	0	0	0	0	0
Bromus arvensis /hordeaceus /secalinus	Seed	Bro.	0	0	0	0	1	0	0	0	0	0	0
Bromus spp.	Seed	UnC.	2	0	0	0	1	0	0	1	1	0	0
Bromus spp.	Seed	Cha.	0	0	1	0	0	0	0	0	0	0	0
Bromus sterilis	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Bromus sterilis	Seed	Cha.	0	0	0	0	0	0	0	1	0	0	0
Bromus tectorum	Seed	UnC.	0	1	0	0	0	2	0	0	0	0	0
Campanula spp.	Seed	UnC.	1	0	2	5	1	3	2	3	3	2	7
Campanula spp.	Seed	Cha.	0	0	0	0	0	0	1	0	1	0	0
Capsella bursa-pastoris	Seed	UnC.	2	1	1	1	1	1	1	1	1	3	1
Capsella bursa-pastoris	Capsule	UnC.	0	0	0	0	0	0	0	1	0	0	0
Carex spp. 2-sided	Seed	UnC.	0	0	1	1	0	0	1	0	2	0	0
Caryophyllaceae	Seed	UnC.	1	2	1	1	0	0	1	1	2	0	1
Caryophyllaceae	Seed	Cha.	0	0	0	0	0	0	1	0	0	0	0
Caryophyllaceae	Capsule	UnC.	0	0	0	1	0	0	0	0	0	0	0

Cerastium sp.	Seed	UnC.	0	0	0	0	0	0	1	0	0	0	0
cf. *Cerastium* sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0
Chara sp. without calcite	Oogonium	UnC.	3	3	2	5	16	8	0	3	7	42	217
Chenopodium album	Seed	UnC.	1	5	0	5	4	3	1	1	3	5	5
Chenopodium sp.	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0
Chenopodium sp.	Bract	Cha.	0	0	0	1	0	0	1	1	1	1	1
Convolvulus sp.	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0
Cornus mas	Seed	UnC.	1	0	0	1	2	0	0	0	1	1	1
Corylus avellana	Nutshell frag.	UnC.	1	0	0	0	1	0	0	0	0	0	0
Corylus avellana/Prunus amygdalus	Nutshell frag.	UnC.	0	0	0	0	0	0	0	0	1	0	0
Cuscuta sp.	Seed	UnC.	1	2	1	7	5	7	4	5	6	2	6
Cuscuta sp.	Seed	Sin.	0	0	0	0	0	0	1	0	0	0	0
Cyperaceae	Seed	UnC.	1	0	0	0	0	1	0	1	0	3	0
Dianthus sp.	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0
Digitaria/Setaria sp.	Seed	UnC.	0	0	1	0	0	0	0	0	0	0	0
Euphorbia cf. *helioscopia*	Seed	UnC.	1	0	0	0	0	0	1	0	0	0	0
Fabaceae [small]	Seed	Cha.	2	0	0	0	1	0	0	0	0	0	0
Fabaceae [small]	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
cf. Fabaceae [small]	Seed	Cha.	1	0	0	0	1	0	0	0	0	0	0

Fallopia convolvulus	Seed	UnC.	1	2	1	3	4	1	2	1	1	1	1
Fallopia convolvulus	Seed core	UnC.	1	0	0	0	0	0	0	0	0	0	0
Ficus carica	Seed	UnC.	7	13	7	7	9	14	7	3	3	4	6
Fragaria vesca	Seed	UnC.	3	3	2	14	7	15	4	11	17	25	51
Fumaria officinalis	Seed	UnC.	0	1	0	1	0	1	0	0	1	1	1
Lamium spp.	Seed	UnC.	0	1	0	0	0	0	0	1	0	0	0
Galium spp.	Seed	UnC.	1	0	1	1	0	2	1	1	1	0	0
Galium spp.	Seed	Cha.	0	0	1	0	0	1	0	0	0	0	0
Geranium sp.	Seed	Cha.	0	0	0	0	1	0	0	0	0	0	0
Glebionis segetum	Seed	UnC.	3	1	1	1	1	1	0	1	1	4	1
cf. *Glebionis segetum*	Seed	Cha.	0	0	0	0	1	0	0	0	0	0	0
Heliotropium europaeum	Seed	UnC.	1	0	0	0	0	2	0	0	0	2	2
cf. *Heliotropium europaeum*	Seed	Cha.	0	0	0	0	0	1	0	0	0	0	0
Holosteum umbellatum	Seed	UnC.	0	1	0	2	1	0	1	0	0	0	0
Hordeum sp. (wild)	Rachis segment	UnC.	0	0	0	1	0	0	0	0	0	0	0
Hypericum perforatum	Seed	UnC.	1	3	2	7	8	13	9	2	4	13	24
Hypericum spp.	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0
Juncus sp.	Seed	UnC.	0	0	0	0	0	0	0	1	0	2	0
Juniperus cf. *communis*	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0

Juniperus cf. *oxycedrus*	Seed	UnC.	1	0	0	0	0	0	0	0	1	1	2
Juniperus cf. *oxycedrus*	Pitch gland (if no seed)	UnC.	0	0	0	0	0	0	1	0	0	0	0
Lamiaceae	Seed	UnC.	0	0	0	0	0	0	1	0	0	0	0
Lapsana communis	Seed	UnC.	0	0	0	0	1	0	1	0	0	0	0
Maloideae	Seed	UnC.	0	1	0	0	1	0	1	0	0	1	0
Maloideae	Calyx	UnC.	0	0	0	0	0	1	0	0	0	0	0
Maloideae	Seed inside	UnC.	0	0	0	0	1	1	0	0	0	1	1
Maloideae	Endocarp	UnC.	0	1	0	0	0	0	0	0	0	0	0
Malus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	1
cf. *Medicago* sp.	Pod	UnC.	0	0	0	0	1	0	0	0	0	0	0
Mentha aquatica	Seed	UnC.	0	0	0	0	0	0	0	0	0	2	0
Mentha longifolia	Seed	UnC.	0	0	0	1	1	1	0	1	1	1	4
Najas marina	Seed	UnC.	1	0	1	0	1	1	1	0	0	1	1
Najas sp.	Seed	UnC.	0	0	0	1	0	0	0	0	1	0	1
Origanum vulgare	Seed	UnC.	0	0	1	1	1	2	1	2	2	3	1
Ostrya carpinifolia	Seed	UnC.	0	1	1	0	0	0	0	0	0	1	0
Papaver sp.	Capsule	UnC.	1	1	0	0	0	0	1	0	0	0	0
Petrorhagia spp.	Seed	UnC.	1	1	0	0	0	0	0	1	2	0	5
Petrorhagia spp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1

Petrorhagia sp./*Dianthus* sp.	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	1
Phragmites australis	Seed	UnC.	0	1	0	1	1	0	0	0	0	1	0
Phragmites australis	Culm	Cha.	0	0	0	0	0	0	0	0	1	0	0
Pinus sp.	Needle	UnC.	0	0	0	0	1	0	1	0	0	0	0
Pinus sp.	Needle	Cha.	0	0	0	0	1	0	0	0	0	0	0
cf. *Pinus* sp.	Needle	UnC.	0	0	0	0	0	0	0	0	0	1	0
Pistacia terebinthus	Nutshell frag.	UnC.	2	0	13	3	3	5	1	8	5	5	0
Pistacia terebinthus	Nutshell frag.	Cha.	0	0	0	0	0	0	0	0	1	0	0
Pistacia terebinthus	Attachment point	UnC.	0	0	0	0	0	0	0	0	1	0	0
cf. *Pistacia terebinthus*	Nutshell frag.	Cha.	0	0	0	0	1	0	0	0	0	0	0
Plantago sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0
Plantago sp.	Seed	Cha.	0	0	0	0	0	0	1	0	0	0	0
Poa cf. *trivialis*	Seed	UnC.	0	0	2	0	0	0	0	0	1	0	1
Poaceae	Seed	UnC.	3	0	0	0	0	1	1	0	0	0	1
Poaceae	Palea/lemma	UnC.	0	0	0	0	1	2	0	0	0	0	0
Poaceae	Chaff	UnC.	0	0	0	0	0	0	0	2	0	0	0
Poaceae >2mm	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0
Poaceae <2mm	Seed	UnC.	0	0	1	1	0	1	0	2	0	1	0
Polycnemum arvense	Seed	Cha.	0	0	0	0	1	0	0	0	0	0	0

Polygonaceae	Seed	UnC.	1	0	0	1	1	1	0	0	0	0	0
Polygonaceae	Perianth	UnC.	0	0	0	0	2	1	0	0	0	0	0
Polygonaceae	Seed	Cha.	2	0	0	1	0	0	0	0	0	0	1
Polygonum aviculare	Seed	UnC.	0	0	0	1	1	1	0	2	0	2	2
Polygonum cf. *aviculare*	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0
Polygonum sp.	Seed core	UnC.	1	0	0	1	0	0	0	0	0	0	0
Potamogeton sp.	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0
Pyrus/Sorbus	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Quercus sp.	Nutshell base	UnC.	0	0	0	1	0	1	2	0	0	0	1
Quercus sp.	Nutshell frag.	UnC.	1	0	0	1	0	0	0	0	0	0	0
Ranunculus spp.	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	1
Rosa spp.	Seed	UnC.	4	0	1	1	1	3	2	3	3	3	2
Rubus fruticosus agg.	Seed	UnC.	64	75	75	107	127	156	35	14	8	15	29
Rubus fruticosus agg.	Seed	Sin.	0	0	1	0	2	1	0	0	0	0	0
Rubus fruticosus agg.	Seed	Cha.	0	0	0	1	0	0	0	0	0	0	0
Rubus idaeus	Seed	UnC.	4	4	1	2	1	3	0	0	1	3	3
Rumex cf. *acetosella*	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0
Sambucus cf. *ebulus*	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Sambucus cf. *nigra*	Seed	UnC.	0	0	0	0	0	0	0	1	0	0	0

Sambucus spp.	Seed	UnC.	1	1	1	1	1	0	0	1	0	0	1
Scleranthus annuus	Exocarp	UnC.	0	0	0	1	0	1	1	0	1	1	0
Scleranthus cf. *annuus*	Exocarp	UnC.	0	0	0	0	0	1	0	0	0	0	0
Silene spp.	Seed	UnC.	1	3	1	2	2	2	1	2	2	7	1
Silene sp.	Capsule	UnC.	2	2	1	6	5	1	3	5	8	2	6
Silene sp.	Capsule	Cha.	0	0	0	1	0	0	0	0	0	1	0
Sonchus cf. *asper*	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0
Stellaria media	Seed	UnC.	3	0	2	4	2	1	1	2	3	1	1
Taraxacum sp.	Seed	UnC.	1	1	0	2	2	2	2	2	3	2	0
Taraxacum sp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	1	0
Teucrim spp.	Seed	UnC.	0	0	0	1	0	1	1	0	1	1	0
cf. *Tilia platyphyllos*	Exocarp	UnC.	0	0	0	0	0	1	0	0	0	0	0
Tordylium maximum	Seed	UnC.	1	0	0	0	0	0	1	0	1	0	0
Trifolium sp.	Exocarp	UnC.	0	1	1	1	0	0	0	0	1	0	0
cf. *Trifolium* sp.	Exocarp	UnC.	0	0	0	0	0	0	1	0	0	0	0
Urtica dioica	Seed	UnC.	0	0	0	1	0	0	1	0	1	0	0
Valeriana cf. *dentata*	Seed	Cha.	0	0	0	1	0	0	0	0	0	0	0
Valeriana dentata	Seed	UnC.	2	1	0	2	0	1	0	0	0	0	1
Valeriana dentata	Seed core	UnC.	2	0	0	0	0	0	0	0	0	0	0

Valeriana locusta	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0
Verbascum spp.	Seed	UnC.	1	1	0	2	1	6	2	6	4	7	1
Verbena officinalis	Seed	UnC.	1	0	0	1	0	2	1	0	1	1	1
Viola sp.	Capsule	UnC.	0	0	0	0	1	0	0	0	0	0	0
Viola sp. [small]	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	6
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	0	0	1	0	0	1	0	0	1	1	1
Vitis vinifera subsp. *sylvestris*	Pedicel	UnC.	0	0	0	0	0	0	0	1	2	0	0
INDETERMINATE													
Indet	Capsule	UnC.	1	1	0	0	0	1	0	2	0	0	0
Indet	Cf. Lichen	Cha.	1	1	0	2	1	1	0	0	0	0	3
Indet	Flower	UnC.	0	0	0	1	0	0	0	0	0	0	0
Indet	Fruit tissue	Cha.	1	0	1	0	18	0	0	1	2	8	6
Indet	Seed/Fruit	UnC.	0	0	1	0	0	0	0	0	1	0	1
Indet	Seed/Fruit	Cha.	2	0	1	3	2	0	4	1	0	0	0
Indet	Stem	Cha.	1	0	0	0	1	2	0	0	0	0	0

Table 5: Archaeobotanical dataset for Core TLM19 70. Late Neolithic and Later Bronze Age samples.

Core TLM19 70																				
SAMPLE CODE			70.1	70.2	70.3	70.4	70.5	70.6	70.7	70.8	70.9	70.10	70.11	70.12	70.13	70.14	70.15	70.16	70.17	70.18	70.19
PERIOD			LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN/ LBA	LBA	LBA	LBA	LBA
VOLUME SAMPLE (ml)			160	45	200	350	350	325	300	250	450	300	150	300	200	200	50	150	100	100	50
TAXA	TYPE	PRES.																			
CROP																					
Cerealia	Basal rachis segmnet	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Cerealia	Rachis segment	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Cerealia	Grain with emb.-end	Cha.	0	0	0	0	3	0	0	1	0	0	3	0	0	0	0	0	0	0	0
Cerealia	Embryo	Bro.	0	0	0	0	0	5	0	0	0	0	0	0	4	0	0	0	0	3	0
Cerealia	Embryo	Cha.	0	0	5	0	0	14	0	2	0	0	0	0	0	15	0	0	2	0	0
Cerealia	Grain frag. with emb.-end	Cha.	0	0	0	1	0	0	0	0	0	2	0	0	4	0	0	0	0	0	0
Cerealia	Bulgur	Cha.	5	1	10	12	5	0	0	0	0	9	0	0	0	0	0	0	2	0	0

Cerealia	Testa with hilum (>2mm)	UnC.	554	140	420	453	344	365	232	260	408	253	115	331	109	75	26	168	83	9	62
Cerealia	Awn, straight barbed	Cha.	67	10	37	72	102	32	32	26	47	26	10	53	4	0	3	19	18	13	6
Cerealia	Awn, twisted	Cha.	0	0	0	0	0	5	0	2	6	0	0	0	4	1	0	0	0	0	0
Cerealia	Ear base	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	0
Cerealia	Culm node	Cha.	0	0	0	0	0	0	0	0	0	0	0		1	0	0	0	0	0	0
Cerealia	Culm pinched	Cha.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Fabaceae	Pod frag.	UnC.	37	8	18	27	34	12	1	7	11	19	2	23	1	2	4	10	8	11	18
Fabaceae	Pod frag.	Sin.	5	0	0	0	0	9	0	0	0	1	0	0	0	0	0	0	0	0	0
Fabaceae	Pod frag.	Cha.	67	3	0	6	1	23	0	8	0	5	0	1	0	0	2	0	0	0	12
Fabaceae	Pedicel	UnC.	0	0	5	1	6	0	0	0	6	0	0	0	0	0	0	7	1	0	0
Fabaceae	Pedicel	Cha.	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Hilum	UnC.	0	0	0	6	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Fabaceae	Hilum	Bro.	1	0	10	0	0	0	5	2	12	6	0	0	0	0	0	0	0	0	0
Fabaceae	Hilum	Cha.	0	0	0	6	0	0	0	0	0	0	0	0	4	3	0	0	0	0	0
Fabaceae [large]	Seed	Cha.	0	0	0	0	0	1	0	0	12	0	0	0	1	0	0	0	0	0	0
Fabaceae [large] cf	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Hordeum cf. *distichon*	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0

H. distichon, cf. naked	Rachis segment	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0
H. distichon, hulled	Rachis segment	Cha.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. distichon, naked	Rachis segment	Cha.	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. vulgare	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
H. vulgare	Grain with emb.-end, bulgur	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. vulgare /distichon	Rachis segment	Cha.	0	0	10	6	10	0	0	0	6	5	0	6	4	0	0	0	0	0	0
H. vulgare cf. hulled	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
H. vulgare cf. hulled	Rachis segment	Cha.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
H. vulgare, hulled	Rachis segment	Bro.	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
H. vulgare, hulled	Rachis segment	Cha.	0	0	0	6	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0
H. vulgare, hulled	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
H. vulgare, naked	Rachis segment	Cha.	0	2	0	6	0	5	0	2	0	0	0	8	0	0	0	0	0	0	0
H. vulgare, naked	Rachis segment	Bro.	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
H. vulgare/ distichon	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0
H. vulgare/ distichon	Grain with emb.-end, bulgur	Cha.	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0

H. vulgare/ distichon	Rachis segment	Sin.	0	0	0	0	0	0	21	0	19	0	0	0	0	0	0	0	0	0	0
H. vulgare/ distichon	Rachis segment	Bro.	9	0	0	6	1	9	0	4	0	13	2	0	0	0	0	0	0	0	0
H. vulgare/ distichon	Rachis segment	UnC.	233	32	224	277	21	129	67	4	33	22	20	49	47	6	3	0	4	5	7
H. vulgare/ distichon	Basal rachis segment	Cha.	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. vulgare/ distichon	Ear base	Cha.	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H. vulgare/ distichon	Basal rachis segment	Bro.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
H. vulgare/ distichon	Ear base	Bro.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
H. vulgare/ distichon, cf. naked	Rachis segment	Bro.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
H. vulgare/ distichon, naked	Rachis segment	Cha.	0	0	0	12	5	0	0	2	0	0	0	0	0	0	0	0	0	0	0
H. vulgare/ distichon, naked	Lemma base	Cha.	0	0	0	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Lens culinaris	Seed	Cha.	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Lens culinaris	Hilum	UnC.	0	0	0	0	0	14	0	6	0	0	0	6	0	0	0	0	0	0	0
Lens culinaris	Hilum	Cha.	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Linum usitatissimum	Capsule segment	UnC.	51	23	187	48	25	52	51	19	74	43	39	58	19	30	15	10	6	3	6
Linum usitatissimum	Capsule segment	Sin.	1	0	0	0	0	0	0	0	6	0	0	0	0	1	0	0	0	0	0
Linum usitatissimum	Seed	UnC.	0	0	0	0	0	6	4	1	0	0	1	6	5	0	0	0	0	0	0

Linum usitatissimum	Seed with hilum	UnC.	6	3	16	37	5	0	0	2	7	14	2	6	0	8	2	7	2	3	5
Linum usitatissimum	Stem	UnC.	5	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0
Papaver somniferum	Seed	UnC.	10	8	134	132	62	54	18	19	35	68	28	36	16	38	15	177	150	129	75
Papaver somniferum	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	6	0	0	2	0	2	0	0
cf. *Pisum sativum*	Hilum	UnC.	0	0	0	0	5	0	0	0	0	0	0	0	0	3	0	4	0	0	0
cf. *Pisum sativum*	Hilum	Cha.	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
cf. *Pisum sativum*	Pod frag.	Sin.	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Triticum aestivum	Rachis segment	UnC.	0	1	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. aestivum /durum	Rachis segment	Cha.	0	0	5	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T. aestivum /durum	Rachis segment	UnC.	0	0	5	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. aestivum /durum	Rachis segment	UnC.	0	0	5	3	22	0	0	0	0	0	4	0	0	0	0	0	0	0	0
T. aestivum /durum	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
T. cf. *dicoccum*	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0
T. cf. *dicoccum*	Grain with emb.-end, 2-seeded	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. cf. *spelta*	SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
T. cf. *timopheevii*	SPK/GB	Cha.	0	0	0	2	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
T. cf. *timopheevii*	Basal rachis	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0

T. dicoccum	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
T. dicoccum	SPK/GB	Bro.	18	2	5	1	14	0	4	0	10	0	2	4	0	6	0	4	2	0	0
T. dicoccum	Terminal SPK/GB	UnC.	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. dicoccum	Terminal SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	0	0	1	2	1	2	0	0	0	0
T. dicoccum	SPK/GB	Cha.	33	5	29	8	22	25	0	18	31	2	4	27	47	15	1	11	2	0	0
T. dicoccum/ monococcum/ timopheevii	Grain frag.	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
T. dicoccum/ monococcum/ timopheevii, 2-seeded	Grain frag.	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
T. dicoccum/ monococcum/ timopheevii	SPK/GB	UnC.	3381	767	3076	3814	2142	1762	1189	339	2115	1096	492	2454	1462	782	372	431	269	219	279
T. dicoccum/ monococcum/ timopheevii	SPK/GB	Sin.	128	23	199	221	182	30	56	46	216	81	27	139	29	45	15	8	10	0	12
T. dicoccum/ monococcum/ timopheevii	SPK/GB	Bro.	18	6	7	48	2	25	21	0	0	2	2	35	16	0	0	10	4	17	17

T. dicoccum/ monococcum/ timopheevii	SPK/GB	Cha.	11	4	28	48	9	59	10	14	52	34	17	61	94	22	16	22	6	17	15
T. dicoccum/ timopheevii	SPK/GB	Cha.	0	1	0	0	0	0	0	2	14	0	0	0	0	2	0	0	0	3	0
T. dicoccum/ timopheevii	SPK/GB	Bro.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0
T. dicoccum/ timopheevii	Terminal SPK/GB	Bro.	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
T. monococcum	Grain with emb.-end 1-grain	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
T. monococcum	SPK/GB	Bro.	0	0	0	0	10	0	0	0	0	9	2	2	6	2	4	9	2	5	3
T. monococcum	SPK/GB	Cha.	15	5	21	15	4	24	5	18	48	12	6	71	59	13	17	10	6	9	3
T. timopheevii	SPK/GB	Bro.	0	0	0	0	0	0	0	0	12	0	0	0	0	2	0	0	0	0	0
T. timopheevii	SPK/GB	Cha.	7	4	2	0	0	0	8	0	4	0	2	19	0	1	2	10	0	0	0
Triticum spp.	Basal rachis segment	Cha.	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Triticum spp.	Grain with emb.-end	Cha.	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Triticum spp.	Bulgur	Cha.	5	0	5	0	5	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Triticum spelta	SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1
Vicia ervilia	Seed	Cha.	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	1	0	0	0

Vicia ervilia	Hilum	Bro.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Vicia ervilia	Hilum	Cha.	0	0	0	0	5	5	0	4	6	5	2	12	0	0	0	0	0	0	0
NON-CROP																					
Abies alba	Needle	UnC.	2	1	1	1	7	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Abies sp.	Needle	UnC.	5	2	1	8	0	0	4	1	1	0	0	2	0	0	0	0	0	1	4
cf. *Abies* sp.	Needle	Cha.	0	0	5	0	0	0	0	0	6	0	0	0	0	3	0	0	0	0	0
cf. *Acer* sp.	Seed	UnC.	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. *Acer* sp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	5	0	1	0	0	0	4	2	0	0
Agrimonia eupatoria	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Agrostemma githago	Seed	UnC.	1	0	0	0	0	0	0	0	6	0	1	0	0	1	0	4	2	0	3
Alchemilla/ Aphanes spp.	Seed	UnC.	0	1	0	1	0	5	11	2	19	5	2	6	8	3	0	0	0	7	4
Alkekengi officinarum	Seed	UnC.	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Alnus cf. *glutinosa*	Seed	UnC.	0	0	5	6	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0
Amaranthaceae	Seed	UnC.	0	0	0	6	0	0	4	0	6	5	0	0	0	0	6	0	2	5	0
Amaranthaceae	Seed core	Bro.	0	4	0	36	18	50	28	48	35	110	8	0	0	3	0	0	0	5	0
Amaranthaceae	Seed core	Cha.	5	0	33	0	0	0	0	2	18	0	0	18	0	0	1	7	2	3	9
Prunus amygdalus	Nutshell frag.	UnC.	0	0	1	3	4	8	10	6	28	26	20	40	12	13	0	3	1	1	0
Prunus amygdalus	Nutshell frag.	Cha.	0	0	0	0	0	0	1	0	0	1	0	6	1	0	0	0	0	0	0

Lysimachia arvensis	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Apiaceae	Seed	UnC.	2	0	0	0	0	0	0	0	6	0	1	0	0	0	0	1	0	0	1
Arenaria serpyllifolia	Seed	UnC.	0	0	19	54	27	45	18	16	41	55	10	24	12	18	8	16	18	3	0
cf. *Arenaria serpyllifolia*	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
cf. *Arenaria serpyllifolia*	Seed	UnC.	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Seed	UnC.	0	1	5	6	0	0	0	0	0	5	0	6	0	0	0	0	0	1	0
cf. *Avena* sp.	Lemma base	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Bifora cf. *radians*	Seed	UnC.	0	0	0	0	0	0	0	1	1	1	1	15	11	4	2	1	2	3	3
Brassicaceae	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Brassicaceae	Seed	UnC.	0	2	5	8	5	0	4	2	12	1	4	12	0	3	1	13	4	0	1
Brassicaceae	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Bromus arvensis	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus arvensis/ hordeaceus/secalinus	Seed	UnC.	0	0	0	1	1	5	0	0	0	0	0	0	0	0	0	4	0	0	1
Bromus cf. *sterilis*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Bromus hordeaceus	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus spp.	Seed	UnC.	1	0	5	26	2	5	0	4	6	13	0	8	0	3	0	0	4	1	3

cf. *Bromus* spp.	Seed	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Bromus sterilis	Seed	UnC.	0	0	0	1	0	0	0	0	1	0	0	6	4	0	0	0	0	1	0
Bromus tectorum	Seed	UnC.	0	0	0	0	1	0	0	7	1	0	2	3	0	0	0	4	0	0	0
Camelina microcarpa	Capsule	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	6	2	1	1
Campanula spp.	Seed	UnC.	1	0	0	0	0	0	7	4	24	13	0	0	0	6	4	16	16	9	19
Campanula spp.	Seed	Cha.	0	0	0	6	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Capsella bursa-pastoris	Seed	UnC.	0	2	5	0	0	5	0	8	6	0	0	6	4	0	0	0	6	8	0
Carex spp. 2-sided	Seed	UnC.	0	0	0	6	0	0	0	0	0	6	0	0	4	0	0	0	0	0	0
Caryophyllaceae	Seed	UnC.	5	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Caryophyllaceae	Seed	Cha.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0
Caryophyllaceae	Capsule	UnC.	0	0	0	0	0	0	0	0	1	0	0	7	0	3	2	0	0	0	0
Cerastium sp.	Seed	UnC.	0	0	0	0	0	9	7	2	12	5	0	6	0	0	0	0	0	0	0
Chara spp. with calcite	Oogonium	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	12	9	7	23	10	14	9
Chara spp. without calcite	Oogonium	UnC.	8	1	5	6	5	9	0	12	12	5	8	12	0	51	164	166	89	112	87
Chenopodium album	Seed	UnC.	0	1	14	0	0	9	0	10	6	0	2	6	8	6	2	38	38	61	42
Chenopodium sp.	Seed	UnC.	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Chenopodium sp.	Seed	Cha.	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	2	0	0

Coriandrum sativum	Seed	Bro.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cornus mas	Seed	UnC.	4	2	8	4	0	5	6	0	22	3	3	15	3	4	0	4	5	1	4
Corylus avellana	Nutshell frag.	UnC.	6	2	3	0	2	0	0	4	6	4	4	5	3	1	0	0	0	0	0
Crataegus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Cuscuta sp.	Seed	UnC.	1	1	20	49	5	45	7	8	0	9	6	12	0	3	0	1	0	0	3
Cyperaceae	Seed	UnC.	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	8	6	0	0
Cyperus fuscus	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	3	0
cf. *Daucus* sp.	Seed	UnC.	0	0	5	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
cf. *Digitaria* sp.	Seed	UnC.	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	2	0	0
Euphorbia cf. *helioscopia*	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	3	0
Euphorbia cf. *helioscopia*	Seed	UnC.	0	0	0	0	0	0	0	2	6	0	0	0	0	0	0	0	0	0	0
Fabaceae [small]	Seed	Cha.	0	0	0	0	0	5	0	0	0	5	0	0	0	0	0	0	0	1	0
Fallopia convolvulus	Seed	UnC.	8	0	6	8	7	8	4	2	16	6	2	16	6	6	3	7	2	6	3
Ficus carica	Seed	UnC.	0	1	10	13	14	32	18	4	48	35	6	18	1	10	9	31	33	38	37
Fragaria vesca	Seed	UnC.	41	21	264	295	66	64	6	36	174	61	24	82	27	9	3	38	12	15	13
Fragaria vesca	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Fragaria/ Potentilla sp.	Seed	UnC.	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0

Fumaria officinalis	Seed	UnC.	1	0	1	0	1	0	0	2	2	5	1	6	0	1	1	0	2	0	0
Galium spp.	Seed	UnC.	0	0	37	24	0	5	0	0	0	5	0	1	0	0	1	1	1	0	0
Galium spurium	Seed	UnC.	0	2	1	1	5	0	0	2	0	0	0	0	0	1	0	0	0	3	0
Geranium cf. *purpureum*	Outer seed coat	UnC.	0	0	0	0	0	0	0	0	0	5	0	6	0	0	0	0	0	0	0
Geranium cf. purpureum	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Glebionis segetum	Seed	UnC.	5	0	0	12	0	1	4	2	6	5	0	12	2	6	2	4	4	3	0
Heliotropium europaeum	Seed	UnC.	0	0	0	0	0	5	0	1	0	5	0	0	0	0	0	4	6	3	0
Heliotropium europaeum	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Holosteum umbellatum	Seed	UnC.	0	0	5	12	5	9	7	0	0	5	0	0	0	0	0	0	0	0	0
Hypericum perforatum	Seed	UnC.	0	4	23	24	18	23	7	24	53	38	10	29	4	3	1	4	0	3	6
Hypericum perforatum	Seed	Cha.	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum spp.	Seed	UnC.	0	0	0	0	5	0	7	0	0	9	2	6	0	0	0	0	0	3	6
Juncus sp.	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	6	0	0	0	0	0	0	0
Juniperus cf. *oxycedrus*	Seed	UnC.	36	0	0	2	0	0	0	1	12	0	1	6	0	0	0	1	0	0	1

Juniperus sp.	Seed	UnC.	1	0	0	0	0	0	0	0	2	8	0	12	3	0	0	0	0	0	0
Juniperus sp.	Seed	Sin.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Juniperus sp.	Needle/leaf	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
Lamiaceae	Seed	UnC.	0	0	0	12	1	9	0	2	0	0	0	0	0	0	0	1	4	0	0
Lapsana communis	Seed	UnC.	0	0	0	6	5	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Maloideae	Seed	UnC.	0	1	0	0	6	6	1	2	8	6	3	14	5	6	3	4	7	0	3
Maloideae	Calyx	UnC.	0	0	0	2	0	0	0	0	3	2	1	3	1	3	2	0	0	0	0
Maloideae	Seed	Cha.	0	0	0	0	0	0	0	0	6	0	0	1	0	0	0	4	0	0	0
Maloideae	Tissue inside seed	UnC.	7	2	2	3	6	6	4	3	7	7	5	17	4	6	3	5	0	4	3
Maloideae	Endocarp tissue	UnC.	5	2	4	5	2	6	1	0	0	1	0	0	0	0	0	0	0	1	0
Malus sp.	Seed	UnC.	2	0	2	1	1	0	0	0	0	1	1	3	1	2	2	0	0	0	0
Malvaceae	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Malva cf. *sylvestris*	Mericarp	UnC.	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Medicago sp.	Pod	UnC.	6	0	0	7	1	0	0	0	0	0	0	6	0	3	1	5	2	4	8
Medicago sp.	Pod	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Mentha aquatica	Seed	UnC.	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mentha longifolia	Seed	UnC.	0	0	0	0	0	0	4	2	0	9	2	0	0	0	0	0	0	3	3
Mentha/*Origanum* sp.	Seed	UnC.	0	0	0	0	5	0	0	0	6	0	0	0	0	0	0	0	4	3	0

Mentha/Origanum sp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Najas marina	Seed	UnC.	0	0	0	1	0	1	1	2	9	9	2	1	0	4	3	14	12	10	12
Najas sp.	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	2	0	0	3	0	5	0	0	3
cf. *Neslia paniculata*	Capsule	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Origanum vulgare	Seed	UnC.	5	0	0	18	0	5	7	2	0	9	0	0	0	3	0	4	0	3	0
Ostrya carpinifolia	Seed	UnC.	0	0	0	2	4	2	0	0	2	0	0	6	0	0	0	0	2	3	4
Papaver sp.	Seed	UnC.	0	0	0	6	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Papaver sp.	Capsule	UnC.	0	1	5	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Persicaria lapathifolia	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Petrorhagia spp.	Seed	UnC.	0	1	0	6	0	14	0	0	12	9	4	12	4	3	3	7	8	7	0
Petrorhagia sp./ *Dianthus* sp.	Seed	UnC.	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0
Petrorhagia sp./ *Dianthus* sp.	Capsule	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Phragmites communis	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3
Phragmites australis	Culm	Cha.	11	2	0	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
cf. Phragmites australis	Seed	UnC.	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0

Picris hieracioides	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pinus sp.	Needle	UnC.	1	2	0	0	7	6	5	3	7	13	13	49	9	5	1	5	0	1	1
Pinus sp.	Needle	Cha.	0	0	0	0	0	5	0	0	6	0	0	0	0	0	0	0	0	0	0
Pinus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Pistacia terebinthus	Seed	UnC.	8	3	6	36	39	18	6	3	33	17	5	29	6	6	3	0	1	1	1
Pistacia terebinthus	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0
Poa annua	Seed	UnC.	5	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Poa cf. *trivalis*	Seed	UnC.	0	0	5	0	5	9	0	0	0	0	0	0	4	0	1	0	6	0	0
Poa/Phlem	Seed	UnC.	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Poaceae <2mm	Seed	UnC.	0	1	0	0	5	5	4	2	6	0	0	6	4	0	0	0	0	0	7
Poaceae >2mm	Lemma base	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Poaceae >2mm	Seed	UnC.	0	0	0	0	9	5	0	2	0	0	0	0	0	0	0	4	2	0	4
Polycnemum arvense	Seed	UnC.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7	2	3	0
Polygonaceae	Seed	UnC.	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	3
Polygonaceae	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Polygonum aviculare	Seed	UnC.	5	0	5	6	6	5	0	4	13	13	4	0	0	0	1	5	2	7	6
Potamogeton sp.	Seed	UnC.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Prunus cf. *spinosa*	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Prunus cf. *spinosa*	Seed	UnC.	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

Pyrus/Sorbus	Seed	UnC.	0	0	0	0	1	0	0	0	0	0	0	2	1	2	2	4	0	1	0
Quercus sp.	Nutshell base	UnC.	4	1	1	0	1	2	5	1	15	5	1	5	2	7	7	0	0	1	2
Quercus sp.	Cupule frag.	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Nutshell frag.	Cha.	0	0	0	0	0	2	0	0	1	12	0	1	0	0	2	0	0	0	0
Quercus sp.	Nutshell frag.	UnC.	37	3	5	18	22	5	36	1	18	0	8	221	10	35	40	62	52	21	34
Ranunculus spp.	Seed	UnC.	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	1	2	2	0
cf. *Ranunculus* spp.	Seed	Cha.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Rosa spp.	Seed	UnC.	2	0	1	1	0	2	10	1	17	14	4	23	5	10	2	3	0	0	2
Rubus fruticosus agg.	Seed	UnC.	224	56	412	1252	493	758	342	220	1618	369	196	1982	617	753	291	179	50	91	121
Rubus fruticosus agg.	Seed	Sin.	5	0	0	0	5	0	0	1	0	0	0	6	4	0	0	0	0	0	0
Rubus fruticosus agg.	Seed	Cha.	0	0	5	0	5	9	0	1	0	0	0	1	0	1	0	0	1	0	3
Rubus fruticosus/idaeus	Seed	UnC.	10	4	14	6	1	23	0	4	12	0	4	0	0	0	4	0	0	7	2
Rubus idaeus	Seed	UnC.	0	0	1	6	0	15	18	2	19	10	0	0	0	0	5	4	0	3	1
Rubus sp.	Twig	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Rumex sp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Sambucus cf. *ebulus*	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus cf. *nigra*	Seed	UnC.	6	0	0	6	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Sambucus spp.	Seed	UnC.	0	0	1	6	1	1	1	1	1	5	1	0	0	4	1	1	1	2	0

Sanguisorba minor	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Sanguisorba minor	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Schoenoplectus /Scirpus sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	4	2	0	0
Scleranthus annuus	Exocarp	UnC.	0	0	0	0	5	9	7	4	25	13	2	0	0	12	1	0	2	0	0
Silene spp.	Seed	UnC.	5	1	11	12	14	18	7	4	6	13	0	0	4	3	1	5	4	13	0
Silene spp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Silene sp.	Capsule	UnC.	6	3	30	5	6	6	0	6	19	5	0	6	4	0	0	4	0	5	4
Silene sp.	Capsule	Cha.	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Sonchus cf. *oleraceus*	Seed	UnC.	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	Seed	UnC.	10	2	0	6	5	5	14	4	0	0	2	24	0	6	0	4	0	11	0
Stellaria media	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Stellaria sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	14
Taraxacum sp.	Seed	UnC.	0	1	10	25	28	9	4	0	6	5	0	0	0	3	0	0	0	0	0
Teucrium spp.	Seed	UnC.	0	0	0	0	0	5	0	0	0	0	0	12	1	0	0	4	0	0	4
Thlaspi arvense	Seed	Cha.	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0
cf. *Tilia platyphyllos*	Exocarp	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tordylium maximum	Seed	UnC.	0	1	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	1
cf. *Torilis* sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Trifolium sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Trifolium sp.	Exocarp	UnC.	3	1	1	0	5	5	4	2	6	0	1	0	0	0	1	4	4	11	8
Urtica dioica	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4	2	5	4
Valeriana cf. *coronata*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0
Valeriana dentata	Seed	UnC.	0	0	0	0	5	0	0	2	12	0	2	6	0	3	0	0	0	0	0
Valeriana spp.	Seed	UnC.	0	0	0	0	0	5	0	0	6	0	0	0	4	3	2	0	2	3	6
Verbascum spp.	Seed	UnC.	0	0	5	18	5	14	11	4	6	5	4	6	23	0	0	0	0	0	0
Verbena officinalis	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Viola sp. [large]	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Viola sp. [small]	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	7	0	0	0
Viola sp.	Capsule	UnC.	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Vitis vinifera subsp. *sylvestris*	Seed	UnC.	0	0	0	1	2	0	0	1	0	0	2	0	0	1	0	0	0	0	1
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	0	0	5	6	0	3	1	0	4	6	0	1	1	1	2	2	1	4	2
Vitis vinifera subsp. *sylvestris*	Seed	Sin.	1	1	6	3	1	0	0	0	0	6	2	1	2	1	0	0	1	0	0
INDETERMINATE																					
Indet	Bulb	Cha.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Capsule	UnC.	1	0	5	6	0	5	1	0	6	0	0	6	4	0	0	0	1	3	0

Indet	cf. Lichen	UnC.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indet	cf. Lichen	Cha.	30	3	0	84	53	18	18	0	59	21	16	35	8	0	0	0	0	0	0
Indet	Cupule frag.	UnC.	0	0	14	24	0	18	35	0	19	5	0	6	4	4	0	0	0	0	0
Indet	Cupule frag.	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Indet	Flower	UnC.	2	0	0	6	1	5	0	0	0	0	0	7	1	0	0	0	0	0	0
Indet	Fruit skin	Cha.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Nutshell	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Indet	Pedicel	Cha.	0	1	0	1	0	9	0	0	12	0	2	0	0	0	0	0	0	0	1
Indet	Pod	Cha.	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Seed/Fruit	UnC.	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	6	5	0
Indet	Seed/Fruit	Cha.	0	0	5	12	0	0	0	0	2	0	0	0	2	1	0	4	3	4	3

Table 6: Archaeobotanical dataset for Core QLM19 10. One of two tables. Late Neolithic samples.

Core QLM19 10 (Table 1 of 2)																
SAMPLE CODE			10.1.1	10.1.2	10.1.3	10.1.4	10.1.5	10.1.6	10.1.7	10.1.8	10.1.9	10.1.10	10.1.11	10.1.12	10.1.13	10.1.14	10.1.15
PERIOD			LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN
VOLUME SAMPLE			90	95	100	110	120	160	140	110	90	85	90	110	135	75	150
TAXA	TYPE	PRES.															
CROP																	
Cerealia	Basal rachis	UnC.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Cerealia	Basal rachis	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Cerealia	Embryo	Bro.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Cerealia	Embryo	Cha.	0	0	0	0	2	2	4	2	0	0	0	1	0	0	5
Cerealia	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	6	0	2	0
Cerealia	Grain with api.-end	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	6	0	0
Cerealia	Bulgur	Cha.	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0

Cerealia	Testa with hilum (>2mm)	UnC.	19	0	0	15	38	2	63	96	225	110	38	36	14	10	60
Cerealia	Awn, straight, barbed	Cha.	3	0	8	6	2	2	11	2	24	8	6	4	3	2	21
Cerealia	Awn, twisted	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	10
Cerealia	Culm node	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Fabaceae	Pod frag.	UnC.	9	2	24	11	6	8	11	2	3	5	1	2	9	9	13
Fabaceae	Pod frag.	Cha.	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Pedicel	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4
Fabaceae	Hilum	Bro.	0	0	0	0	0	0	11	7	0	3	0	0	0	0	5
Fabaceae [large]	Seed	Cha.	0	0	0	0	0	0	4	1	0	0	0	0	0	1	0
Hordeum cf. distichon naked	Rachis segment	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0	4	0
Hordeum distichon	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0
Hordeum distichon cf. hulled	Rachis segment	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Hordeum distichon cf. naked	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

Hordeum distichon naked	Rachis segment	Cha.	0	1	0	0	0	1	0	1	0	0	0	7	0	0	1
Hordeum distichon, hulled	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	3	0	0
Hordeum vulgare	Rachis segment	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	5
Hordeum vulgare cf. hulled	Rachis segment	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Hordeum vulgare hulled	Rachis segment	Cha.	0	1	0	0	0	0	0	1	0	0	5	0	6	2	0
Hordeum vulgare/distichon	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Hordeum vulgare/distichon	Rachis segment	Cha.	2	0	5	0	0	0	0	0	0	0	4	5	0	2	0
Hordeum vulgare/distichon	Rachis segment	Bro.	0	0	0	5	10	32	0	13	3	5	0	5	12	2	9
Hordeum vulgare/distichon	Rachis segment	UnC.	0	9	275	67	47	55	44	101	85	68	18	13	21	34	56
Hordeum vulgare/distichon hulled	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Hordeum vulgare/distichon naked	Rachis segment	Cha.	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0
cf. *Lens culinaris*	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1

Linum usitatissimum	Stem	UnC.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Linum usitatissimum	Capsule segment	UnC.	10	15	41	36	50	14	67	96	158	23	28	26	21	17	51
Linum usitatissimum	Capsule segment	Cha.	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0
Linum usitatissimum	Seed	UnC.	2	5	0	6	14	10	14	36	21	0	0	0	0	8	0
Linum usitatissimum	Seed with hilum	UnC.	1	2	8	3	2	4	12	7	12	3	4	5	3	0	5
cf. *Linum usitatissimum*	Seed with hilum	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Papaver somniferum	Seed	UnC.	2	1	4	6	0	6	11	16	19	3	9	13	17	34	21
cf. *Pisum sativum*	Seed	Cha.	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
cf. *Pisum sativum*	Hilum	Bro.	1	0	0	0	0	0	0	1	6	0	0	0	0	2	0
cf. *Pisum sativum*	Hilum	Cha.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Triticum aestivum	Rachis segment	Cha.	0	0	4	0	0	1	0	0	0	3	0	0	0	0	0
Triticum aestivum/durum	Rachis segment	UnC.	0	0	5	0	0	4	0	0	0	0	0	0	0	0	0
Triticum aestivum/durum	Rachis segment	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	5
Triticum cf. *aestivum*	Rachis segment	UnC.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0

Triticum cf. *monococcum*	Grain with api.-end	Cha.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Triticum cf. *monococcum*	SPK/GB	Cha.	0	3	2	2	0	0	0	2	0	7	4	0	6	0	10
Triticum cf. *monococcum*, 1-seeded	Grain with api.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Triticum dicoccum	Grain with emb.-end	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Triticum dicoccum	SPK/GB	Bro.	2	0	0	5	4	2	0	14	0	6	0	0	8	6	0
Triticum dicoccum	Terminal SPK/GB	Bro.	0	0	0	0	0	0	0	0	0	0	0	0	2	26	0
Triticum dicoccum	SPK/GB	Cha.	0	1	4	1	2	2	21	3	25	12	17	34	16	0	49
Triticum dicoccum/monococcum/timopheevii	SPK/GB	UnC.	53	70	1960	901	1154	896	1015	1948	1141	1130	377	449	1217	1499	1797
Triticum dicoccum/monococcum/timopheevii	SPK/GB	Sin.	16	12	0	265	153	319	139	136	129	245	34	7	96	182	315
Triticum dicoccum/monococcum/timopheevii	SPK/GB	Bro.	6	19	4	98	54	158	63	52	34	35	18	28	34	51	56
Triticum dicoccum/monococcum/timopheevii	Basal SPK/GB	Cha.	0	0	0	0	0	4	4	0	2	2	4	2	0	0	0

Triticum dicoccum/monococcum/timopheevii	SPK/GB	Cha.	8	1	0	6	4	2	0	2	0	12	0	15	1	20	84
Triticum dicoccum/timopheevii	Terminal SPK/GB	Bro.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
Triticum dicoccum/timopheevii	Terminal SPK/GB	Cha.	0	0	0	0	0	0	0	0	2	0	0	5	0	0	0
Triticum monococcum	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Triticum monococcum	Grain with api.-end	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Triticum monococcum	SPK/GB	Sin.	0	0	0	2	0	0	0	0	0	0	0	0	3	0	0
Triticum monococcum	SPK/GB	Bro.	0	2	0	10	2	6	0	0	4	0	0	3	3	6	0
Triticum monococcum	SPK/GB	Cha.	3	0	13	8	4	22	28	8	21	18	8	26	30	28	5
Triticum monococcum, 1-seeded	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Triticum monococcum, 1-seeded	Grain with api.-end	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Triticum monococcum, 1-seeded	Grain with api.-end, bulgur	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Triticum spp.	Basal rachis	UnC.	0	0	0	3	0	0	7	0	0	0	0	0	0	0	0

Triticum spp.	Rachis segment	Cha.	0	0	0	0	0	0	4	0	0	0	0	0	0	0	5
Triticum spp.	Grain with emb.-end	Cha.	0	0	0	0	0	1	1	0	1	1	0	0	3	1	6
Triticum timopheevii	SPK/GB	Bro.	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Triticum timopheevii	SPK/GB	Cha.	1	0	2	0	2	0	0	0	2	0	0	5	7	0	5
Triticum timopheevii	Terminal SPK/GB	Cha.	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Vicia ervilia	Hilum	Bro.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Vicia ervilia	Hilum	Cha.	0	0	0	0	0	0	7	7	1	0	0	0	0	0	0
Vicia ervilia	Seed	Cha.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
NON-CROP																	
Abies alba	Needle	UnC.	3	7	0	7	3	0	0	4	0	0	2	0	0	0	0
Abies sp.	Needle	UnC.	3	2	15	0	2	3	5	1	4	1	1	1	1	1	5
cf. *Abies* sp.	Needle	Cha.	1	0	0	0	0	0	1	0	0	0	0	0	0	2	0
cf. *Acer* sp.	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	2	3	0	0	0
Agrostemma githago	Seed	UnC.	1	0	4	0	2	0	1	1	0	1	0	1	0	1	1
Alkekengi officinarum	Seed	UnC.	0	0	0	0	2	0	1	0	0	0	0	0	1	0	0
Alnus glutinosa	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Alnus glutinosa	Seed	Cha.	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0

Amaranthaceae	Seed core	Bro.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Amaranthaceae	Core	Cha.	0	3	0	0	0	2	7	1	0	7	9	3	0	2	5
Amaranthaceae	Seed	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Amaranthaceae	Seed	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Amaranthaceae	Seed	UnC.	0	1	0	0	2	0	0	0	0	0	0	0	3	0	0
Apiaceae	Seed	UnC.	0	0	5	0	0	0	0	1	1	0	0	0	0	1	0
Arenaria serpyllifolia	Seed	UnC.	2	2	0	9	0	12	14	7	0	3	2	3	6	10	13
Arenaria serpyllifolia	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Asteraceae	Seed	UnC.	0	0	4	0	0	0	5	7	6	0	0	0	0	0	0
Atriplex sp.	Seed	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Seed	UnC.	2	1	0	0	4	3	4	4	0	0	0	0	0	0	0
Brassicaceae	Seed	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Brassicaceae	Seed	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Bromus hordeaceus	Seed	UnC.	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0
Bromus arvensis /hordeaceus /secalinus	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Bromus arvensis /hordeaceus /secalinus	Seed	Bro.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Bromus spp.	Seed	Cha.	0	0	0	0	0	0	5	1	0	0	0	0	6	0	0

Bromus spp.	Seed	UnC.	0	0	0	3	0	0	0	5	0	2	0	0	0	0	0
Bromus sterilis	Seed	Cha.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1
Bromus sterilis/tectorum	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Bromus tectorum	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	3	3	1	0
Camelina microcarpa	Capsule	UnC.	0	0	0	0	2	0	4	0	0	0	0	0	0	0	0
Campanula spp.	Seed	UnC.	0	1	0	0	0	0	0	0	0	7	2	0	3	0	5
Capsella bursa-pastoris	Seed	UnC.	1	0	0	6	0	12	4	4	0	0	0	0	6	0	0
Carex spp. 2-sided	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
cf. Caryophyllaceae	Capsule	UnC.	0	0	7	0	0	0	0	0	0	3	0	0	0	0	0
Cerastium sp.	Seed	UnC.	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Chara spp. with calcite	Oogonium	UnC.	11	5	0	0	2	0	0	0	0	0	0	0	0	0	0
Chara spp. without calcite	Oogonium	UnC.	73	49	18	12	34	16	74	52	6	3	0	0	3	2	26
Chenopodium album	Seed	UnC.	2	2	0	3	0	4	7	0	0	5	0	0	0	2	0
Cornus mas	Seed	UnC.	0	1	1	2	3	1	8	6	2	4	8	2	4	4	3
Corylus avellana	Nutshell frag.	UnC.	0	0	0	0	8	0	0	0	1	3	4	1	1	1	5
Corylus avellana	Nutshell frag.	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cuscuta sp.	Seed	UnC.	0	1	0	0	0	2	11	13	15	0	0	5	0	2	9
Cyperaceae	Seed	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eupatorium cannabinum	Seed	UnC.	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0

Euphorbia cf. *helioscopia*	Capsule	Cha.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Fabaceae [small]	Seed	Cha.	0	0	0	0	0	2	0	0	6	0	0	0	0	0	0
Fallopia convolvulus	Seed	UnC.	1	1	0	3	6	3	8	4	8	7	3	7	4	3	7
Fallopia convolvulus	Seed	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ficus carica	Seed	UnC.	2	2	4	9	2	4	7	13	6	7	1	7	6	4	13
Fragaria vesca	Seed	Sin.	0	0	0	0	0	0	0	0	0	0	8	5	0	0	0
Fragaria vesca	Seed	UnC.	3	7	12	12	22	15	7	16	0	22	36	55	9	16	31
Fragaria vesca	Seed	Cha.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Fragaria/Potentilla sp.	Seed	UnC.	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0
Fumaria officinalis	Seed	UnC.	1	1	0	3	0	0	0	0	0	0	0	1	0	0	0
Galium spurium	Seed	UnC.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium spp.	Seed	UnC.	0	0	0	0	2	0	4	1	6	1	0	0	1	2	0
Geranium cf. *purpureum*	Seed outer coat	UnC.	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
Glebionis segetum	Seed	UnC.	0	1	0	0	0	4	4	4	6	0	0	3	3	2	9
Glebionis segetum	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Heliotropium europaeum	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holosteum umbellatum	Seed	UnC.	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0
Hypericum perforatum	Seed	UnC.	0	6	4	3	6	10	0	13	3	3	18	30	0	4	17

Hypericum perforatum	Seed	Cha.	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum spp.	Seed	UnC.	0	0	0	0	0	0	4	0	0	3	0	0	0	0	0
Juncus sp.	Seed	UnC.	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0
Juniperus cf. *oxycedrus*	Seed	UnC.	0	1	0	0	1	0	1	1	0	1	4	14	8	2	2
cf. *Juniperus* sp.	Fruit flesh and skin	UnC.	0	1	0	0	0	0	0	3	0	0	0	0	1	1	1
Juniperus sp.	Needle	UnC.	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0
Juniperus sp.	Pitch gland (when no seed)	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Lamiaceae	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lamium spp.	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laspana communis	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Maloideae	Seed inside tissue	UnC.	3	1	5	4	3	2	5	5	1	6	3	3	3	3	4
Maloideae	Endocarp tissue	UnC.	0	1	0	0	1	0	0	5	1	0	3	0	3	3	2
Maloideae	Seed	UnC.	1	0	0	4	0	2	1	0	0	0	0	3	1	5	7
Maloideae	Seed	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Maloideae	Calyx	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Malus sp.	Seed	UnC.	0	0	2	0	4	0	0	2	1	0	1	1	4	0	3

Medicago sp.	Pedicel	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Medicago sp.	Pod	UnC.	0	0	5	4	0	0	4	0	4	3	2	3	0	2	1
Mentha longifolia	Seed	UnC.	0	1	0	0	0	2	0	7	6	0	0	3	0	0	0
Najas marina	Seed	UnC.	3	0	4	0	0	0	1	0	3	0	0	0	0	0	0
Najas sp.	Seed	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Najas sp.	Seed	UnC.	1	2	0	1	1	0	0	0	0	0	0	0	0	0	1
Origanum vulgare	Seed	UnC.	0	0	0	0	0	0	4	4	3	0	4	3	0	2	5
Ostrya carpinifolia	Seed	UnC.	0	3	0	0	0	0	4	5	0	1	0	0	0	2	5
Ostrya carpinifolia	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0
Digitaria/Setaria	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Papaver sp.	Capsule	UnC.	0	0	0	0	4	0	0	0	4	0	0	0	0	0	5
Papaver sp.	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Petrorhagia spp.	Seed	UnC.	1	0	0	0	0	2	0	4	3	5	2	3	3	0	5
Petrorhagia sp. */Dianthus* sp.	Seed	UnC.	0	0	0	0	2	0	4	0	0	0	0	0	0	0	0
Poa/Phleum	Seed	UnC.	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Phragmites australis	Culm	UnC.	0	0	0	0	0	0	0	0	0	3	0	0	0	1	1
Phragmites australis	Seed	UnC.	0	0	4	6	0	0	4	0	0	0	0	0	3	0	0
Pinaceae	Needle	UnC.	0	0	0	0	0	0	0	4	0	3	0	4	4	1	0

Pinus sp.	Cone scale	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pinus sp.	Needle	UnC.	2	0	1	0	0	0	0	7	0	0	0	0	0	0	7
Pistacia terebinthus	Nutshell frag.	Sin.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Pistacia terebinthus	Nutshell frag.	UnC.	1	4	27	20	6	3	12	17	18	4	5	2	4	3	2
Pistacia terebinthus	Nutshell frag.	Cha.	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0
Poa annua	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Poa cf. *trivialis*	Seed	UnC.	1	0	0	3	0	0	4	4	3	0	0	7	0	2	5
Poaceae	Chaff	UnC.	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
Poaceae <2mm	Seed	UnC.	0	0	0	0	0	0	0	4	0	3	4	0	0	0	0
Poaceae >2mm	Palea/lemma	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Polygonaceae	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	Seed	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Polygonum aviculare	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Potamogeton sp.	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Prunus amygdalus	Nutshell frag.	UnC.	0	2	1	2	0	0	3	13	3	0	0	1	1	1	2
Prunus amygdalus	Nutshell frag.	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Prunus cf. *spinosa*	Fruit endocarp	UnC.	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0
Pyrus/Sorbus	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3

Quercus sp.	Nutshell base	UnC.	4	0	1	6	1	0	5	4	2	2	1	2	10	23	2
Quercus sp.	Cupule frag.	UnC.	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Nutshell frag.	Cha.	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0
Quercus sp.	Nutshell frag.	UnC.	7	7	31	44	9	1	8	25	4	3	0	2	58	8	4
Ranunculus spp.	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0
Rosa spp.	Seed	UnC.	0	0	1	2	1	0	1	1	2	2	2	6	3	2	9
Rosa spp.	Fruit cap/top	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Rosaceae	Seed	UnC.	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Rubus fruticosus agg.	Seed	Sin.	0	0	0	0	0	0	7	14	12	13	6	13	6	4	10
Rubus fruticosus agg.	Seed	Cha.	0	0	0	0	0	0	0	0	9	0	2	0	0	0	0
Rubus fruticosus agg.	Seed	UnC.	3	18	125	118	63	32	319	221	305	162	206	635	247	118	291
Rubus idaeus	Seed	UnC.	1	0	0	3	0	2	0	4	0	3	4	14	4	0	6
Rubus sp.	Seed	UnC.	2	1	0	6	2	3	4	0	3	3	4	5	3	0	9
Sambucus cf. *nigra*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	0	4	0	1
Sambucus spp.	Seed	UnC.	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0
Scleranthus annuus	Exocarp	UnC.	0	0	0	0	2	0	0	0	3	3	2	0	0	4	0
Silene sp.	Capsule	UnC.	0	0	0	7	2	2	30	11	4	14	6	5	12	2	9
Silene sp.	Capsule	Cha.	0	0	0	0	0	0	0	4	3	0	0	0	0	0	0
Silene spp.	Seed	UnC.	0	0	0	0	0	2	8	4	3	6	2	3	3	2	0

Silene spp.	Seed	Cha.	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Solanaceae	Seed	UnC.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Stellaria cf. *media*	Seed	UnC.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	Seed	UnC.	1	0	0	0	2	4	4	0	3	3	2	3	3	2	9
Taraxacum sp.	Seed	UnC.	0	1	0	3	2	2	4	11	7	6	2	5	9	14	7
Taraxacum sp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Teucrim sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0
cf. *Tilia platyphyllos*	Exocarp	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
cf. *Tordylium maximum*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Tordylium maximum	Seed	UnC.	1	1	0	1	1	2	1	1	0	1	0	3	0	0	0
cf. *Torilis* sp.	Seed	UnC.	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium sp.	Exocarp	UnC.	1	0	0	9	2	1	4	7	6	3	0	0	5	4	5
Trifolium sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Urtica dioica	Seed	UnC.	3	3	0	3	0	0	4	0	0	0	0	0	0	2	5
Valeriana cf. *coronata*	Seed	UnC.	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Valeriana dentata	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	2	0	0	0	5
Valeriana spp.	Seed	UnC.	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Verbascum spp.	Seed	UnC.	0	0	4	0	2	0	4	7	6	5	2	3	0	2	5
Verbena officinalis	Seed	UnC.	0	1	0	0	2	0	0	0	0	0	2	5	0	4	9

Veronica sp.	Seed	UnC.	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Viola sp.	Capsule	UnC.	0	2	0	0	0	0	0	0	0	0	2	6	1	3	0
Viola sp. [small]	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Vitis vinifera subsp. *sylvestris*	Seed	Sin.	1	0	0	0	0	1	4	0	0	0	0	0	0	0	0
Vitis vinifera subsp. *sylvestris*	Seed	UnC.	0	0	1	0	0	0	3	1	1	1	0	3	4	3	0
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	1	2	0	1	0	1	1	0	1	1	1	0	1	0	1
Vitis vinifera subsp. *sylvestris*	Pedicil	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. *Vitis vinifera* subsp. *sylvestris*	Seed	UnC.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
INDETERMINATE																	
Indet	Capsule	UnC.	1	0	0	1	0	0	7	0	0	0	0	0	0	0	0
Indet	cf. Lichen	UnC.	0	0	0	0	0	0	0	0	9	0	0	0	0	0	5
Indet	cf. Lichen	Cha.	0	0	0	18	20	10	42	11	22	14	4	11	28	22	70
Indet	Cupule frag.	UnC.	0	0	0	3	2	0	4	7	3	4	0	0	1	2	6
Indet	Flower	UnC.	1	1	0	3	2	0	0	5	0	1	0	0	3	0	1
Indet	Flower	Cha.	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Indet	Fruit	Cha.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Indet	Fruit flesh	Cha.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Fruit skin	UnC.	0	2	0	0	0	0	0	3	6	7	0	0	0	0	0
Indet	Fruit skin	Cha.	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
Indet	Seed	Cha.	2	0	0	0	0	2	0	0	0	1	0	5	0	0	0
Indet	Stem	Cha.	1	0	0	0	0	0	0	1	0	0	0	0	0	0	5

Table 7: Archaeobotanical dataset for Core QLM19 10. Two of two tables. Late Neolithic.

Core QLM19 10 (Table 2 of 2)														
SAMPLE CODE			10.0.1	10.0.2	10.0.3	10.0.4	10.0.5	10.0.6	10.0.7	10.0.8	10.0.9	10.0.10	10.0.11	10.0.12	10.0.13
PERIOD			LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN	LN
VOLUME SAMPLE (ml)			100	80	90	95	135	100	145	30	135	170	170	60	55
TAXA	TYPE	PRES.													
CROP															
Cerealia	Basal rachis	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1
Cerealia	Ear base	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1
Cerealia	Rachis segment	Cha.	0	0	0	0	0	0	0	2	0	0	0	0	0
Cerealia	Rachis segment	UnC.	5	12	0	0	0	0	0	0	0	0	0	0	1
Cerealia	Embryo, sprouted?	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Cerealia	Embryo	Sin.	0	0	1	0	0	0	0	0	0	0	0	0	0
Cerealia	Embryo	Cha.	0	2	1	1	4	0	4	1	7	1	1	0	1
Cerealia	Grain with emb.-end	Cha.	1	0	0	0	0	0	0	0	1	0	1	0	0
Cerealia	Bulgur	Cha.	0	0	1	4	0	8	1	1	0	0	2	0	1
Cerealia	Testa with hilum (>2mm)	UnC.	75	93	129	20	22	16	29	42	51	38	16	5	7

Cerealia	Awn, straight, barbed	Cha.	8	34	18	6	10	2	4	5	24	8	6	6	5
Cerealia	Awn, twisted	Cha.	2	2	8	0	28	0	0	1	0	0	0	0	0
Fabaceae	Pod frag.	UnC.	3	1	7	4	3	2	2	2	2	1	1	0	0
Fabaceae	Pod frag.	Sin.	0	0	3	0	0	0	0	0	1	0	0	0	0
Fabaceae	Pod frag.	Cha.	1	0	1	0	0	2	0	0	3	0	0	0	1
Fabaceae	Stem	Cha.	0	0	0	0	0	0	0	0	0	0	0	2	0
Fabaceae	Attachment point	UnC.	0	0	0	0	2	0	0	0	1	0	0	0	0
Fabaceae	Attachment point	Cha.	2	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	Hilum	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	1
Fabaceae	Hilum	Bro.	0	2	2	0	0	0	3	1	1	0	0	0	0
Fabaceae	Hilum	Cha.	0	0	0	0	2	0	1	3	2	1	0	0	0
Cf. Fabaceae	Attachment point	UnC.	0	0	1	0	0	0	0	0	0	0	0	0	0
Cf. Fabaceae	Attachment point	Sin.	2	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae [large]	Seed	Cha.	0	0	0	1	0	0	0	0	1	1	1	1	1
Hordeum cf. distichon naked	Rachis segment	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0
Hordeum vulgare/distichon	Rachis segment	Sin.	0	0	0	0	0	0	0	3	0	0	0	0	0
Hordeum vulgare, 6-rowed	Rachis segment	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Hordeum vulgare, 6-rowed, hulled	Rachis segment	Cha.	0	0	0	0	0	2	0	0	1	1	0	0	0
Hordeum vulgare, 6-rowed, naked	Rachis segment	Sin.	0	0	1	0	0	0	0	0	0	0	0	0	0

Hordeum vulgare, cf. hulled	Rachis segment	Cha.	0	0	0	0	0	0	0	0	2	0	0	0	0
Hordeum vulgare/distichon	Grain with emb.-end	Cha.	1	0	1	0	0	0	0	0	1	0	1	0	0
Hordeum vulgare/distichon	Rachis segment	Cha.	4	0	0	0	0	0	0	1	1	2	0	0	0
Hordeum vulgare/distichon	Culm	Cha.	2	0	0	1	0	0	0	0	0	0	0	0	0
Hordeum vulgare/distichon	Rachis segment	Bro.	2	0	0	0	0	0	1	0	0	1	0	0	0
Hordeum vulgare/distichon	Rachis segment	UnC.	1	1	16	5	8	43	11	6	20	3	5	6	0
Hordeum vulgare/distichon nudum	Lemma base	Cha.	2	2	1	0	0	0	0	1	0	0	0	0	0
Lens culinaris	Seed	Cha.	1	0	0	0	0	0	0	0	0	1	2	0	0
Lens culinaris	Hilum	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Lens culinaris	Hilum	Bro.	0	0	0	0	0	0	1	2	1	0	0	0	0
Lens culinaris	Hilum	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0
cf. *Lens culinaris*	Seed	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0
Linum usitatissimum	Capsule segment	Sin.	0	0	2	0	2	0	1	0	1	0	0	0	0
Linum usitatissimum	Capsule segment	UnC.	26	24	14	3	8	14	3	3	9	9	6	3	4
Linum usitatissimum	Seed with hilum	UnC.	1	4	4	2	2	0	3	2	0	1	1	2	2
cf. *Linum usitatissimum*	Seed with hilum	UnC.	2	0	0	0	0	0	0	0	0	0	0	0	0
Papaver somniferum	Seed	UnC.	22	22	80	47	176	6	21	8	13	17	4	4	10
cf. *Pisum sativum*	Hilum	Bro.	0	0	0	2	0	0	0	1	0	0	0	0	0
cf. *Pisum sativum*	Hilum	Cha.	2	0	0	0	0	0	0	0	0	0	0	0	0

Triticum aestivum	Rachis segment	UnC.	0	0	0	0	0	0	0	1	1	0	0	0	0
Triticum aestivum	Rachis segment	UnC.	0	0	0	0	0	0	0	0	0	0	0	1	0
Triticum aestivum/durum	Rachis segment	Cha.	0	0	2	0	0	0	0	0	0	0	0	0	0
Triticum aestivum/durum	Grain	Cha.	1	0	0	0	0	0	0	0	0	0	0	0	0
Triticum cf. *dicoccum*	SPK/GB	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Triticum cf. *monococcum*	SPK/GB	Cha.	2	6	0	2	0	0	0	0	1	0	0	0	0
Triticum dicoccum	SPK/GB	Bro.	12	15	5	0	6	8	0	1	1	1	0	0	0
Triticum dicoccum	SPK/GB	Cha.	25	0	8	5	11	8	0	3	5	4	1	2	5
Triticum dicoccum/monococcum/timopheevii	SPK/GB	UnC.	652	651	443	184	442	756	255	247	502	53	128	94	84
Triticum dicoccum/monococcum/timopheevii	SPK/GB	Sin.	73	103	44	34	36	36	24	33	66	20	25	14	4
Triticum dicoccum/monococcum/timopheevii	SPK/GB	Bro.	15	12	31	0	4	16	1	4	22	3	9	7	6
Triticum dicoccum/monococcum/timopheevii	SPK/GB	Cha.	4	10	11	18	23	6	16	1	18	8	6	13	9
Triticum dicoccum/timopheevii	Terminal SPK/GB	Cha.	2	0	0	0	0	0	0	0	0	0	0	0	0
Triticum monococcum	SPK/GB	Bro.	4	0	0	4	6	0	9	0	2	1	1	0	0
Triticum monococcum	SPK/GB	Cha.	2	0	3	7	14	12	6	5	7	2	10	2	5
Triticum monococcum, 1-seeded	Grain with emb.-end	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0
Triticum spp.	Basal rachis	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Triticum spp.	Rachis segment	Cha.	0	0	0	0	0	0	0	2	0	0	0	0	0
Triticum spp.	Grain with emb.-end	Cha.	0	0	0	0	0	0	0	0	0	0	2	0	0

Triticum spp.	Bulgur	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Triticum timopheevii	SPK/GB	Bro.	0	2	0	0	4	0	0	0	0	0	0	0	0
Triticum timopheevii	SPK/GB	Cha.	4	0	0	0	6	2	0	2	0	0	0	0	0
Vicia ervilia	Hilum	Bro.	0	0	1	0	0	0	0	0	0	2	1	0	0
Vicia ervilia	Hilum	Cha.	0	0	0	0	0	0	4	0	0	3	0	0	0
NON-CROP															
cf. *Abies* sp.	Needle	UnC.	1	2	0	1	2	0	0	0	0	0	0	0	0
Abies sp.	Needle	UnC.	2	0	4	0	0	1	0	1	2	0	0	0	0
Abies sp.	Needle	Cha.	1	0	0	0	0	0	0	0	1	0	0	0	0
cf. *Acer* sp.	Seed	UnC.	0	0	0	0	0	0	0	1	0	0	0	1	0
Aegilops sp.	Glume base	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1
Aegilops sp.	Culm	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0
Agrostemma githago	Seed	UnC.	0	3	0	0	0	0	0	0	1	1	0	0	0
Alchemilla/Aphanes spp.	Seed	UnC.	1	0	0	1	2	6	1	0	4	3	0	7	2
Alisma sp.	Seed	UnC.	2	0	0	0	0	0	0	0	0	0	0	0	0
Alkekengi officinarum	Seed	UnC.	1	0	0	0	2	0	1	0	1	0	0	1	0
Alnus glutinosa	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0
Amaranthaceae	Seed core	Bro.	10	2	0	0	2	18	0	0	6	0	0	0	0
Amaranthaceae	Seed core	Cha.	0	0	14	7	0	10	16	7	30	20	5	14	14

Amaranthaceae	Seed	UnC.	0	0	0	0	0	4	0	0	0	0	0	0	0
Arenaria serpyllifolia	Seed	UnC.	6	4	2	2	6	8	1	3	2	11	3	10	1
Asteraceae	Seed	UnC.	0	1	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	Seed	UnC.	2	0	0	0	0	0	0	0	0	0	0	1	1
cf. Asteraceae	Seed	Cha.	0	1	0	0	0	0	0	0	0	0	0	0	0
Atriplex sp.	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Avena sp.	Floret base	Cha.	0	0	1	0	0	0	0	0	0	0	0	0	0
Bifora cf. *radians*	Seed	UnC.	2	0	0	0	0	0	0	0	0	0	0	0	0
Brassicaceae	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	1	0	0
Brassicaceae	Seed	UnC.	2	4	1	1	0	6	0	0	0	1	0	2	0
Brassicaceae	Capsule	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Brassicaceae	Seed	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Bromus arvensis /hordeaceus /secalinus	Seed	UnC.	0	0	1	0	0	0	0	0	0	0	0	0	0
Bromus arvensis /hordeaceus /secalinus	Seed	Bro.	0	0	0	0	0	0	0	0	1	0	0	0	1
Bromus spp.	Seed	UnC.	0	0	0	1	0	2	0	0	3	0	0	0	0
Bromus spp.	Seed	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Bromus spp.	Lemma/palea	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Bromus sterilis	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Bromus tectorum	Seed	UnC.	1	0	1	1	0	8	3	0	2	0	0	0	1

Camelina microcarpa	Capsule	UnC.	0	0	0	0	3	0	0	0	0	0	0	0	0
Campanula spp.	Seed	UnC.	4	0	1	1	6	4	2	0	8	15	2	4	4
Capsella bursa-pastoris	Seed	UnC.	6	0	0	1	0	4	1	0	2	1	1	1	0
cf. *Capsella bursa-pastoris*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	1
Caryophyllaceae	Seed	UnC.	0	0	0	0	2	0	0	0	0	0	3	0	0
Caryophyllaceae	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Cerastium sp.	Seed	UnC.	4	4	0	1	0	0	2	2	1	2	0	0	0
Chara spp. with calcite	Oogonium mit Kalkhülle	UnC.	0	0	2	0	0	0	0	0	0	0	0	0	6
Chara spp. without calcite	Oogonium ohne Kalkhülle	UnC.	6	7	0	0	0	6	4	2	3	3	3	1	5
Chenopodium album	Seed	UnC.	4	0	0	0	2	2	1	21	4	5	5	3	2
Chenopodium sp.	Seed	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	1
Cirsium/Carduus sp.	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Cornus mas	Seed	UnC.	3	5	3	0	5	1	0	0	1	1	0	1	0
Cornus mas	Seed	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0
Corylus avellana	Nutshell frag.	UnC.	0	0	0	2	3	0	0	0	2	0	0	1	0
Crataegus sp.	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0
Crepis sp.	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Cuscuta sp.	Seed	UnC.	4	4	8	1	2	0	4	3	3	3	1	2	0
Cuscuta sp.	Seed	Min.	0	0	0	0	0	2	0	0	0	0	0	0	0

Cyperaceae	Seed	UnC.	8	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus fuscus	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0
Euphorbia cf. *helioscopia*	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1
Euphorbia cf. *helioscopia*	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	0	1	0
Euphorbia cf. *helioscopia*	Capsule	UnC.	2	0	1	0	0	0	0	0	0	0	0	0	1
Fabaceae [small legume indet]	Seed	UnC.	0	0	0	0	0	0	0	1	0	0	0	0	0
Fabaceae [small legume indet]	Seed	Cha.	0	0	1	0	0	0	0	0	1	0	0	0	0
Fallopia convolvulus	Seed	UnC.	0	2	2	1	0	2	1	3	5	2	1	1	1
Ficus carica	Seed	UnC.	8	14	3	6	14	10	2	1	3	7	8	1	2
Ficus carica	Seed	Cha.	0	0	1	0	0	0	1	0	0	0	0	0	0
Fragaria vesca	Seed	UnC.	4	14	10	13	6	6	7	4	27	39	12	8	12
Fragaria vesca	Seed	Cha.	0	0	0	0	0	0	1	0	0	0	0	0	0
Fragaria/Potentilla sp.	Seed	UnC.	0	0	0	1	0	0	0	0	0	0	0	0	0
cf. *Fumaria officinalis*	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	1	0
Fumaria officinalis	Seed	UnC.	0	0	0	1	0	0	1	0	1	1	0	0	1
Galium aparine	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0
Galium spp.	Seed	UnC.	0	2	1	0	0	2	1	0	0	0	0	0	1
Geranium sp.	Seed	Cha.	0	2	0	0	0	0	0	0	0	0	0	0	0
Glebionis segetum	Seed	UnC.	5	0	3	1	2	0	1	2	3	3	1	1	1

Heliotropium europaeum	Seed	UnC.	0	0	0	0	0	0	0	0	0	2	0	0	0
Heliotropium europaeum	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	1
Hypericum perforatum	Seed	UnC.	10	4	5	2	6	6	10	7	15	13	8	16	13
Hypericum spp.	Seed	UnC.	0	0	1	0	0	0	1	0	0	6	1	1	1
Juncus sp.	Seed	Cha.	0	0	0	0	2	0	0	0	0	0	0	0	0
Juniperus cf. *oxycedrus*	Seed	UnC.	1	1	4	1	4	2	0	1	0	1	0	0	0
cf. *Juniperus* sp.	Fruit flesh and skin	UnC.	1	0	0	0	0	0	0	0	0	0	0	0	0
Lamium spp.	Seed	UnC.	0	0	0	0	2	0	2	0	0	0	0	0	0
Lamium spp.	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
cf. *Lamium* spp.	Seed	UnC.	0	0	0	0	0	0	0	0	1	1	0	0	0
Lapsana communis	Seed	UnC.	2	2	0	0	0	0	0	0	0	0	0	0	0
Lapsana communis	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Lysimachia arvensis	Seed	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0
Maloideae	Seed	UnC.	1	2	3	1	1	2	0	0	1	0	0	3	1
Maloideae	Tissue inside seed	UnC.	1	3	2	2	3	3	0	0	1	2	1	1	1
Maloideae	Endocarp tissue	UnC.	0	0	0	1	0	1	0	0	0	0	0	0	0
Maloideae	Calyx	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0
cf. Maloideae	Seed	Cha.	0	0	0	0	0	0	0	0	0	1	0	0	0
Malus sp.	Seed	UnC.	1	0	0	0	3	1	0	1	0	0	1	1	0

Malva cf. *sylvestris*	Mericarp	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	1
Malvaceae	Seed	UnC.	0	0	0	0	0	0	1	0	0	0	0	0	0
Medicago sp.	Pod	UnC.	1	0	1	0	0	0	0	0	0	1	1	1	0
Melampyrum sp.	Capsule	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Mentha aquatica	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0
Mentha longifolia	Seed	UnC.	0	0	0	1	0	0	0	0	2	3	1	0	0
Mentha /Origanum sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	2	0	0	0
Najas marina	Seed	UnC.	2	2	1	1	0	1	1	1	2	1	1	1	1
Najas sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	0	1
Origanum vulgare	Seed	UnC.	4	0	0	3	0	0	0	0	0	0	1	0	0
Ostrya carpinifolia	Seed	UnC.	0	0	0	0	0	2	0	0	0	1	0	0	1
Papaver sp.	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	1	0	0
Papaver sp.	Capsule	UnC.	3	0	1	1	2	0	0	1	0	0	0	0	0
Petrorhagia spp.	Seed	UnC.	4	2	1	0	2	0	1	2	1	6	2	3	0
Phragmites australis	Seed	UnC.	0	0	0	0	0	0	0	1	3	1	0	0	0
Phragmites australis	Culm	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0
Phragmites australis	Culm	Cha.	0	2	1	4	2	0	0	0	0	0	0	0	0
cf. Phragmites australis	Culm	Cha.	0	0	0	0	0	0	0	1	0	0	0	0	0
Picris hieracioides	Seed	UnC.	0	0	0	0	0	0	0	1	0	0	0	0	0

Pinus sp.	Needle	UnC.	0	2	0	1	0	2	0	0	0	1	1	0	0
Pinus sp.	Needle	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	1
Pinus sp.	Cone scale	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Pistacia terebinthus	Nutshell frag.	UnC.	0	1	0	0	0	0	0	5	2	1	2	2	0
Pistacia terebinthus	Nutshell frag.	Cha.	0	0	0	0	0	0	0	0	0	0	0	1	0
cf. *Pistacia terebinthus*	Nutshell frag.	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Plantago sp.	Seed	Cha.	0	0	1	0	0	0	0	0	0	0	0	0	0
Poa sp.	Seed	Cha.	0	0	0	0	0	0	0	0	0	1	1	0	0
Poa annua	Seed	UnC.	0	0	1	0	0	0	0	0	0	0	0	0	0
Poa cf. *trivialis*	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Poa cf. *trivialis*	Seed	UnC.	0	0	2	0	0	2	0	0	0	0	0	0	0
Poa/Phleum	Seed	UnC.	0	0	0	0	0	0	0	0	0	1	0	0	0
Poaceae <2mm	Seed	UnC.	0	0	0	1	2	0	1	1	1	1	0	1	1
Poaceae >2mm	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	0	1	0
Poaceae >2mm	Seed	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Polygonaceae	Seed	UnC.	0	0	1	0	0	0	0	0	0	0	1	0	0
Polygonaceae	Seed	Cha.	0	0	0	0	0	0	0	0	1	1	0	0	0
Polygonaceae	Seed inner part	Cha.	0	0	0	0	0	0	0	0	1	0	0	0	0
Polygonaceae	Seed	Cha.	0	0	0	1	0	2	1	0	0	0	0	0	0

Polygonum aviculare	Seed	UnC.	2	4	0	1	4	2	3	2	1	1	0	0	1
Prunus amygdalus	Nutshell frag.	UnC.	1	0	6	1	8	4	0	7	2	3	1	3	0
Pyrus/Sorbus	Seed	UnC.	0	1	0	0	0	0	0	0	0	0	0	1	0
Quercus sp.	Nutshell base	UnC.	1	0	6	4	1	0	0	0	0	2	0	0	0
Quercus sp.	Cupule frag.	UnC.	0	1	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Nutshell frag.	UnC.	3	2	23	5	2	1	0	0	0	1	1	0	0
Quercus sp.	Nutshell frag.	Cha.	2	0	0	0	0	0	0	0	0	0	0	0	0
Quercus sp.	Nut kernel	Cha.	0	0	0	1	0	0	0	0	0	0	0	0	0
Rancunculus sp.	Seed	UnC.	0	0	0	0	0	4	1	0	0	0	0	0	0
Rosa spp.	Seed	UnC.	1	2	2	1	2	4	0	1	4	1	0	0	0
Rubus fruticosus	Seed	UnC.	101	122	107	90	60	38	18	46	219	96	62	32	41
Rubus fruticosus	Seed	Sin.	0	0	2	0	0	0	2	0	0	1	1	0	0
Rubus fruticosus/idaeus	Seed	UnC.	3	2	0	0	0	0	0	0	0	4	1	2	0
Rubus idaeus	Seed	UnC.	2	10	5	3	2	4	0	1	0	5	3	1	3
Rubus sp.	Seed	UnC.	0	0	0	0	3	0	0	0	7	0	0	2	0
Rubus sp.	Seed	Cha.	4	1	0	0	3	0	1	0	0	0	1	1	1
Sambucus cf. *ebulus*	Seed	UnC.	0	0	0	0	0	0	0	2	0	0	0	1	1
Sambucus spp.	Seed	UnC.	0	1	1	1	1	1	0	1	1	1	0	1	0
Sambucus spp.	Seed	Cha.	0	2	0	0	0	0	0	0	0	0	0	0	0

Scleranthus annuus	Exocarp	UnC.	0	0	1	0	0	0	0	1	0	2	0	6	2
Silene spp.	Seed	UnC.	3	2	4	1	0	4	3	3	7	3	0	3	1
Silene sp.	Capsule	UnC.	4	6	4	1	0	3	0	1	5	4	2	1	5
Silene sp.	Capsule	Cha.	2	0	0	0	0	0	3	0	0	0	0	0	0
cf. *Silene* sp.	Capsule	UnC.	0	0	0	5	0	0	0	0	0	0	0	0	0
Sonchus cf. *oleraceus*	Seed	UnC.	0	0	0	0	0	2	0	0	0	0	0	0	0
Stellaria media	Seed	UnC.	4	6	0	0	0	4	0	0	0	2	0	1	1
Stellaria sp.	Seed	UnC.	4	0	1	0	0	0	0	0	0	0	0	0	0
Taraxacum sp.	Seed	UnC.	2	4	1	2	2	2	1	2	2	0	1	1	0
Taraxacum sp.	Seed	Cha.	0	0	0	0	0	2	0	0	0	0	0	0	0
Teucrim spp.	Seed	UnC.	0	2	0	1	0	0	1	3	1	0	0	1	0
cf. *Tilia platyphyllos*	Exocarp	Cha.	0	0	0	0	0	0	0	0	0	0	1	0	0
Tordylium maximum	Seed	UnC.	1	2	0	0	0	2	0	0	1	0	1	0	0
Cf. *Tordylium maximum*	Seed	UnC.	0	0	1	0	0	0	0	0	0	0	0	0	0
Trifolium sp.	Seed	UnC.	0	0	0	0	0	1	0	0	0	0	0	0	0
Trifolium sp.	Exocarp	UnC.	0	2	8	2	2	0	1	1	2	0	1	1	1
Urtica dioica	Seed	UnC.	0	0	0	1	0	6	0	0	1	1	0	0	1
Valeriana coronata	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	1	0	0
Valeriana dentata	Seed	UnC.	0	0	0	0	0	0	1	0	1	1	1	1	0

Valeriana dentata	Seed inner	UnC.	2	0	0	0	0	0	0	0	0	0	0	0	0
Valeriana locusta	Seed	UnC.	0	0	0	0	0	0	0	0	0	0	1	0	0
Valeriana rimosa	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	1	0
Valeriana spp.	Seed	UnC.	0	0	2	0	0	0	0	0	0	0	0	0	0
Verbascum spp.	Seed	UnC.	4	4	6	1	2	0	2	0	1	4	2	4	2
Verbascum spp.	Seed	Cha.	0	0	7	0	0	0	0	0	0	0	0	0	0
Verbena officinalis	Seed	UnC.	0	0	1	0	0	0	1	0	1	0	0	0	0
Viola sp.	Capsule	UnC.	5	0	0	0	2	0	0	0	0	0	0	0	1
Viola sp. [small]	Seed	UnC.	0	0	0	0	0	0	0	0	1	0	0	0	0
Vitis vinifera subsp. *sylvestris*	Seed	UnC.	1	0	1	2	1	1	0	0	0	0	0	3	1
Vitis vinifera subsp. *sylvestris*	Seed	Cha.	2	0	0	0	1	1	1	1	1	2	1	2	1
Vitis vinifera subsp. *sylvestris*	Pedicel	UnC.	0	0	0	0	0	0	0	0	0	0	0	2	0
INDETERMINATE															
Indet	Bulb	Cha.	0	0	1	0	0	0	0	0	0	0	0	0	0
Indet	Capsule	UnC.	0	0	0	1	0	0	0	1	1	0	1	0	0
Indet	Capsule	Cha.		2	2	0	0	0	0	0	0	0	0	0	0
Indet	cf. Lichen	UnC.	0	0	5	0	0	0	0	0	0	0	1	0	0
Indet	cf. Lichen	Cha.	9	28	4	1	12	0	0	0	3	1	4	5	3
Indet	Cupule frag.	UnC.	0	0	3	1	2	0	0	0	0	2	1	0	0

Indet	Fruit frag.	Cha.	0	0	0	0	0	0	0	0	0	2	0	0	0
Indet	Fruit pedicel	Cha.	0	0	1	0	0	0	0	0	0	0	0	0	0
Indet	Nut kernel	Cha.	0	0	0	0	0	0	0	0	0	0	0	0	0
Indet	Nutshell	Cha.	0	0	0	0	0	0	0	0	0	0	1	1	0
Indet	Seed/Fruit	Cha.	2	0	1	4	0	0	0	1	0	0	0	2	0
Indet	Stem	Cha.	2	0	0	0	0	0	0	0	3	0	0	6	0

6.0 Appendix 2: Catalogue of archaeobotanical remains

6.1 IDENTIFICATION OF RELEVANT TAXA

Relevant species were identified using the 'Flora of Greece web Vascular Plants of Greece, An Annotated Checklist' (Dimopoulos et al. 2013). If a given species was present in the North Pindos and/or North Central regions of Greece, it was considered relevant to the area of Lake Ohrid and hence considered during the process of taxonomic identification (Figure 1).



Figure 1: Map of vegetational zones in 'Flora of Greece web Vascular Plants of Greece, An Annotated Checklist'. If species were present in the North Pindos (NPi) and/or North Central (NC) regions of Greece, they were considered relevant to the proximal Lake Ohrid basin (shown as a pale blue oval). Map from Dimopoulos et al. 2013.

Macrofossils were compared with modern material from the reference collection at the Archaeobotany Laboratory, School of Archaeology, University of Oxford, Oxford (henceforth, 'the

reference collection') and images/descriptions in relevant atlases (e.g. Körber-Grohne, 1991; Bojňanský and Fargašová, 2007; Cappers et al. 2012). The reference collection held at the Deutsches Archäologisches Institut (DAI) in Berlin was also consulted, to which Dr. Ferran Antolín, head of the Natural Sciences Unit kindly granted access. Unless specified, quantification followed the principal of MNI (e.g. 1 seed = 1 count). Nomenclature follows Flora Europaea for crops and World Flora Online for all other taxa.

6.2 GLOSSARY

Terminology

In this catalogue, terminology has been kept simple to increase accessibility to non-botanists. Terms such as 'seed' or 'capsule' are used in a broad sense to evoke an idea of the botanical part, rather than following strict botanical definitions.

Apex: the tip furthest from the point of attachment.

Awn: the bristle on the ear of many grasses.

Bulb: a storage organ that is usually underground.

Calyx: the sepals of a flower.

Capsule/pod/exocarp: The terms capsule/pod/exocarp are used in a loose sense to describe a structure that holds the seed(s). The term used reflects common usage for different taxa e.g. pulse *pod* or poppy *capsule*.

Cf.: Abbreviation for 'compares favourably'. Precedes less confident identification.

Cotyledon: the embryonic leaf inside the seed.

Dorsal: relating to the back (opposite ventral).

Floret: part of the grass spikelet with the seed, lemma and palea.

Glume base: half a spikelet fork – one glume and one glume base on the rachis internode.

Glume: each of the dry bracts surrounding the spikelet of a grass.

Hilum: the attachment point/scar on a seed.

Keel: a ridge or folded edge.

Lemma: a bract surrounding the grain in a spikelet, larger than the palea.

Palea: a bract surrounding the grain in a spikelet, smaller than the lemma.

Pedicel: the stalk connecting a fruit with a branch.

Radicle: the embryonic root of the seed that emerges during germination.

Seed: The term seed is used in a loose sense to refer to the botanical part which is the unit of reproduction. This includes botanical parts variably called 'nutlets', 'fruitlets' and 'achenes.' It was chosen to use the single term 'seed' rather than multiple botanical terms as the use of different terms varies between publications (e.g. between Cappers et al. 2012 and Bojňanský and Fargašová, 2007). All of these macrofossils were also included as 'seeds' in the crop processing analysis and functional weed ecology.

Spikelet fork: the rachis internode, glume base and two glumes in glume wheats.

Sp.: [following genus] one species of the genus

Spp.: [following genus] multiple species of the genus

Suture: a line, groove or a seam where two parts connect.

Terminal: the final or distal part.

Testa: seed coat.

Surface patterns

Descriptive terms of surface patterning were used following Bojňanský and Fargašová, 2007.

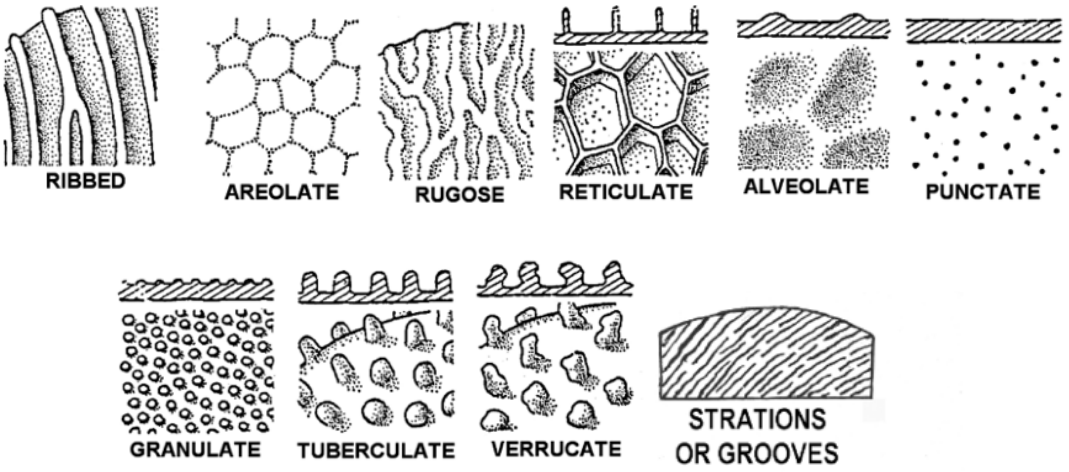


Figure 2: Terms used for describing the surface pattern of macrofossils. Drawings by Margaret R. Murley published within Bojňanský and Fargašová (2007, pg. xxxiii-xxxiv).

Shapes and features

Descriptive terms of shapes and anatomical features were used following Bojňanský and Fargašová, 2007.

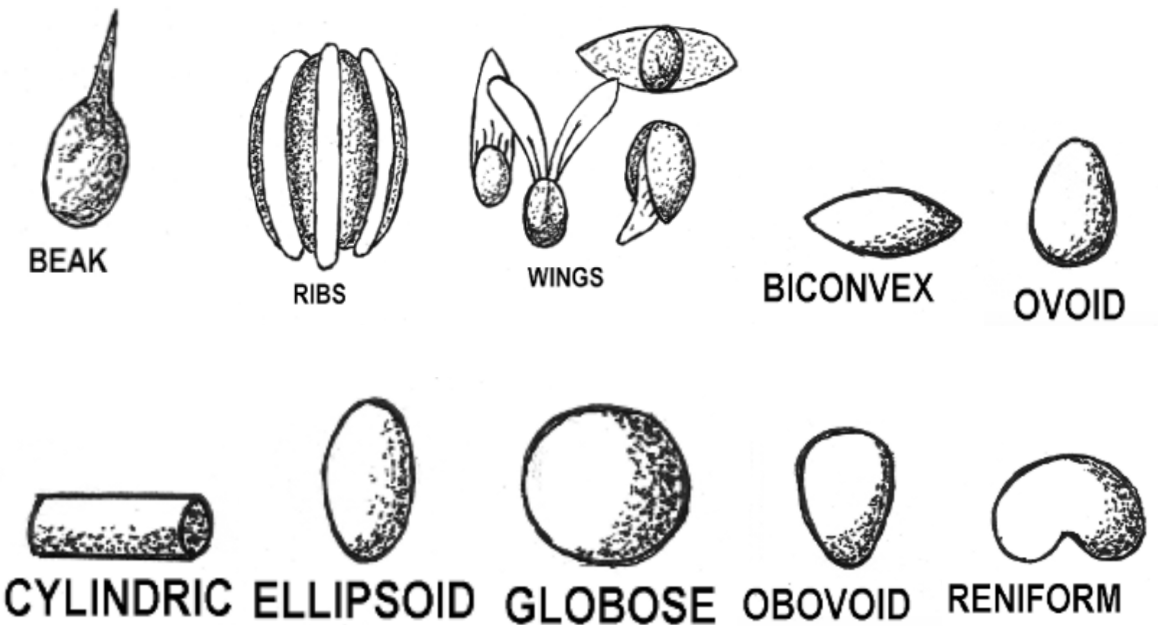


Figure 3: Terms used for describing the shape of macrofossils and anatomical features. Drawings by Margaret R. Murley published within Bojňanský and Fargašová (2007, pg. xxxv).

PICTORIAL KEY TO SHAPES

Shapes based on the sphere and ellipsoids, distinguished by the ratio of a : b

1 : 1 globose or spherical
1 : 2 subglobose or prolate spheroidal
1 : 3 broadly ellipsoidal (sub-prolate) to ellipsoidal (prolate)
1 : 4 oval (per-prolate)
1 : 5 fusiform

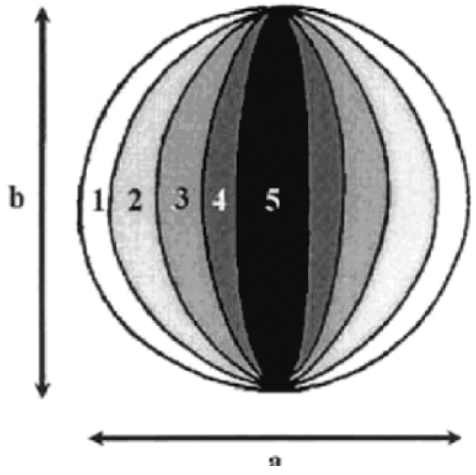


Figure 4: Terms used for describing the shape of spherical-ellipsoidal macrofossils. Diagram from Bojňanský and Fargašová (2007, pg. xxxv).

6.3 TAXA IDENTIFED AT PLOČA MIČOV GRAD

Alismataceae: *Alisma* sp.

N=6 Figure 5 a

A small number of uncharred macrofossils were identified as the water-plantain, *Alisma*, comparing well to images in Bojňanský and Fargašová (2007) and Cappers et al. (2012). Three species of *Alisma* are present in the North Pindos and North Central regions of Greece (*A. plantago-aquatica* L., *A. gramineum* Lej. and *A. lanceolatum* With.; Dimopoulos et al. 2013). However, these rare seed-like fruits were fragile and not well-preserved. As such identification was not taken further.

Amaranthaceae:

N=1377 seed cores; n=52 seeds

The seed and seed cores of Amaranthaceae (syn. Chenopodiaceae) were common. Seed cores were found partially ('browned') or fully charred. These flattened, round discs matched the size and shape of Amaranthaceae seed cores, but further identification was not possible. A few uncharred seeds were poorly preserved and fragmented and, as such, were only identified to family.

Amaranthaceae: *Chenopodium album* L. group

N=509 Figure 5 b

Many uncharred and some charred seeds were identified as fat-hen, *Chenopodium album* L. group following comparison with the reference collection. These lustrous, black seeds were round and laterally flattened/lenticular with a keel around the edge. Faint radial lines were present on the seed surface. Seeds within the *Chenopodium album* L. group are similar (*C. album, C. giganteum, C. jenissejense, C. opulifolium, C. strictum* and *C. suecicum*). Further identification was not attempted.

Amaranthaceae: *Chenopodium* sp.

N=13

A small number of uncharred and charred seeds were identified as *Chenopodium* sp. based on the size and shape of the black, lustrous seeds, but further identification was not possible due to preservation.

Amaranthaceae: *Atriplex* sp.

N=30 Figure 5 c

Some uncharred and charred seeds were identified as saltbush/orache, *Atriplex*, based on the size and shape of the black, lustrous seed, with a pronounced nose. These macrofossils compared well with modern material in the reference collection. Further identification was not possible due to preservation.

Amaranthaceae: *Polycnemum arvense* L.

N=27 Figure 5 d

Several uncharred and charred macrofossils were identified as *Polycnemum arvense* L. These flattened, pinched reniform shaped seeds were a lustrous black with a strong tuberculate surface. It was distinguished from *P. majus* L. (the other ecologically viable species, Dimopoulos and al. 2013) based on its smaller size. It compared well with images in Cappers et al. (2012).

Anacardiaceae: *Pistacia terebinthus* L.

N=790 Figure 5 e

A large number of uncharred (and a small number of charred) macrofossils were identified as the nutshell of pistachio (*Pistacia*) based on the nutshell size, cross-section features and smooth surface. They had a slightly large concave hilum and a slight asymmetrically pointed base. Two whole nutshells were particularly important during identification. This type was distinguished from almond (*Prunus amygdalus*) and hazelnut (*Corylus*) based on the size and thickness of the nutshell. It also differed from the nutshells of acorn (*Quercus*) being smaller and being composed of one layer type. Identification

followed comparison with the reference material and publications by Bojňanský and Fargašová (2007) and Cappers et al. (2012). A publication listing the key criteria for distinguishing the *Pistacia* varieties was also pivotal for understanding intra-species diversity and diagnostic features (Rousou et al. 2021). All *Pistacia* species were considered and *P. terebinthus* L. was the closest match. This is also the only species known to grow wildly in the North Central regions of Greece. *P. lentiscus* L. grows in the North Pindos region but is largely constrained to coastal zones (Dimopoulos et al. 2013). The nutshell fragments were counted using a size threshold of 12 mm^2. This was approximately one eight of a nutshell. In cases, where a quarter, half or whole nutshell was present this was counted accordingly. This enables an estimate of whole nutshells in each sample, by dividing the number of fragments by eight.

Apiaceae

N=24

Some uncharred macrofossils were identified to the family Apiaceae. Genus or species identifications were not made due to preservation or the rarity of these types. Future work could enable identifications.

Apiaceae: cf. *Daucus* sp.

N=7 Figure 5 f

A few uncharred macrofossils were identified as wild carrot (*Daucus* sp.) These seeds have a flat face with three longitudinal ridges and a curved face with numerous longitudinal ridges. The archaeological specimens compared well with modern reference material and images published in Cappers et al. (2012) identified as *Daucus carota* spp. *sativus*. Three different species of *Daucus* are known in the North Pindos and North Central regions of Greece – *D. carota* L., *D. broteri* Ten. and *D. guttatus* Sm (Dimopoulos et al. 2013). Due to the low number of species and the variability in reference material, identification to *Daucus* is tentative.

Apiaceae: *Bifora* cf. *radians* M.Bieb

N=68 Figure 5 g

A number of uncharred and charred macrofossils were identified as the seeds of the wild bishop (*Bifora* cf. *radians* M.Bieb.). These matched closely with images in Bojňanský and Fargašová (2007) and Cappers et al. (2012). The seeds had a heart-shaped protruding hilum with an uneven slightly wrinkled surface. A similar species, *Bifora testiculata* Roth, was available for comparison in the reference collection. These had a more protruding hilum. As it was not possible to directly compare the archaeobotanical remains with examples of *Bifora radians* M.Bieb. the identification was given a 'cf.'

Apiaceae: *Coriandrum sativum* L.

N=4 Figure 5 h

A small number of partially charred/browned macrofossils were identified as coriander (*Coriandrum sativum* L.) seeds. According to the 'Flora of Greece' coriander is not known to be growing in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). However, the seeds compared very well with the modern reference material. They were large (4.37-3.84mm, n=1), semiglobose with a prominent cell pattern. There were not any other plausible candidates.

Apiaceae: *Tordylium maximum* L.

N=47 Figure 6 d

Some uncharred macrofossils were identified as hartwort, *Tordylium maximum* L. These seeds were flattened and circular/cordate. Four dark-brown/black lines of a consistent thickness ran from the apex to the base on both sides. For these seeds, three genera were considered – *Heracleum*, *Pastinaca* and *Tordylium*. Identification was made to *Tordylium maximum* L. based on the shape of the seed (broader than many other relevant species, with a thick margin), consistency of the lines (which for several other relevant species often fluctuated in thickness or extended only 2/3rds of the length) and the shape of

the apex which came to a sharp point (split into two in the archaeological specimens, rather than a 'bobble' or 'hat' as in many several other relevant species e.g. *Pastinaca*). One aspect which differed between the archaeological specimens and modern seeds of *Tordylium maximum* L. from the reference collection was the hairs or bristles present on one side of the modern material. However, it is suggested that these did not preserve given the similarity of all other features. *T. officinale* L. and *T. apulum* L. (known to grow in the North Pindos and North Central regions of Greece, Dimopoulos et al. 2013) were readily excluded based on their shape and morphology (particularly the shape and thickness of the margin) (Malta Wild Plants, 2022; Last accessed 15.03.2023).

Apiaceae: cf. *Torilis* sp.

N=6

A small number of macrofossils were identified as hedge parsley (*Torilis*). These seeds were narrow with prominent hairs/bristles on one side. They compared well with the modern material in the reference collection. Seven species of *Torilis* are known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Due to preservation, identification was not made to species and was left tentative (signalled by cf.).

Asteraceae

N=74

Some uncharred macrofossils were identified as the seeds of the family Asteraceae. Genus or species identifications were not made due to preservation or the rarity of these types. Future work could enable identifications.

Asteraceae: *Carduus/Cirsium* sp.

N=7 Figure 6 a

A few uncharred macrofossils were identified as the seeds of the thistles *Carduus/Cirsium*. These macrofossils were relatively large and robust compared to many other genera in the Asteraceae family with a blunt apex and slightly asymmetric appearance (Bojňanský and Fargašová, 2007). They compared well to reference material. However, given the large number of known species in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013) and limited number of macrofossils, further identifications was not attempted.

Asteraceae: *Carthamus lanatus* L./*dentatus* (Forssk.) Vahl

N=1 Figure 6 e

One uncharred seed was identified as the thistle *Carthamus*, based on the size and asymmetric shape of the seed with a large hilum to one side and ribs running laterally along the surface. Two species are known in the North Pindos and North Central regions of Greece – *C. lanatus* L. and *C. dentatus* (Forssk.) Vahl (Dimopoulos et al. 2013). The former was available for comparison in the reference collection and proved a very close match. As *Carthamus dentatus* (Forssk.) Vahl. could not be excluded the identification was left as one of the two species.

Asteraceae: *Crepis* sp.

N=5

A small number of uncharred macrofossils were identified as hawksbeard (*Crepis*). These seeds narrowed towards the apex and the crest and had longitudinal ribs along the surface. They are morphologically reminiscent of *Lapsana communis* L., but they were much larger. The archaeological specimens compared well with those in the reference collection. Nineteen different species are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013), and as such, given the low number in the archaeological assemblage, identification to species was not attempted.

Asteraceae: *Eupatorium cannabinum* L.

N=10

A small number of uncharred macrofossils were identified as hemp-agrimony (*Eupatorium cannabinum* L.) These macrofossils were particularly fragile, and often fragmented, due to their thin tissues. The seeds were long, thin with a narrow base at the hilum. The body of the seed was composed of several longitudinal sections, giving the appearance of ridges or furrows. The archaeological specimens compared well to the reference collection and images/descriptions in Bojňanský and Fargašová, (2007) and Cappers et al. (2012).

Asteraceae: *Glebionis segetum* Fourr.

N=249 Figure 6 b

A number of uncharred (and a few charred) macrofossils were identified as corn marigold (*Glebionis*). The seeds were cylindrical with strong ribs running longitudinally. Formerly taxonomically included in the genus *Chrysanthemum*, species of *Glebionis* and *Chrysanthemum* are known to show high intra-species variability. The archaeological assemblage similarly included broader and narrower types, both of which matched accessions in the reference collection. No other species of *Glebionis* are known to grow in the North Pindos and Central North regions of Greece (Dimopoulos et al. 2013). The one viable species of *Chrysanthemum* (*C. parthenium* (L.) Bernh. syn. *Tanacetum parthenium* (L.) Sch. Bip.; Dimopoulos et al. 2013) was excluded based on features such as the number of ridges (Bojňanský and Fargašová, 2007).

Asteraceae: *Lapsana communis* L.

N=30 Figure 6 c

Some uncharred and charred macrofossils were identified as common nipplewort (*Lapsana communis* L.) based on the shape (symmetrical cylindrical with a slight curve) and size of the seeds. The macrofossils were pale yellow brown with numerous longitudinal furrows. The macrofossils compared well to the modern material in the reference collection and images/descriptions in atlases (Bojňanský

and Fargašová, 2007; Cappers et al. 2012). *L. communis* L. is the only species of its genus known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Asteraceae: *Picris hieracioides* L.

N=4

A small number of uncharred macrofossils were identified as the seeds of hawkweed oxtongue (*Picris hieracioides* L.). These macrofossils were dark-brown to black, curved elongated ellipsoidal shape with longitudinal furrows and prominent lateral wrinkles. They compared well with modern specimens from the reference collection and images/descriptions in Bojňanský and Fargašová (2007) and Cappers et al. (2012). Two other species of *Picris* are known in the North Pindos and North Central regions of Greece: *P. pauciflora* Willd. and *P. rhagadioloides* (L.) Desf. (Dimopoulos et al. 2013). Suitable comparative material was not available for these species. However, the match with *Picris hieracioides* L. was sufficiently strong.

Asteraceae: *Sonchus* cf. *asper* (L.) Hill.

N=1

A single uncharred macrofossil was identified as the seed of prickly sow thistles (*Sonchus* cf. *asper* (L.) Hill.). These macrofossils were brown, flattish ellipsoid with longitudinal ribs. Four species of *Sonchus* are present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Identification was made to *S. asper* (L.) Hill. based on its broad width, size and surface pattern, following comparison with modern reference material. The identification remained tentative (signalled by cf.) based on the low number of macrofossils.

Asteraceae: *Sonchus* cf. *oleraceus* L.

N=7 Figure 6 f

A few uncharred macrofossils were identified as the seed of sow thistles (*Sonchus* cf. *oleraceus* L.). These macrofossils were brown, flattish ellipsoid with longitudinal ribs. Four species of *Sonchus* are present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Identifications were made to *S.* cf. *oleraceus* L. depending on size, shape and surface pattern (with fine transversal wrinkles) following comparison with modern reference material. The identification remained tentative (signalled by cf.) based on the low number of macrofossils.

Asteraceae: *Taraxacum* sp.

N=263 Figure 6 g

A large number of uncharred (and a few charred) macrofossils were identified as the seeds of dandelion (*Taraxacum*). These pale brown macrofossils were obconic with longitudinal furrows with a verrucose surface pattern which transformed to spines by the apex. The macrofossils compared well to modern accessions of the common dandelion *Taraxacum officinale* L. held in the reference collection. However, as many species of *Taraxacum* (n=84) are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013), further identification to species was not attempted. Further identification should be possible with sufficient comparative material.

Betulaceae: *Alnus glutinosa* (L.) Gaertn.

N=34 Figure 7 a, e

The uncharred and charred seeds of the common alder (*Alnus glutinosa* (L.) Gaertn.) were also recovered. These macrofossils were identified based on the size, shape and thickness of the fruits, following comparison with the reference material. These morphological features excluded other ecologically viable taxa *A. incana* (L.) Moench and *Betula pendula* Roth (Dimopoulos et al. 2013). One *Alnus* tree-cone was also identified.

Betulaceae: *Corylus avellana* L.

N=116 Figure 7 h, i

Many uncharred and charred nutshell fragments were identified as hazelnut (*Corylus avellana* L.) These nutshell fragments were a similar thickness to the nutshell fragments of *Prunus amygdalus.* In cross-section the deep canals/vessel cavities were more uniformly arranged towards the exterior of the shell. The surface of the nutshell was more lustrous. The shell did not have the pitted surface characteristic of *Prunus amygdalus.* The hilum of hazelnut shells is morphologically diagnostic with a minimally ridged buff surface, slightly receded from rest of the nutshell surface. The archaeological specimens compared well with reference material and images/descriptions in relevant publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012). Based on the size and appearance of the hilum and identification was made to *Corylus avellana* L. The nutshell fragments were counted using a size threshold of 25 mm^2. The was approximately one eight of a nutshell. In cases, where a quarter, half or whole nutshell was present this was counted accordingly (as 2, 4 or 8 respectively). This enables an estimate of whole nutshells in each sample, by dividing the number of fragments by eight.

Betulaceae: *Ostrya carpinifolia* Scop.

N=103

Many uncharred macrofossils were identified as hop-hornbeam (*Ostrya carpinifolia* Scop.) based on the size and ovoid shape of the seeds. The macrofossils had a thin medium-brown lustrous outer coat with some faint-to-prominent ribs. The apex tapered to a sharp peak. Under the thin outer coat was a thick dull, lustrous broad surface. The macrofossils compared well with the images/descriptions in Bojňanský and Fargašová (2007) and with modern material in the reference collection held at the Deutsches Archäologisches Institut (DAI) in Berlin. No other species of *Ostrya* is present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Boraginaceae: *Heliotropium europaeum* L.

N=59 Figure 7 b

The European heliotrope or European turn-sole (*Heliotropium europeaum* L.) was identified (uncharred and charred) in many samples, based on the seed's pear shape, rugose surface and oval hilum. Six species of *Heliotropium* are recorded in the North Pindos and Central North regions of Greece (Dimopoulos et al. 2013). Two were eliminated following comparison in the reference collection. Sufficient comparative material was not available to exclude three species (*H. halacsyi* Riedl., *H. hirsutissimum* Grauer, and *H. supinum* L.). However, the match with *Heliotropium europaeum* L. (a very common species in modern floras and in archaeobotanical assemblages) was adequate to make the identification.

Brassicaceae

N=240 seeds; n=4 capsules

Some uncharred macrofossils were identified to the family Brassicaceae. Genus or species identifications were not made due to preservation or the rarity of these types. Future work could enable identifications.

Brassicaceae: *Camelina microcarpa* Andrz. ex DC.

N=26 Figure 7 f

Fragments of uncharred capsule were identified as *Camelina,* following comparison to the modern material in the reference collection and images available at the Cappers et al. (2012). Diagnostic features included the overall shape of the capsule (slightly asymmetric teardrop which laterally split into two halves with significant margins). The veining on the surface of the capsule was also prominent. *Camelina microcarpa* Andrz. ex DC. Is the only species that is known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). MNI counts were estimated based on the number, size and shape of capsule fragments in each sample.

Brassicaceae: *Capsella bursa-pastoris* Medik.

N=170 Figure 7 c

Many uncharred seeds were identified as shepherd's purse (*Capsella bursa-pastoris* Medik). The seeds were compared to modern material in the reference collection and relevant publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012). Morphologically similar genera in the Brassicaceae family were excluded (e.g. *Cardamine* and *Descurainia*). The cell pattern, seed shape and size closely matched *Capsella bursa-pastoris* Medik. Another species *Capsella grandiflora* (Fauché et Chaub.) Boiss. was ecologically viable (Dimopoulos et al. 2013), however, comparative reference material or publications relating to the species were unavailable. Given the commonality of *Capsella bursa*-pastoris, and the similarity between the archaeological material and this species, the identification was made.

Brassicaceae: cf. *Neslia paniculata* (L.) Desv.

N=1 Figure 7 g

A single macrofossil was identified as *Neslia paniculata* (L.) Desv. based on sub-circular shape, alveolate surface, size and hardness. It compared well with modern material in the reference collection. However, according to the 'Flora of Greece web', this species is not present in the North Pindos or North Central regions of Greece (Dimopoulos et al. 2013). No other viable alternatives were identified. As such the identification was made tentatively, signalled by 'cf.'

Brassicaceae: *Thlaspi arvense* L.

N=4 Figure 7 d

A few uncharred and charred macrofossils were identified as field penny-cress (*Thlaspi arvense* L.). This black, distinctive seed were slightly flattened, elliptic in shape with the adjoined tips of the radicle and cotyledons. The surface had parallel ribs and furrows which curved with the seed. The seed was morphology and surface pattern differed notably from *T. alliaceum* L. (Bojňanský and Fargašová, 2007) the only other species known to grown in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The seeds compared well with modern reference material.

Campanulaceae: *Campanula* spp.

N=398 Figure 8 a

Many uncharred (and a few charred) macrofossils were identified as bellflower (*Campanula*) based on the size and oval shape of the seeds with a clear surface pattern (longitudinally arranged narrow cells) and prominent margin which matched many species in the reference collection and the Atlas of Seeds and Fruits of Central East-European Flora (Bojňanský and Fargašová, 2007). While there were some recurring types, there was variability in the archaeological assemblage suggesting the presence of multiple species. However, as twenty-eight species of *Campanula* are known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013), further identification was not attempted. Identification to species is likely possible with future work and sufficient comparative material.

Caprifoliaceae: *Valeriana* cf. *coronata* (L.) Mill.

N=11 Figure 8 b

A small number of uncharred macrofossils were identified as *Valeriana coronata* (L.) Mill. (syn. *Valerianella coronata* (L.) DC.) based on the ovoid shape of the seeds with a crown-like protrusion surrounding a compression on the ventral side. The seeds compared well with modern material in the reference collection. Thirteen types of *Valerianalla* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The "crown" was considered diagnostic for this species. Identification was left tentative due to insufficient comparative material (signalled by 'cf.') to confidently eliminate other species.

Caprifoliaceae: *Valeriana dentata* (L.) All.

N=113 Figure 8 c

Many uncharred (and a few charred) macrofossils were identified as narrow-fruited cornsalad, *Valeriana dentata* (L.) All. (syn. *Valerianella dentata* (L.) Pollich.). These seeds were teardrop-shaped with a rounded base and a pointed apex. The ventral side had circular sculpting. The granulate surface was clear, particularly on the dorsal side. The macrofossils compared well with modern material in the reference collection. Thirteen types of *Valerianalla* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The size, shape and sculpting of the ventral side enabled species identification.

Caprifoliaceae: *Valeriana locusta* L.

N=17

A small number of uncharred macrofossils were identified as lamb's lettuce, *Valeriana locusta* L. (syn. *Valerianella locusta* (L.) Laterr.). These distinctive seeds/achenes are quite different in appearance to other members of the genus. Their irregular shape resembles several *Valeriana* seeds adhered together. Ridges appear down the sides of the seed. The seeds compared well with modern material in the reference collection and were distinctive from the twelve other species of *Valerianella* known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Caprifoliaceae: *Valeriana* cf. *rimosa* (Bastard) Christenh. et Byng

N=2

A couple of uncharred macrofossils were identified as broad-fruited cornsalad, *Valeriana rimosa* (Bastard) Christenh. et Byng (syn. *Valerianella rimosa* Bastard). These seeds were similar in shape as *V. coronata* (L.) Mill. and *V. dentata* (L.) All., although slightly smaller with less robust walls. The granulate surface was clear. The seeds compared well with modern material in the reference collection. Thirteen types of *Valerianalla* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Identification was left tentative due to insufficient comparative material (signalled by 'cf.') to confidently eliminate other species.

Caprifoliaceae: *Valeriana* spp.

N=39

A small number of uncharred macrofossils were only identified to the genus of valerian (*Valeriana*). The seeds shape, size and morphology matched those of species of *Valeriana* but preservation or fragmentation inhibited further identification to one of the thirteen species known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Caryophyllaceae

N=63 seeds; n=55 capsule fragments

Some macrofossils were identified to the family Caryophyllaceae. Genus or species identifications were not made due to preservation or the rarity of types. Future work could enable identifications.

Caryophyllaceae: *Scleranthus annuus* L.

N=211 Figure 8 d

A number of uncharred macrofossils were identified as the exocarp of German knotgrass or annual knawel (*Scleranthus annuus* L.) These were lustreless, pale brown and ovoid with pronounced longitudinal furrows. The sepals were not preserved. The compared well to modern material in the reference collection and images/descriptions in Bojňanský and Fargašová (2007) and Cappers et al. (2012). Three species of *Scleranthus* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Images and descriptions of *S. perennis* L. and *S. verticillatus* Tasch. suggested the species could be distinguished based on size and shape. As such, an identification was made to *Scleranthus annuus* (L.) Vill.

Caryophyllaceae: *Stellaria* sp.

N=44

Some uncharred seeds were identified as chickweed (*Stellaria*) based on the laterally flattened, circular shape and stilliform papillae. Further identification was not possible for these macrofossils based on preservation and fragmentation. It is unclear if multiple species were present. However, many are likely fragments of *Stellaria media* (L.) Vill.

Caryophyllaceae: *Stellaria media* (L.) Vill.

N=234 Figure 8 e

The symmetrical shape, size and prominence of the papillae enabled the identification of some uncharred macrofossils to *Stellaria media* (L.) Vill. based on comparison to modern reference material and descriptions/images of *Stellaria* species in Bojňanský and Fargašová (2007). Eight species of *Stellaria* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Sufficient comparative material was not found for *S. cupaniana* (Jord. et Fourr.) Bég. and *S. aquatica* (L.) Scop. However, given the similarity to *S. media* (L.) Vill. and the relative rarity of the other species, the identification was made.

Caryophyllaceae: *Silene* spp.

N=352 seeds; n=415 capsule fragments Figure 8 h, i, j

A large number of uncharred and charred seeds were identified as catch-fly (*Silene* spp.). These red-brown or black seeds were reniform and laterally flattened. Variation in the shape, prominence of the hilum and surface pattern suggested multiple species were in the assemblage. Fourth-five species of *Silene* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Some compared very well with *Silene cretica* L. following comparison to modern material in the reference collection. However, there was insufficient comparative resources to exclude the other species. Identification to species should be possible in the future. Some fragments of capsule were also identified to *Silene* sp. These had a strong 'zigzag' surface pattern. They were thicker than many other members of the Caryophyllaceae family (e.g. *Arenaria*, *Stellaria* and *Cerastium*) and thinner than

other such as *Petrorhagia* and *Dianthus*. Some fragments gave an indication of the curvature and shape of the capsule suggesting a broad, bulbous outline with an undulating surface at the attachment point. This compared very well with the capsules of *Silene cretica* L. in the reference collection. However, other species could not be excluded. Capsule fragments were counted using a size guide of (1=12 mm^2). This size was chosen as it is the size guide used for *Pistacia* and other tissues. The size of the capsule depends on the species and so is hard to estimate a MNI.

Caryophyllaceae: *Agrostemma githago* L.

N=55

Uncharred fragments of common corn-cockle (*Agrostemma githago* L.) seeds were common. The seed coats were identified based on their size, the numerous prominent acute tubercles and the surface pattern in comparison to the reference material and publications by Bojňanský and Fargašová (2007) and Cappers et al. (2012). No other species of *Agrostemma* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Caryophyllaceae: *Arenaria serpyllifolia L.*

N=1201 Figure 8 f

The uncharred seeds of thyme-leaf sandwort (*Arenaria serpyllifolia* L.) were frequently found in the assemblage. Identification was made based on the cell pattern, shape and size (Bojňanský and Fargašová, 2007; Cappers et al. 2012). These seeds were variable in size and morphology; however, variability was also seen between and within accessions in the reference material. Some seeds had a tuberculate surface similar to *Arenaria serpyllifolia subsp. leptoclados* (Rchb.) Nyman, while others had a smoother surface similar to *Arenaria serpyllifolia* subsp. *serpyllifolia*. However, a spectrum of features was seen within the archaeological assemblage and in the reference material inhibiting the distinction between these two types.

Caryophyllaceae: *Cerastium* sp.

N=109

Some uncharred seeds were identified as *Cerastium.* Identification was made based on the cell pattern, shape and size (Bojňanský and Fargašová, 2007; Cappers et al. 2012). Many were whole. It is unclear if multiple species are present as some are poorly preserved. They were distinguished from *Stellaria media* L. based on their asymmetrical shape. Separation from *Stellaria* was more challenging. Overall, the asymmetrical shape and the surface pattern made an identification to *Cerastium* more likely. Further identification was not attempted.

Caryophyllaceae: *Holosteum umbellatum* L.

N=59

A number of uncharred seeds were identified as jagged chickweed (*Holosteum umbellatum* L.). This distinctive seed was small and cordate/shield-shaped with a large radical or radical-like feature running from a slightly notched apex down the centre of the seed. The seed matched images and descriptions in Bojňanský and Fargašová (2007) and Cappers et al. (2012). A very distinctive seed, there were not any other possible candidates in the genus or even in the family.

Caryophyllaceae: *Petrorhagia* spp.

N=243 Figure 8 g

Several uncharred (and a few charred) macrofossils were identified as *Petrorhagia*. These seeds are similar to *Dianthus*. The *Petrorhagia* seeds were distinguished from the relevant *Dianthus* seed based on the distinctive protruding margin on one side, which showed a slightly different cell pattern. The seeds strongly resembled *Petrorhagia prolifera* (L.) P. W. Ball, due to the cell pattern, marginal rim and the shape near to the apex (more shield-shaped than tear-dropped) (compared to the reference collection and images/descriptions Bojňanský and Fargašová, 2007). The macrofossils also resemble

SEM images published on 'Manual of the Alien Plants of Belgium' (Verloove, 2012) for *Petrorhagia prolifera* (L.) P. W. Ball and a couple of seeds resembled *Petrorhagia dubia* (Raf.) G. López et Romo (Verloove, 2012). However, eight species of *Petrorhagia* are present in the North Pindos and North Central regions of Greece so further identifications were not made due to insufficient comparative material (Dimopoulos et al. 2013).

Caryophyllaceae: *Petrorhagia* sp./*Dianthus* sp.

N=26 seeds, n=1 capsule

Some uncharred seeds were identified only to *Petrorhagia* sp. or *Dianthus* sp. based on preservation or rare examples with a slightly different shape (more teardrop) and size to the *Petrorhagia* type and missing the protruding margin. Twenty-one species of *Dianthus* and eight species of *Petrorhagia* are present in the North Pindos and North Central regions (Dimopoulos et al. 2013).). As such, while further identification might be possible for some of these macrofossils, species identification was not made at this stage. One fragment of Caryophyllaceae capsule was identified to *Petrorhagia* sp. or *Dianthus* sp. due to the shape and curvature of the fragment suggesting a long and thin capsule. The surface pattern and the thickness of the capsule (thicker than those of other Caryophyllaceae genera present in the assemblage) also supported this identification. Capsule fragments were counted using a size guide of (1=12 mm^2).

Characeae: *Chara* spp.

N=9100 Figure 9 a

The uncharred oogonium (the female organ) of the stonewort (*Chara*) a charophyte freshwater green algae were commonly found across the samples, sometimes in large numbers. The oval oogonium has spirally arranged cells and can be covered in a calcium carbonate ($CaCO_3$) deposit. These macrofossils compared well to images in Maier (2001). Counts of oogonium with calcium carbonate and those

without were recorded separately. The oogonium varied in size, shape and colour (yellow and black) and as such it is thought multiple species are present. Further identifications have not been attempted.

Convolvulaceae: *Convolvulus* sp.

N=1

One uncharred seed was identified as bindweed or morning glory (*Convolvulus*). This seed was relatively large and trigonous with a rounded hilum to the apex. It compared favourably with specimens in the reference collection and images in relevant publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012). Eight species of *Convolvulus* have been reported in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). However, as only one seed was preserved, further identification was not attempted.

Convolvulaceae: *Cuscuta* sp.

N=509 Figure 9 b

A large number of macrofossils were identified as seeds of the parasitic plant, dodder (*Cuscuta* sp.), the vast majority of which were uncharred, but a few were charred and one was mineralised. The seeds were sub-circular with a small depression marking the hilum. The surface was characteristic being rough, irregular, lustreless and yellow in colour. They compared favourably with specimens in reference collection and descriptions in Bojňanský and Fargašová (2007). Six different *Cuscuta* species are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Due to distortion following waterlogging, it was challenging to elucidate the seed size and shape. They were also often found fragmented. As such, further identification to species was not made.

Cornaceae: *Cornus mas* L.

N=255 Figure 9 e

The seed or stone of cornelian cherry (*Cornus mas* L.) was numerous in the assemblage. The majority were uncharred. Many were recovered whole. The stones were ellipsoid tapering to a point at each end. The surface was slightly puckered and deep furrows ran from the apex. The interior of the stone was highly characteristic with large irregular cavities. The archaeological macrofossils compared very well with specimens in the reference collection and in relevant publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012). The shape and surface pattern distinguished *Cornus mas* L. from the other known species in the North Pindos and North Central regions of Greece, *Cornus sanguinea* L. (Dimopoulos et al. 2013).

Cupressaceae: *Juniperus cf. communis* L.

N=73 Figure 9 c

Uncharred seeds of the common juniper (*Juniperus communis* L.) were identified based on their irregular longish-ovoid/triangular shape, following comparison with specimens from the reference collection. The seeds were very hard with a pale brown, dull surface. These seeds resembled *Rosa*, but they were differentiated due to the surface texture, the thickness of the seed wall and the internal surface pattern. Five juniper species are known for the North Pindos and North Central regions of Greece (*J. communis* L., *J. excelsa* M. Bieb., *J. foetidissima* Willd., *J. oxycedrus* L. and *J. sabina* L.; Dimopoulos et al. 2013). These seeds were much smaller than those identified as *J.* cf. *oxycedrus* L., were paler in colour and lacked pitch glands. Relevant atlases (e.g. Bojňanský and Fargašová, 2007; Cappers et al. 2012) offer quite variable images and descriptions for the *Juniperus* species, and hybridisation is known. As such, identification was left as tentative, signalled by 'cf.'

Cupressaceae: *Juniperus cf. oxycedrus* L.

N=73 Figure 9 d

Uncharred seeds of the cade juniper or prickly juniper (*Juniperus oxycedrus* L.) were identified based on their irregular longish-ovoid/triangular shape. These seeds were much larger than those identified

as *J. communis* (which matched descriptions in Bojňanský and Fargašová, 2007). The seeds were very hard with an orange-brown, dull surface and a dark brown 'cap' towards the apex (similar to the drawing of *J. oxyxedrus* shown in Bojňanský and Fargašová, 2007). The seeds had numerous large pitch glands running longitudinally, which could become detached. Such pitch glands are not mentioned for this species in Bojňanský and Fargašová (2007) but were present in reference material collected during vegetation surveys in northern Greece. The seeds also compared well with modern material in the reference collection held at the Deutsches Archäologisches Institut (DAI) in Berlin. The seeds also compared well to an image of an archaeological *J. oxycedrus* s.l. seed from a Bronze Age well in Sardinia published in Sabato et al. (2015). Four other juniper species are known for the North Pindos and North Central regions of Greece (*J. communis* L., *J. excelsa* M. Bieb., *J. foetidissima* Willd. and *J. sabina* L., Dimopoulos et al. 2013), which were excluded based on the size and shape of the seeds. Relevant atlases (e.g. the Bojňanský and Fargašová, 2007; Cappers et al. 2012) offer quite variable images and descriptions form *Juniperus* species, and hybridisation is known. As such, identification was left as tentative, signalled by 'cf.'

Cupressaceae: cf. *Juniperus excelsa M. Bieb./foetidissima Willd./sabina L.*

N=27 Figure 9 f

Some uncharred seeds were identified to *Juniperus*, however, differed significantly from those identified to *J. communis* L. and *J. oxycedrus* L. These seeds could be *J. excelsa* M. Bieb., *J. foetidissima* Willd. and *J. sabina* L. based on the species known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Insufficient comparative material inhibited identification to species. These seeds were highly variable in size and shape. It is known that the shape of juniper seeds can vary, relating to the number of seeds in the cone (Dimitri et al. 2017). The interior of these seeds differed from those identified as *J. communis* L. and *J. oxycedrus* L. containing a fibrous tissue. This resembled images of infested *J. excelsa* seeds from Lebanon by the parasite *Trisetacus kirghizorum* (Douaihy et al. 2013). Given the lack of comparative material, variability in descriptions/images in

relevant atlases for *Juniperus* species (e.g. Bojňanský and Fargašová, 2007; Cappers et al. 2012) and known hybridisation, identification was not taken further, beyond signalling a difference from the *J.* cf. *communis* L. and *J.* cf. *oxycedrus* L. macrofossils.

Cupressaceae: *Juniperus* sp.

N=47 fruit fragments; n=12 scales/needles

Some other uncharred and charred macrofossils were identified as juniper. One fruit-like tree cone was identified, as a juniper seed could be seen inside the flesh. It is likely, but not certain, that this seed was *Juniperus* cf. *oxcyedrus*. Based on this identification, a number of other small fragments of juniper cone was also identified. A small number of juniper scales or needles were identified, based on comparison to modern material from the reference collection. Further work might identify these to species.

Cyperaceae

N=35

Some uncharred macrofossils were identified to the family Cyperaceae. Genus or species identifications were not made due to preservation or the rarity of these types. Future work could enable identifications.

Cyperaceae: *Schoenoplectus/Scirpus*

N=30

Some uncharred macrofossils were identified as *Schoenoplectus/Scirpus*. These dark seeds were broad obovoid with a beaked apex. They compared well to modern material in the reference collection. Five species of *Schoenoplectus* and one species of *Scirpus* is known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Further identification was not attempted.

Cyperaceae: *Carex* spp.

N=39 Figure 9 g

Some uncharred remains were identified as the seeds of sedges (*Carex*). These seeds varied morphologically in size and in shape (e.g. some two-sided and others the rarer three-sided), suggesting many different species were present. Given the number (n=51) of known *Carex* in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013), no further identifications were currently made. The preservation is sufficient to enable species-level identifications with future work.

Cyperaceae: *Cyperus fuscus* L.

N=18

A number of uncharred specimens were identified as a sedge sometimes known as brown galingale or brown flatsedge (*Cyperus fuscus* L.). These seeds were small and trigonous. The pale outer seed coat was largely translucent, revealing an internal darker (light brown) layer. Thirteen species of Cyperus are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). While information regarding all thirteen species was not available, the archaeological specimens matched very well with modern seeds of *Cyperus fuscus* from the reference collection permitting the identification.

Euphorbiaceae: *Euphorbia* cf. *exigua* L.

N=1

A single seed was identified as dwarf spurge or small spurge (*Euphorbia exigua* L.) The sub-rectangular seed tapered to the hilum. A clear suture was visible running longitudinally from the hilum to the apex. The distinctive rugose surface pattern of the seed was diagnostic. Sixty-nine species of *Euphorbia* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). There was not sufficient reference material to exclude all species, but the archaeological specimens compared

well with *Euphorbia exigua* L. from the reference collection and images/descriptions in Bojňanský and Fargašová, (2007) and Cappers et al. (2012). The identification was made tentatively (cf.)

Euphorbiaceae: *Euphorbia* cf. *helioscopia* L.

N=17 Figure 9 h

Many uncharred and charred seeds were identified as sun spurge or madwoman's milk (*Euphorbia helioscopia* L.). The seeds were similar in obovoid, narrowing towards the hilum. As with *Euphorbia exigua* L. a clear suture ran longitudinally from the hilum to the apex. The surface pattern of *Euphorbia helioscopia* L. differed significantly from *Euphorbia exigua* L. showing a coarse reticulate surface pattern. Many (n=69) species of Euphorbia are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). There was not sufficient reference material to exclude all species, but the macrofossils fitted very well with seeds of *Euphorbia helioscopia* L. from the reference collection and images/descriptions in the Bojňanský and Fargašová, (2007) and Cappers et al. (2012). As such, a tentative identification was made signalled by cf.

Fabaceae: large, indeterminate

N=38 seeds; n=46 pedicel; n=1 nose; n=1236 pod fragments; n=54 detached seed coats with hilum Figure 10 c

A number of macrofossils were identified as Fabaceae. Due to their size, these macrofossils belonged to a large-seeded Fabaceae. Based on the finds of lentil, pea and bitter vetch seeds, it is likely that many/all of these macrofossils are these three taxa. These macrofossils compared well with modern material in the reference collection. The seeds and detached seed coats with hilum could not be identified further due to preservation. Pale yellow pulse pod fragments were identified based on the presence of two key layers. Some pieces retained part of the outline of the pod. Identification of pulse pod to species is very challenging and requires higher magnification (e.g. Scanning Electron Microscopy). Pulse pod fragments were counted using a threshold of c. 12 mm^2.

Fabaceae: *Lens culinaris* Medik.

N=12 seeds; n=9 detached seed coat with hilum Figure 10 f, h

Some charred seeds were identified as lentil (*Lens culinaris* L.) based on their lenticular, laterally compressed shape and elongated hilum (1.07 mm-0.33 mm). The seeds compared well with modern accessions in the reference collection and images/descriptions in Butler (1990). Some detached uncharred and charred fragments of seed coat with the hilum was also identified as lentil (see Paper 3 of this thesis).

Fabaceae: *Medicago* sp.

N=154 Figure 10, b

Fragments of uncharred pod of medick or burclover (*Medicago*) were identified. These pods were a spiral of thin, spiny tissue, with veins that could become detached. These pods compared very well with *M. minima*. They also compared well with *M. praecox* and *M. disciformis* in the reference collection at Archaeobotany Lab, School of Archaeology (Oxford). Given nineteen species of *Medicago* are known in the North Pindos and North Central regions of Greece, further identification to species was not made (Dimopoulos et al. 2013). The pods were always fragmentary. An estimate of the number of whole pods in a sample was given.

Fabaceae: cf. *Pisum sativum L.*

N=4 seeds; n=41 detached seed coat with hilum Figure 10 e, g

Some seeds were identified as pea (*Pisum sativum* L.) based on their spherical shape. The hilum was not preserved. The seeds compared well with modern accessions in the reference collection and images/descriptions in Butler (1990). However, due to preservation the identification was kept tentative, signalled by cf. Some detached fragments of seed coat with the hilum were also identified as pea based on their size and the curvature of the aerenchyma layer (see Paper 3 of this thesis).

Fabaceae: Small-seeded legume

N=47 Figure 10 a

Several macrofossils were identified as small-seeded legumes. These small specimens were considered members of the Fabaceae family based on their shape (flattened, elongated) with a prominent radicle. Further identification was not possible due to preservation.

Fabaceae: *Trifolium* sp.

N=206 exocarp; n=6 seeds Figure 11 a

A number of uncharred macrofossils were identified as the flower-like 'exocarp' and seeds of clover (*Trifolium*). These were identified based on the long triangular body of the exocarp with ridges and a crown. The seeds were ovoid with long radicle and a rounded hilum. They compared well with modern material in the reference collection. Many species of *Trifolium* are known in the North Pindos and North Central regions of Greece. At this stage, further identification to species was not attempted.

Fabaceae: *Vicia ervilia* (L.) Willd.

N=14 seeds; n=122 detached seed coat with hilum Figure 10 d, f

Some charred seeds were identified as bitter vetch (*Vicia ervilia* (L.) Willd.) based on their angular/triangular shape and oval hilum (0.66±0.08 mm-0.41±0.07 mm). The seeds compared well with modern accessions in the reference collection and images/descriptions in Butler (1990). Some detached fragments of uncharred and charred seed coat with the hilum were also identified as bitter vetch based on their size and the angularity of the aerenchyma layer (see Paper 3 of this thesis).

Fagaceae: *Quercus* sp.

N=157 nutshell bases/hilum; n=1,148 nutshell fragments; n=1 nut kernel; n= 6 cupule fragments Figure 11 b

A large number of uncharred (and some charred) fragments of nutshell were identified as acorn (*Quercus*). These were distinguished from almond (*Prunus amygdalus*), hazelnut (*Corylus avellana* L.) and terebinth (*Pistacia terebinthus*) based on the thickness, cross-section and surface pattern. The nutshells were composed of layers of two types of tissue (an external light-brown and an internal dark-brown layer). They compared well with material from the reference collection. The hilum base was also very diagnostic – a flat disc with shallow perforations. Identification to species is challenging based on the nutshell fragments alone, due to intra-species variability, and often requires the cupule. The small number of uncharred cupule fragments recovered, and their preservation, prevented identification attempts. Nine different species of *Quercus* are present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The nutshell fragments were counted using a size threshold of 25 mm^2. The was approximately one eight of a nutshell. In cases, where a quarter, half or whole nutshell was present this was counted accordingly as two, four or eight respectively. This enables an estimate of whole nutshells in each sample, by dividing the number of fragments by eight.

Geraniaceae *Geranium* sp.

N=3

Three charred seeds were identified as cranesbills, *Geranium,* based on their shape and the positioning of the radical. Twenty-two species of *Geranium* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Due to preservation and the small number of macrofossils, further identification was not attempted.

Geraniaceae *Geranium* cf. *purpureum* Vill.

N=23

Some uncharred macrofossils were identified as the fruits of *Geranium* cf. *purpureum* Vill. The fruits were elongated with a central rib from which strong veins originated. This outer tissue was often found in small fragments. The shape of the fruitlet and the surface patterning excluded many of the twenty-

one additional *Geranium* species that are known in the area (Dimopoulos et al. 2013), by comparison with the reference collection and relevant publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012). Species of *Erodium* were also considered and eliminated. Not all viable species had sufficient comparative material to be excluded. However, the fruits matched *Geranium* cf. *purpureum* Vill. well and so a tentative identification was made signalled by a 'cf.'

Hydrocharitaceae: *Najas marina* L.

N=168

Several uncharred macrofossils were identified as the seeds of spiny water nymph or spiny naiad (*Najas marina* L.) These seeds were large, robust and elongated oval in shape which tapered slightly towards each end. These light brown glossy seeds had a strongly foveolate (little pits) surface. The archaeological macrofossils compared well to images/descriptions in the Bojňanský and Fargašová (2007) and Cappers et al. (2012). No other species of *Najas* are recorded for the North Pindos and North Central regions of Greece.

Hydrocharitaceae: *Najas* sp.

N=41

A small number of macrofossils were smaller and thinner walled than those identified as *Najas marina* L. An identification of *Najas minor* All. was considered based on Bojňanský and Fargašová (2007), however as this species is not listed for the region (Dimopoulos et al. 2013), identification was kept at *Najas*. It is possible that these macrofossils are unusual specimens of *N. marina* and/or that taphonomic factors could have degraded the seed walls.

Hypericaceae: *Hypericum* spp.

N=101

Some uncharred and charred seeds were identified as St. John's Wort (*Hypericum* spp.). Identification for these seeds was only identified to genus. For some this was due to preservation and fragmentation. Many of these seeds were likely another species than *Hypericum perforatum* L., having a different shape (often curved and thinner), colour (some were pale) with a finer surface pattern. Sixteen species of *Hypericum* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Future work could enable identification to species.

Hypericaceae: *Hypericum perforatum* L.

N=1035 Figure 11 c

A large number of uncharred (and some charred) dark brown/black narrow, cylindrical seeds were identified as St. John's Wort, *Hypericum perforatum* L. The surface pattern on these seeds was uniform with reticulate lines running longitudinally. Both ends of the seeds were slightly pinched. Generally, these seeds were straight. The seeds matched modern material in the reference collection and images and descriptions in the Bojňanský and Fargašová (2007) and Cappers et al. (2012). Fifteen other *Hypericum* seeds are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Some could not be excluded based on insufficient comparative material. However, an identification to *H. perforatum* L. was still made as the match was strong.

Juncaceae: *Juncus* sp.

N=19

A small number of uncharred seeds of rushes (*Juncus*) were identified based on their small size, elliptic shape, surface pattern and style at the apex, (Körber-Grohne, 1991). Twenty-six species of *Juncus* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Further identification to species was not attempted.

Lamiaceae:

N=39

Some uncharred macrofossils were identified to the family Lamiaceae having a ridge down the centre of the seed/nutlet and a hilum scar at the base. Genus or species identifications were not made due to preservation or the rarity of these types. Future work could enable identifications.

Lamiaceae: *Teucrium* spp.

N=59

Some uncharred macrofossils were identified as the seeds/nutlets of germanders (*Teucrium* spp.). There was variation in these specimens (e.g. size, colour and prominence of the hilum) suggesting that multiple species were present in the assemblage. The seeds compared well with modern reference material. They differed from the morphologically and genetically close genus (*Ajuga*) due to the shape and surface pattern of the relevant species. Seven species of *Teucrium* are known from the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). There were insufficient comparative resources to identify these macrofossils to species, but this should be possible with future work.

Lamiaceae: *Ajuga chamaepitys* (L.) Schreb.

N=3 Figure 11 i

Rare uncharred seeds of the yellow bugle (*Ajuga chamaepitys* (L.) Schreb.) were identified, following comparison to the reference material and publications by Bojňanský and Fargašová (2007) and Cappers et al. (2012). Six species of *Ajuga* are present in the North Pindos and the North Central Region of Greece (Dimopoulos et al. 2013). Identification was made based on their elongated shape, large sub-rectangular hilum, and prominent surface pattern. Descriptions or images of *Ajuga orientalis* L. and *Ajuga piskoi* Degen et Bald could not be found. However, the match between the archaeological seeds and *Ajuga chamaepitys* (L.) Schreb. was strong.

Lamiaceae: *Lamium* spp.

N=12

A small number of uncharred macrofossils were identified as dead-nettles (*Lamium* sp.) These seeds had a slightly convex flat dorsal surface and a two-sided ventral surface with a flattened base. Some of these had strong surface pattern. *Galeopsis* was eliminated due to the size and the surface pattern, following comparison with the modern material in the reference collection. A number of *Lamium* species are plausible (five known in the North Pindos and North Central regions of Greece; Dimopoulos et al. 2013) and it is likely multiple species are in the assemblage. Given the low number of archaeological macrofossils (many of which were fragmented), identification to species was not attempted.

Lamiaceae: *Mentha aquatica* L.

N=19 Figure 11 e

A few uncharred macrofossils were identified as water-mint (*Mentha aquatica* L.) following comparison with modern material in the reference collection. These seeds were ovate, with a base that tapered to a point at hilum with a 'scoop' out of either side. Three other species of *Mentha* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). *M. spicata* and *M. pulegium* was excluded based on the hilum morphology (Bojňanský and Fargašová, 2007) and *M. longifolia* based on the size and surface pattern following comparison with the reference collection.

Lamiaceae: *Mentha longifolia* L.

N=85 Figure 11 d

Several uncharred macrofossils were identified as horse-mint (*Mentha longifolia* L.) based on the small size, the pronounced surface pattern and hilum morphology of these seeds. Three other species of *Mentha* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

M. spicata, *M. pulegium,* and *M. aquatica* L. was excluded based on the hilum morphology, size and surface pattern (Bojňanský and Fargašová, 2007).

Lamiaceae: *Mentha/Origanum*

N=27

Identification of some uncharred macrofossils beyond *Mentha/Origanum* was not possible due to preservation. These specimens were similar to macrofossils identified as *Mentha aquatica* L., *Mentha longifolia* L. and *Origanum vulgare* L.

Lamiaceae: *Melissa officinalis* L.

N=5

A very small number of uncharred macrofossils were identified as lemon balm, *Melissa officinalis* L. These dark-brown/black seeds were elongated pear-shaped with a flattened dorsal surface, a subtlety two-sided ventral face and a small hilum. This is the only known species of *Melissa* in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Other members of the Lamiaceae family were not plausible candidates.

Lamiaceae: *Origanum vulgare* L.

N=133 Figure 11 f

A number of uncharred macrofossils were identified as oregano (*Origanum vulgare* L.) following comparison with modern material in the reference collection. These seeds were obovate, with a base that tapered to a point at the hilum with a 'scoop' out of either side. Some specimens overlapped in size with those identified as *M. longifolia* L. and *M. aquatica* L., but the cell pattern and shape differed. No other *Origanum* species are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Linaceae: *Linum usitatissimum* L.

N=3,009 capsule fragments; n=746 seeds Figure 11 g, h

A large number of uncharred and some charred macrofossils were identified as flax (*Linum usitatissimum*), including capsule fragments and seeds. These seeds were identified based on their shape (flattened, ellipsoid shape with a hook at the hilum). The prominent surface pattern was rounded-pentagonal cells. Thirty-three species of *Linum* that are known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The size and the prominence of the peak excluded other *Linum* species. Not all species were available for comparison, but the match between the macrofossils and modern reference material was sufficient to permit identification. Each capsule section would hold one seed. The capsule fragments were counted to provide a MNI of capsule segments (if both sides/the tip was present).

Malvaceae

N=3 Figure 12 b

A small number of seeds were identified to the family Malvaceae. Genus or species identifications were not made due to preservation or the rarity of these types and the similarity between different genera. Future work could enable identifications.

Malvaceae: *Malva* cf. *sylvestris* L.

N=21 Figure 12 a

The capsule-like mericarp of mallow (*Malva sylvestris* L.) was identified uncharred based on its size, subcircular shape and angular sculpting with a clear reticulate surface pattern. Eleven species of *Malva* are known to grown in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Comparisons with modern material in the reference collection and images/descriptions in atlases (Bojňanský and Fargašová, 2007; Cappers et al. 2012) enabled the identification to *Malva* cf. *sylvestris*

L. Images found online were also used to (less confidently) exclude species (Hinsley, 2004; Giuliano, 2008; Mifsud, 2022). The identification was tentative signalled by 'cf.' as while descriptions, images and reference specimens were available for all relevant species, some material was not sufficient to confidently exclude all other species.

Malvaceae: cf. *Tilia platyphyllos* Scop.

N=6 Figure 12 c

A small number of macrofossils compared well to the exocarp of the large-leaved lime/large-leaved linden, *Tilia platyphyllos* Scop. These grey macrofossils were globose with angular sides. They were often still partially attached to a stem. One other species of *Tilia* is known to grow in the North Pindos and North Central regions of Greece – *T. cordata* Mill. (Dimopoulos et al. 2013), but these capsules were not angular. They compared well with images/descriptions in Bojňanský and Fargašová (2007). However, as there was not any modern material to directly compared with the archaeological material, the identification was left tentative (signalled by cf.).

Moraceae: *Ficus carica* L.

N=854 Figure 12 c

Uncharred fig (*Ficus carica* L.) was a common feature of the archaeobotanical assemblage. A few charred fig seeds were also recovered. These seeds are obovoid in shape with a laterally extending the length of the seed from the apex. The seeds were variable in shape, some with a more pronounced point. Some seeds were sub-circular whereas others appeared sub-rectangular. Many seeds were found whole but small fragments were also identified, following comparison with whole archaeological seeds and the modern reference collection. A faint punctate surface pattern aided the identification of small fragments. No other species of *Ficus* is known in the North Pindos and North Central regions of Greece.

Onagraceae: *Epilobium* sp.

N=5

A few uncharred macrofossils were identified as willowherbs (*Epilobium* sp.). The seeds were long, narrowing at the apex, with a deep undulating furrow. They compared well with modern material in the reference collection and with descriptions in Bojňanský and Fargašová, (2007). Eighteen species are known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). As the specimens were small in number, further identification was not attempted.

Orobanchaceae: *Melampyrum* sp.

N=3

A small number of uncharred macrofossils were identified as cow wheat (*Melampyrum*). The large seeds were reddish brown with a smooth surface, lacking a clear surface pattern. One macrofossil was identified as the 'fruit' or capsule of *Melampyrum*. Six species of *Melampyrum* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Due to the small number of fragmented macrofossils further identification was not attempted.

Papaveraceae: *Fumaria officinalis* L.

N=64 Figure 12 f

The uncharred seeds of the common fumitory (*Fumaria officinalis* L.) were a frequent feature of the archaeological assemblage. These macrofossils were latitudinally flattened and elliptic in shape. These seeds were generally shorter and broader than the nine other *Fumaria* species present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The macrofossils were compared to those in the reference collection at the Archaeobotany Lab, School of Archaeology (Oxford) and images/descriptions in Bojňanský and Fargašová (2007) to exclude species.

Papaveraceae: *Papaver* sp.

N=91 seeds, n=53 capsule fragments Figure 12 e

Some poppy seeds were left unidentified to species due to preservation (e.g. fragmentation or charring) which prevented the identification of diagnostic features. Some seeds were likely other species (not *Papaver somniferum* L.). Nine species occur in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Some fragments of poppy capsule were also recovered. Future work could enable their identification.

Papaveraceae: *Papaver somniferum* L.

N=2433 Figure 12 g, h

A large number of uncharred seeds were identified as opium poppy (*Papaver somniferum* L.) due to the size, shape and number of visible reticulate 'cells.' Whole poppy seeds were photographed and measured at the Deutsches Archäologisches Institut (DAI) in Berlin with Dr. Ferran Antolín and Raül Soteras. The poppy seeds were of a similar size to other prehistoric archaeological poppy seeds (Jesus et al. 2021). The Late Neolithic poppy seeds (n=104 measured) were smaller (average width of 0.60 mm and length of 0.75 mm), while the later Bronze Age seeds (n=29 measured) were much larger (average width of 0.80 mm and length of 0.98 mm). Geometric morphometric analysis to assess whether these seeds match the wild morphotype (*P. somniferum* L. subsp. *setigerum*) or the domesticated morphotype (*P. somniferum* L. subsp. *somniferum*) is forthcoming.

Pinaceae

N=17

A few uncharred needles were identified to the family *Pinaceae* due to preservation or fragmentation. It is likely that they belong to either *Abies* or *Pinus* as these two genera were found in large numbers and share many characteristics. It is also possible that they pertain to an (as yet) unidentified genus, or (less likely) another family. Given the small number of needles recovered this was not a priority. Needle apexes were counted to give an MNI.

Pinaceae: *Abies* sp.

N=276

Fir (*Abies* sp.) needles were identified following Strid (1986). Fir needles are relatively wide and flat with two parallel stomata bands (each with 5-9 lines) running from the apex to the attachment point (Strid, 1986). In the uncharred and charred archaeological needles, the stomata bands were sometimes preserved (the number of lines often not countable). If the apex was not preserved or was not emarginate it was identified as *Abies* sp.

Pinaceae: *Abies alba* Mill.

N=949 Figure 13 a

Fir needles with an emarginate apex were identified as silver fir (*Abies alba* Mill.; Strid, 1986). If the apex was not preserved or was not emarginate it was identified as *Abies* sp. The apex of *A. cephalonica* is acute, while the hybrid between *A. alba* and *A. cephalonica (Abies x borisii-regis*) can have a slightly emarginate, obtuse or acute apex (Strid, 1986). While it is possible some needles identified as *A. alba* could, therefore, be *Abies x borisii-regis,* the dominance of needles with pronounced emarginate apexes suggests that the identification of silver fir is more likely. Needle apexes were counted to give an MNI.

Pinaceae: *Pinus* sp.

N=375 needles; n=3 seeds; n=4 cone scales Figure 13 b, c

A number of uncharred and charred macrofossils were identified as pine (*Pinus* sp.). This included many needles/leaves which long, dark brown with faint rows of black stomata and faint longitudinal lines. In cross-section the needles were reniform. The needles tapered to a sharp point. A small number of macrofossils were identified as the seeds of pine being dark brown, large and elliptic-obovoid in shape with a smooth surface. A few charred scales of pinecones were also recovered. They

compared well to modern needles, seeds and pinecone scales of many species of pine in the reference collection. A number of species of pine (n-=6) are known to grow in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Further work might permit identification to species. Needle apexes were counted to give an MNI.

Plantaginaceae: *Plantago* sp.

N=3 Figure 14 a

A very small number of uncharred and charred macrofossils were identified as the seeds of plantain (*Plantago* sp.) based on their flattened ellipsoid shape with an oval hilum in the centre of the ventral surface. This followed comparison with images/descriptions in Bojňanský and Fargašová (2007) and comparison to modern material from the reference collection. Several *Plantago* species (n=15) are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Further identification was not made, given the small number of remains.

Plantaginaceae: *Veronica* sp.

N=4

Four uncharred seeds were identified as speedwell, *Veronica.* These seeds were broad with a central hilum. They compared well with modern material in the reference collection and images/descriptions in Bojňanský and Fargašová (2007). Thirty-three species of *Veronica* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Based on the small number and preservation of the remains, further identification was not attempted. Counting followed the principle of MNI (1=1 seed).

Poaceae: *Poa* sp.

N=2 Figure 14 d

A small number of charred macrofossils were identified as the seed of annual bluegrass (*Poa*) based on the size, narrow shape with a pointed apex and small, rounded hilum. The Körber-Grohne (1991) atlas was used to identify grasses, which is based on the diagnostic features of waterlogged uncharred specimens. Further identification was not possible due to preservation of diagnostic features.

Poaceae: *Poa annua* L.

N=28 Figure 14 b

A number of uncharred macrofossils were identified as the seed coat or 'testa' of annual meadowgrass (*Poa annua* L.) based on the placement and size of the hilum and the shape of the apex and embryo ends (Körber-Grohne, 1991). The hilum was prominent and rounded, the seed sharply tapered to the apex and the surface pattern of large, square fruit wall cells.

Poaceae: *Poa* cf. *trivialis* L.

N=108 Figure 14 c

A number of uncharred and charred macrofossils were identified as the seed coat or 'testa' of rough bluegrass, *Poa trivialis,* based on the placement and size of the hilum and shape of the apex and embryo ends following Körber-Grohne (1991). As not all relevant species could be excluded the identification was left as 'cf.'.

Poaceae: *Poa/Phleum*

N=13 Figure 14 g

A small number of uncharred macrofossils were identified as the seed coat or 'testa' of annual bluegrass (*Poa*) or *Phleum* based on the size, shape and hilum morphology (Körber-Grohne, 1991). Further identification was not possible. Counting followed the principle of MNI (1=1 seed).

Poaceae:

N=91 <2mm; n=132 >2 mm

Several uncharred and charred macrofossils were identified to the family Poaceae. For these seeds or seed coats further identification was not possible due to preservation, fragmentation or the rarity of these types. Macrofossils were split into two categories: one greater than 2 mm and one smaller than 2 mm.

Poaceae: *Aegilops* sp. n=3

N=3

A fragment of charred culm and a charred glume base was identified to Aegilops, based on comparison with reference material based on the thickness of the glumes and their obtuse angle. Identification to species was not attempted for these rare macrofossils as seven species of *Aegilops* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013).

Poaceae: *Avena* sp.

N=10 grains; n=5 lemma base; n=1 floret

A small number of uncharred and charred macrofossils were identified as oat (*Avena* sp.) chaff (floret base and lemma base) and grain. The floret base and the lemma base were identified as oat based on the size and shape of the florets, the disarticulation scars (Jacomet et al. 2006). One elongated grain was identified as oat, *Avena*. Different species of oat are challenging to distinguish in the archaeobotanical record (Jacomet et al. 2006) and so further identification was not attempted.

Poaceae: *Bromus* spp.

N=133

Uncharred seed coats ('testa') or charred seeds of brome (*Bromus* spp.) was commonly recovered from the archaeobotanical assemblage, alongside some charred seeds. The Körber-Grohne (1991) atlas was

used to identify grasses and permitted identification to *Bromus*. Seeds or seed coats were left unidentified to species based on preservation, fragmentation or the rarity of these types.

Poaceae: *Bromus sterilis* L.

N=31

Some uncharred and charred seed coats/seeds of brome were identified as sterile or barren brome (*Bromus sterilis* L.). These seeds were narrow and tapered to a point at the apex. The ventral groove/hilum extended to the apex (Körber-Grohne, 1991).

Poaceae: *Bromus tectorum* L.

N=58 Figure 14 e, f

Several uncharred and charred seed coats/seeds were identified as drooping brome (*Bromus tectorum* L.). Like *B. sterilis* L., these seeds were narrow with a pointed apex. However, they were distinguished from *B. sterilis* L. as the ventral groove/hilum did not extend to the apex (Körber-Grohne, 1991). Counting followed the principle of MNI (1=1 seed).

Poaceae: *Bromus sterilis* L./ *tectorum* L.

N=33

Some uncharred and charred seed coats/seeds of as a brome grass had a pointed apex. Further identification as sterile or barren brome (*Bromus sterilis* L.) or drooping brome (*Bromus tectorum* L.) was not possible due to preservation of diagnostic features (e.g. the ventral groove/hilum) (Körber-Grohne, 1991).

Poaceae: *Bromus arvensis* L.

N=4

A small number of uncharred seed coats/seeds were identified as field brome (*Bromus arvensis* L.) These seeds were relatively broad and had a blunt, rounded apex. The irregularly arranged apical fruit wall cells permitted an identification to *B. arvensis* L. (Körber-Grohne, 1991).

Poaceae: *Bromus hordeaceus* L.

N=7

A few uncharred seed coats were identified as soft brome, (*Bromus hordeaceus* L.). Like *B. arvensis* L. these seeds were relatively broad and had a blunt, rounded apex. The regular arrangement of the apical fruit wall cells permitted an identification to *B. hordeaceus* L. (Körber-Grohne, 1991).

Poaceae: *Bromus arvensis* L./*hordeaceus* L./*secalinus* L.

N=36 Figure 14 i, j

A few uncharred seed coats and charred seeds of brome grass were relatively broad and had a blunt apex. Further identification was not possible due to preservation, fragmentation or lack of visible surface pattern (Körber-Grohne, 1991).

Poaceae: Cerealia

N=1828 awn; n=7953 chaff; n=386 grain/embryo Figure 16 e, f

Many fragments of charred grains or uncharred and charred chaff were identified as relating to cereals but could not be identified further. The size and the morphology of the remains eliminated wild varieties. However, it was not possible to identify the remains to genus based on the preservation or the fragmentary nature of the macrofossils. For detached embryos, identification to genus is not possible. Each rachis segment and grain fragment were counted (1=1 rachis segment). Other cereal fragments (e.g. awns) were counted individually.

Poaceae: *Hordeum* sp. (wild)

N=5

A few uncharred rachis segments were identified as wild barley (*Hordeum* sp. wild). These were far smaller than the cultivated types. Further identification was not attempted. Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum distichon* L.

N=16

Some charred rachises of barley were identified as two-rowed. For this variety the middle spikelet is fertile while the two side spikelets are sterile (Jacomet et al. 2006). Criteria from Jacomet et al. (2006) and Charles et al. (2010; *in prep*) were used. In the archaeological macrofossils, rachis segments identified as two-row were narrow and parallel-sided in shape, slightly widening towards the top of the rachis, were more or less thin in side-view and appeared straight in cross-section. When present the remains of the glume bases on either side of the central grain were 'v-shaped', diverging from each other (Charles et al. 2010). Not all archaeological rachis segments showed all these characteristics due to preservation. For some macrofossils identification was less certain (signalled by cf.). Identification as hulled or naked barley was not possible for these rachis segments. Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum distichon* L., hulled

N=29 Figure 15 b

Some charred rachises of barley were identified as two-rowed and as hulled. Criteria from Jacomet et al. (2006) and Charles et al. (2010; *in prep*) were used. In addition to the relevant criteria for two-rowed barley (above), these rachis segments were also identified as hulled as they had an intact flat low 'pad' in the central floret attachment position, without any trace of adhering lemma/palea base tissue (the latter a characteristic of naked form, see below). For some macrofossils identification was less certain (signalled by cf.). Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum distichon* L., naked

N=56 Figure 15 a

Some charred rachises of barley were identified as two-rowed and as naked. Criteria from Jacomet et al. (2006) and Charles et al. (2010; *in prep*) were used. In addition to the relevant criteria for 2-rowed barley (above), these rachis segments were also identified as naked as they had raised or 'spikey' lemma/palea material emerging from the central floret attachment point. This material would adhere to the grain in the case of hulled barley, while basal material is retained in naked barley. For some macrofossils identification was less certain (signalled by cf.). Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum vulgare* L.

N=17

Some charred rachises of barley were identified as six-rowed. For this variety all three spikelets are fertile (Jacomet et al. 2006). Criteria from Jacomet et al. (2006) and Charles et al. (2010; *in prep*) were used. In the archaeological macrofossils, rachis segments identified as six-row were trapezoidal in shape, widening markedly towards the top of the rachis, were thicker towards the top in side-view and appeared curved in cross-section. The insertion points of the central grain's glume bases (when preserved) were 'u-shaped' diverging initially and then straightening above (Charles et al. 2010). Not all archaeological rachis segments showed all of these characteristics due to preservation. For some macrofossils identification was less certain (signalled by cf.). Identification as hulled or naked barley was not possible for these rachis segments. Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum vulgare* L., hulled

N=79 Figure 15 c

Some charred rachises of barley were identified as six-rowed and as hulled barley. Criteria from Jacomet et al. (2006) and Charles et al. (2010; *in prep*) were used. In addition to the criteria used to identify these rachis segments as six-row (above), these rachis segments were also identified as hulled as they had intact flat low pads in the central floret attachment position, without retaining any lemma/palea basal material. For some macrofossils identification was less certain (signalled by cf.). Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum vulgare* L., naked

N=53 Figure 15 d

Some charred rachises of barley were identified as six-rowed and as naked barley. Criteria from Jacomet et al. (2006) and Charles et al. (2010; *in prep*) were used. In addition to the criteria used to identify these rachis segments as six-row (above), these rachis segments were also identified as naked as they retained 'spikey' lemma/palea basal material emerging from the central floret attachment point. This material would have been removed in the case of hulled barley. For some macrofossils identification was less certain (signalled by cf.). Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Hordeum vulgare* L./*distichon* L.

N= 3984 rachis internodes; n= 34 grain Figure 16 a, d

Many charred and uncharred rachis fragments were not identified further than cultivated barley (*Hordeum vulgare/distichon*), based on the size of the rachis segments. Further identification for all of the uncharred rachis fragments was not attempted as these were distorted. Some partially charred and fully charred rachis segments could not be identified further due to preservation or a mismatch of criteria from both two- and six-row types and naked and hulled types. Some cereal grains were identified as cultivated barley based on the shallow ventral groove and biconvex form. Some grains had a pre-charring break ('bulgur'). Each rachis segment and grain were counted (1=1 rachis segment/1 grain).

Poaceae: *Hordeum vulgare* L./*distichon* L., hulled

N=1

Some charred cereal grains were identified as cultivated barley based on the shallow ventral groove and biconvex form. They also had angular facets suggesting the presence of strong hulls.

Poaceae: *Hordeum vulgare* L./*distichon* L., naked

N= 29

Some charred rachis fragments of cultivated barley (*Hordeum vulgare/distichon*) could not be identified to two- or six-row barley due to preservation. These rachis segments were identified as naked as they had raised or 'spikey' basal lemma/palea material emerging from the central floret attachment point (Charles et al. 2010). This material would have been adhered to the grain in the case of hulled barley. Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Phragmites australis* (Cav.) Trin. ex Steud.

N=35 seeds; n=242 culm fragments Figure 14 h

A number of uncharred seed coats 'testa' were identified as reed (*Phragmites australis* (Cav.) Trin. Ex Steud.). The hilum shape and positioning as well as the shape of the embryo and apex ends were particularly important for identification of *Phragmites australis* (Cav.) Trin. Ex Steud. Seeds (Körber-Grohne 1991). Uncharred and charred fragments of *Phragmites australis* (Cav.) Trin. Ex Steud. culm was identified based on the size, curvature and ridges, following comparison with modern reference material in the reference collection. Counting of seeds followed the principle of MNI (1=1 seed) and individual fragments of culm were counted due to the difficulties of estimating an MNI.

Poaceae: *Digitaria* sp.

N=38

A few uncharred specimens were identified to *Digitaria/Setaria*, based on comparison with modern reference material and images in the Körber-Grohne (1991) atlas. The seed coats/testa were ellipsoid/elliptical in shape with a prominent hilum. Further identification was not possible.

Poaceae: *Digitaria/Setaria*

n=3

A few uncharred macrofossils were identified to *Digitaria/Setaria*, based on comparison with modern reference material and images in the Körber-Grohne (1991) atlas. The seed coats/testa were ellipsoid/elliptical in shape with a prominent hilum. Further identification was not possible.

Poaceae: *Triticum aestivum* L.

N=82 Figure 16 c

Several uncharred and charred macrofossils were identified as the free-threshing wheat, bread wheat (*Triticum aestivum* L.). These rachis segments were distinguished from *Triticum durum* Desf. based on the curvature of the sides (with the maximum width in approximately in the middle of the rachis). The glume parts were smoothly broken off (Jacomet et al. 2006; Zohary et al 2012). Some identifications were less certain (signalled by cf.). Each rachis segment was counted (1=1 rachis segment).

Poaceae: *Triticum aestivum* L./ *durum* L.

N=94 rachis segments; n=1 grain Figure 16 i

Several charred and uncharred rachis segments were identified as free-threshing wheat, based on the shape of the rachis. Due to preservation, further identification to *Triticum aestivum* L. or *Triticum durum* Desf. was not possible. Some identifications were less certain (signalled by cf.). A single charred grain was identified as free-threshing wheat. This grain was oval in form and size (Jacomet et al. 2006). Each rachis segment was counted (1=1 rachis segment, 1=1 grain).

Poaceae: *Triticum dicoccum* Schrank

N=1573 glume bases/spikelet forks; n=8 grains Figure 15 f, i and Figure 16 b, h

Many fragments of charred cereal chaff were identified as the glume bases or spikelet forks of emmer (*Triticum dicoccum* Schrank.). For these the primarily keel (which is projected laterally in emmer) was particularly diagnostic, which formed a right angle in cross-section. The scar was narrower than the other glume wheats, with a clear gap on either side between the ends of the scar and the primary keel. The back of the rachis glume base was generally flat. In lateral view, the broad glumes had some veining (more than einkorn but less than Timopheev's wheat and spelt.) Some terminal glume bases and spikelet forks were identified (lacking a ventral scar) as emmer (einkorn terminal spikelet forks are too ephemeral, while Timopheev's spikelet forks have pronounced lateral veins on the glumes). Glume bases were counted individually. Spikelet forks were counted as two-glume bases.

Poaceae: *Triticum monococcum* L.

N=1805 glume bases/spikelet forks; n=38 grains Figure 15 h

Many fragments of charred cereal chaff were identified as einkorn (*Triticum monococcum* L.). For these the primarily keel was very prominent (projecting forward). The scar was wider than the other glume wheats and connected to the primary keel. The back of the rachis glume base was generally flat. In lateral view, the glumes were generally narrower than the other glume wheats and had very little veining. Glume bases were counted individually. Some grains were identified as einkorn. These were slim and slightly pointed at the ends. The ventrally side was compressed, and the dorsal side had a strong dorsal ridge. A few grains were identified as one-seeded grains. Two-sided grains have a comparatively flat ventral surface (Jacomet et al. 2006). Glume bases were counted individually. Spikelet forks were counted as two-glume bases.

Poaceae: *Triticum timopheevii* (Zhuk.) Zhuk.

N=235 Figure 16 g

Some of the charred glume wheat chaff were identified as Timopheev's wheat (*Triticum timopheevii* (Zhuk.) Zhuk.). For these the primarily keel was very prominent (projecting forward). The scar was wide relative to emmer and deep relative to einkorn. Like einkorn the primary keel was prominent and projecting abaxially and joined at the base to the scar. The secondary keel was very prominent and sharp with a strong vein or cable. The glume bases were generally wider like in emmer. The lateral face of the glume bases was prominently veined. Some terminal glume bases and spikelet forks (lacking a ventral scar) were identified as Timopheev's wheat (einkorn terminal spikelet forks are too ephemeral, while emmer terminal spikelet forks have less pronounced lateral veins on the glumes). Glume bases were counted individually. Spikelet forks were counted as two-glume bases.

Poaceae: *Triticum dicoccum/ timopheevii* (Zhuk.) Zhuk.

N=86

Some of the charred glume wheat chaff had characteristics of emmer and of Timopheev's wheat, such as veining on the lateral faces of the glumes. However, further identification was not possible, due to preservation or a mismatch of diagnostic features for both emmer and Timopheev's wheat. Glume bases were counted individually. Spikelet forks were counted as two-glume bases.

Poaceae: *Triticum monococcum L./ dicoccum* Schrank */timopheevii* (Zhuk.) Zhuk.

N=105534 chaff; n=7 grains Figure 15 e

All of the uncharred glume wheat chaff was not identified further as it was often distorted. Some of the partially charred and fully glume wheat chaff lacked the diagnostic features to enable identification to species. This chaff was left as einkorn/emmer/Timopheev's wheat. Some grains were identified to glume wheat. They had the general shape of glume wheats (dorsal ridge) and in some grains, the longitudinal impressions left by the glumes were identifiable. Some of these grains were identified as two-seeds based on their compressed shape. Glume bases were counted individually. Spikelet forks were counted as two-glume bases. Individual grains were counted.

Poaceae: *Triticum* spp.

N=53 chaff; n=65 grains

Some uncharred and charred rachis internodes were identified as wheat but identification to type or species was not possible. These resembled the shape of glume wheats and free-threshing wheats but lacked the diagnostic features necessary for further identification. Some grains were identified as *Triticum* having a deep ventral groove. Due to preservation, they could not be identified further. Glume bases were counted individually. Spikelet forks were counted as two-glume bases. Individual grains were counted.

Poaceae: *Triticum spelta* L.

N=12 Figure 16 a

Some charred cereal chaff was identified as the glume bases of spelt wheat (*Triticum spelta* L.). This was based on the width of the glume bases and the continuous curve of the glumes in cross-section (Jacomet et al. 2006). Some of these identifications were less clear (signalled by a cf.). Glume bases were counted individually.

Polygonaceae:

N=42

A number of uncharred macrofossils were identified to the family Polygonaceae, based on the trigonous shape of the seeds and surface pattern. However, due to preservation or fragmentation, further identification was not possible.

Polygonaceae: *Fallopia convolvulus* (L.) Á.Löve

N=418 Figure 17 b

One of the most frequent taxa recovered, black-bindweed (*Fallopia convolvulus* (L.) Á.Löve), was identified based on the size of the large, broadly symmetrical, trigonous, uncharred and charred seeds. The minute punctate surface of these black seeds was also diagnostic. Part of the perianth sometimes persisted at the hilum. The seeds matched those in the reference collection at the Archaeobotany Lab, School of Archaeology (Oxford) and images/descriptions in Bojňanský and Fargašová, (2007) and Cappers et al. (2012).

Polygonaceae: *Persicaria lapathifolia* (L.) Delarbre

N=1 Figure 17 a

A single charred macrofossil was identified as pale persicaria (*Persicaria lapathifolia* (L.) Delarbre). This dark-brown/black seed was flattened, elliptic in shape with an abruptly pointed apex. The faces were slightly concave in cross-section. The macrofossil fitted well with the modern material in reference collection and images/descriptions in the Bojňanský and Fargašová (2007) and Cappers et al. (2012).

Polygonaceae: *Polygonum aviculare* L.

N=148

Many uncharred and a few charred macrofossils were identified as common knotgrass (*Polygonum aviculare* L.) based on the trigonous shape of the dark-brown/black seeds which has a triangular cross-section. The apex was pointed. The asymmetry of the two faces on the ventral side giving the appearance of a slight twist was particularly diagnostic. The seeds compared well to material in the reference collection and images/descriptions in Bojňanský and Fargašová 2007) and Cappers et al. (2012).

Polygonaceae: *Polygonum* sp.

N=2

A small number of uncharred macrofossils were identified as knotweed (*Polygonum*), based on the size and trigonous shape of the seeds and surface pattern. Eleven *Polygonum* species are present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). However, due to preservation or fragmentation, further identification was not possible.

Potamogetonaceae: *Potamogeton* sp.

N=8 Figure 17 d

A small number of uncharred macrofossils were identified as the pondweed, *Potamogeton*. These seeds were laterally flattened, sub-spherical with a short, thin, pointed apex. There was a strong ridge separating the ventral and dorsal faces. These pale yellow-ish macrofossils were lustreless with subtle surface pattern. They compared well to the *Potamogeton* species present in the reference collection and images/descriptions in Bojňanský and Fargašová (2007). Eight species of *Potamogeton* occur in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). With sufficient comparative material, further identification to species is probable.

Polygonaceeae: *Rumex* cf. *acetosella* L.

N=12 Figure 17 f

A small number of uncharred macrofossils were identified as the red sorrel/sheep's sorrel (*Rumex* cf. *acetosella*). These small dark brown seeds were rhombic (trigonous and similar in length, width and depth) with slightly concave sides. Twenty-two species of *Rumex* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The macrofossils compared well with modern material in the reference collection and publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012), but not all species could be confidently excluded, leading to the identification as *R.* cf. *acetosella* L.

Polygonaceae: *Rumex* sp.

N=3 seeds; n=4 perianths Figure 17 c

A few uncharred seeds were identified to the genus *Rumex* due to their trigonous shape, size and surface patterning. Further identification was not made due to preservation or a lack of diagnostic features to permit a species-level identification, given twenty-two species of *Rumex* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). A few uncharred perianths (protective coat of the seed) of *Rumex* were also recovered. These perianths compared well with *Rumex sanguineus* L., but other species could not be eliminated. *R. acetosella* L. (of which seeds were recovered) was not a good match. These were well preserved and with sufficient comparative material an identification should be possible.

Primulaceae: *Lysimachia arvensis* (L.) U.Manns et Anderb.

N=7 Figure 17 e

Rare uncharred and charred macrofossils were identified as the seeds of scarlet pimpernel (*Lysimachia arvensis* (L.) U.Manns et Anderb. syn. *Anagalis arvensis* L.) following comparison with the reference material and publications by Bojňanský and Fargašová (2007) and Cappers et al. (2012). These angular seeds were ellipsoid in shape with a flat dorsal surface and two ventral sides, excluding the alternative viable species (*Anagallis foemina* Mill.).

Ranunculaceae: *Adonis annua* L./*flammea* Jacq.

N=1

One incomplete charred macrofossil was identified as *Adonis* annua L./flammea Jacq., using reference material and publications by Bojňanský and Fargašová (2007) and Cappers et al. (2012). The seeds/achenes were slightly wrinkled with a slight curved beak at the apex. *Adonis annua* L. and *flammea* Jacq. are the only two species of *Adonis* present in the North Pindos and/or North Central regions of Greece (Dimopoulos et al. 2013).

Ranunculaceae: *Ranunculus* spp.

N=52

Some uncharred macrofossils were identified as the seed/achene of buttercup (*Ranunculus*). These varied in shape from spherical to ellipsoidal and colour from pale yellow to dark brown. They were laterally flattened with varied sculpting and surface patterning. They resembled modern reference material. Twenty-one species of *Ranunculus* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Future work could enable identifications to species with sufficient comparative material. Identification was left as multiple species (signalled by the spp.) of *Ranunculus.*

Rosaceae:

N=5

A small number of uncharred macrofossils were identified to the Rose family (Rosaceae), based on the seed thickness, shape and the internal surface with faint latitudinal lines. Due to preservation or fragmentation further identification was not possible.

Rosaceae: *Agrimonia eupatoria* L.

N=8 Figure 17 g

Some uncharred and charred fragments of the exocarp/capsule of common agrimony, *Agrimonia eupatoria* L., were identified based upon comparison to the reference material and publications by the Bojňanský and Fargašová (2007) and Cappers et al. (2012). These had pronounced shallow grooves running vertically and some short hairs or bristles were preserved (Bojňanský and Fargašová, 2007). The exocarp shape differed from the other viable *Agrimonia* species (*A. procera*) which has a shorter and more acute exocarp. MNI counts were estimated based on the number, size and shape of exocarp fragments in each sample.

Rosaceae: *Alchemilla/Aphanes* spp.

N=185 Figure 18 b

Twenty species of *Alchemilla* and two *Aphanes* are present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The archaeological uncharred seeds were small, relatively laterally flat, with an acute apex and an obtuse base with an asymmetrical hilum. They compared well with *Aphanes arvensis* L. from the reference material. However, reference material and descriptions in atlases were insufficient to eliminate identification to the morphologically and genetically close genus *Alchemilla*. The remains varied somewhat in size and so it is possible that multiple species(/genera) were also present.

Rosaceae: *Crataegus* sp.

N=6

A few uncharred macrofossils were identified as hawthorn (*Crataegus*) seeds/stones based on the size, shape and surface pattern of the seeds. The ellipsoid seeds were lustreless with indistinct furrows and one more pronounced suture. The internal surface of the stones was characteristic for the Rosaceae family with a slightly lustrous surface with faint latitudinal lines. The stones matched well with that of *Crataegus monogyna* Jacq. from the reference collection. Three additional species are known from the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Sufficient comparative resources were not available for these taxa, further identification was not made.

Rosaceae: *Filipendula vulgaris* Moench.

N=17

A few uncharred macrofossils were identified as dropwort or fern-leaf dropwort (*Filipendula vulgaris* Moench.). These seeds were ellipsoid in shape, flattened and sharply drawing to a peak. The macrofossils matched those in the reference collection and images/descriptions in the Bojňanský and Fargašová, (2007) and Cappers et al. (2012). Another species of *Filipendula* is known to grow in the

North Pindos and North Central regions of Greece (*Filipendula ulmaria* (L.) Maxim.; Dimopoulos et al. 2013), but the shape of these fruits was significantly different.

Rosaceae: *Fragaria vesca* L.

N=3008 Figure 18 c

A large number of uncharred (and a few charred) remains were identified as strawberry (*Fragaria vesca* L.), this was based on the size, shape and surface of the seeds. The seeds were flattened, ovoid in shape, with a rounded apex. The hilum was asymmetrically placed to the side of the base of the achenes. Clear veining can be seen on the surface extending from the hilum. The shape differed from *Potentilla* and *Fragaria viridis* Weston (the only other *Fragaria* species known in the regions of the North Pindos and North Central; Dimopoulos et al. 2013) with a hook at the rounded apex.

Rosaceae: *Fragaria/Potentilla*

N=15

A few uncharred macrofossils were poorly preserved or irregularly shaped and so were identified as *Fragaria/Potentilla.*

Rosaceae: Maloideae:

N=176 seed; n=45 calyces; n=232 inner seed tissue; n=60 endocarp

Several uncharred (and a few charred) seeds were identified as apple, pear or rowan (*Malus, Pyrus* or *Sorbus*) known collectively as Maloideae. These were dark-brown/black in colour with a thick woody seed coat, with longitudinal lines. Due to preservation and fragmentation some seeds identified as Maloideae could not be identified further. Some large, robust calyces of Maloideae were also identified. These had approximately 4-6 cavities in the centre and had a large mass of adhered stone cells. These most likely were *Pyrus* or *Sorbus* as these genera have large numbers of stone cells. Loose stone cells were recorded semi-quantitively. Some tissues were identified as the inner seed tissue of

Maloideae as well as the endocarp of Maloideae. These were challenging to distinguish. The inner seed coat was generally thinner and had a dark 'fingerprint' like fine pattern on one side. These fragments also mimicked the shape of seeds. Some of this tissue came directly out of the archaeological Maloideae seeds, leading to this identification. The endocarp of Maloideae was thicker, with a more plastic-y appearance, it also had wavy lines which resembled fingerprints, however, lacked the dark-brown patterning. The Maloideae seeds, tissues and calyces compared well with reference material. For the tissues, a MNI of seed were estimated from the fragments of inner seed coat. The endocarp fragments were counted using a size-guide of 12 mm^2.

Rosaceae: *Malus* sp.

N=62 Figure 18 e

Some of the uncharred Maloideae seeds were identified to *Malus* following comparison with reference material, based on the surface pattern of the seeds. These macrofossils had numerous thin, short striation on the seed coat. Unlike those identified as *Pyrus/Sorbus*, they did not have impressions of stone cells. These seeds tended to be larger and broader than those identified as *Pyrus/Sorbus*.

Rosaceae: *Potentilla* sp.

N=1

A single uncharred macrofossil was identified as cinquefoil (*Potentilla*) due to the size, shape and surface of the seeds/achenes. This macrofossil was smaller than those identified as *Fragaria vesca* L. Due to the rarity of the type and the number of *Potentilla* species (n=17) present in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013), further identification was not attempted.

Rosaceae: *Prunus amygdalus* Batsch

N=495 fragments and 1 whole seed Figure 18 g

Many uncharred (and a few charred) nutshell fragments were identified as wild almond (*Prunus amygdalus* Batsch, formerly *Amygdalus communis* L.) based on the nutshell size, cross-section thickness with irregularly positioned vessel cavities, and characteristic pitted and grooved surface. Identification followed comparison with the reference material and publications by the Bojňanský and Fargašová (2007) and Cappers et al. (2012). The nutshell fragments were counted using a size threshold of 25 mm^2, following methodology used by the IPAS at the University of Basel. The was approximately one eight of a nutshell. In cases, where a quarter, half or whole nutshell was present this was counted accordingly. This enables an estimate of whole nutshells in each sample, by dividing the number of fragments by eight.

Rosaceae: *Prunus* cf. *spinosa* L.

N=11 Figure 18 f

A small number of uncharred macrofossils were identified as blackthorn or sloe (*Prunus spinosa* L.) These seeds/stones were broad, sub-circular and laterally flattened. A suture ran down one side (however, this was not clear due to the presence of a dark outer tissue). The internal surface matched other members of the Rosaceae family with a slightly lustrous surface with faint latitudinal lines. Eight species of *Prunus* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Several were eliminated by comparison with material from the reference collection and images/descriptions in Bojňanský and Fargašová (2007). Sufficient comparative material was not available to exclude *P. cocomilia* Ten. *P. prostrata* Labill. And *P. webbii* (Spach) Vierh. However, given the similarity between *P. spinosa* L. and the macrofossils the identification was made, signalled as tentative with a cf.

Rosaceae: *Pyrus/Sorbus* sp.

N=29 Figure 18 d

Some of the uncharred Maloideae seeds were identified to *Pyrus* or *Sorbus* following comparison with reference material, based on the surface pattern of the seeds. These macrofossils had a fine areolate surface pattern, without the numerous fine striations of *Malus*. They also had impressions of stone cells. These seeds tended to be smaller and more elongated than those identified as *Malus*.

Rosaceae: *Rosa* spp.

N=298 Figure 17 h

A number of uncharred macrofossils were identified as rosehip (*Rosa*) based on the size and shape of these irregular angular seeds/achenes. These macrofossils varied in size significantly and so it was likely multiple species were present (signalled by the spp.). The macrofossils were yellow brown in colour with a clear suture and a smooth, slightly lustrous surface. Some macrofossils had a faint netted patterning. These macrofossils compared well with specimens of *Rosa* in the reference collection. Sixteen species of *Rosa* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The internal surface of the thick seeds was particularly characteristic for the Rosaceae family with a slightly lustrous surface with faint latitudinal lines. Future work could enable identifications to species with sufficient comparative material.

Rosaceae: *Rubus* sp.

N=241

Relative to *Rubus fruticosus* agg., a small number of uncharred macrofossils were identified to the genus *Rubus* but no further. This was due to fragmentation and preservation inhibiting the identification of diagnostic features.

Rosaceae: *Rubus fruticosus* agg.

N=22,045 Figure 18 a

A very large number of uncharred (and some charred) macrofossils were identified as blackberry (*Rubus fruticosus* agg.). Due to the morphological and genetic similarity of a number of *Rubus* species, *Rubus fruticosus* agg. is a common aggregate group. These seeds were ovoid and slightly laterally compressed. The surface was strongly and irregularly reticulate, and a clear suture ran to one side that widened into a hilum. The seeds were yellow-brown. These seeds were distinguished from *Rubus idaeus* L. based on the size, shape, robustness and prominence of the surface patterning. They compared well with modern material in the reference collection and publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012).

Rosaceae: *Rubus idaeus* L.

N=247

Compared to *Rubus fruticosus* agg., a small number of uncharred macrofossils were identified as raspberry (*Rubus idaeus* L.). Like *R. fruticosus* agg. these light brown seeds were ovoid and laterally compressed with a reticulate surface, and a suture. However, the surface patterning and sutures were less pronounced than *R. fruticosus* agg. The seeds were generally more laterally compressed and elongated. Most diagnostically, these seeds had a slight hook at the apex. They compared well with modern material in the reference collection and publications (Bojňanský and Fargašová, 2007; Cappers et al. 2012).

Rosaceae: *Sanguisorba minor* Scop.

N=2 Figure 17 i

A couple of complete macrofossils (one charred and one uncharred) were identified as salad burnet or pimpernelle (*Sanguisorba minor* Scop.). The pale-brown robust exocarps were slightly asymmetrically ovoid with four faces. Each face had a smooth margined and a coarse rugose surface in between. *Sanguisorba minor* Scop. was a much closer match than the two other *Sanguisorba* species (*S. verrucosa* (G. Don) Ces. and *S. officinalis* L.) known to grow in the North Pindos and North Central

regions of Greece (Dimopoulos et al. 2013), based on modern material in the reference collection and images/descriptions in the Bojňanský and Fargašová (2007) and Cappers et al. (2012).

Rubiaceae: *Galium* spp.

N=19

Many fragments of uncharred tissue were identified as the seed coat of bedstraw (*Galium* spp.). Due to preservation or fragmentation further identification was not possible.

Rubiaceae: *Galium aparine* L.

N=30

Some uncharred macrofossils were identified as cleavers (*Galium aparine* L.). At times the outer tissues were whole giving an indication of the size and shape of the seed-like fruits. The outer hooked coating of the dispersule was missing. The seed-like fruits were oval with a cavity on the ventral side. The size and the elongated netted surface pattern permitted identification to species. The macrofossils compared well with modern material in the reference collection.

Rubiaceae: *Galium spurium* L.

N=154

Some uncharred and charred macrofossils were identified as false cleavers (*Galium spurium* L.). At times the outer tissues were whole giving an indication of the size and shape of the seed-like fruits. The outer hooked coating of the dispersule was missing. The seed-like fruits were oval with a cavity on the ventral side. The size and the round-square netted surface pattern permitted identification to species. The macrofossils compared well with modern material in the reference collection.

Sapindaceae: cf. *Acer* sp. n=50

N=50 Figure 19 a

Some uncharred and charred macrofossils were identified as the seeds of maples (*Acer*). These seeds were often poorly preserved and fragmented. They have a flattened, sub-circular shape with a long, thin hilum to the side. The seed was very wrinkled. Eight species of *Acer* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Comparison with modern *Acer* seeds in the reference collection was inconclusive. However, they remained the closest match and so the identification was made tentatively (signalled by a cf.).

Solanaceae:

N=3

A small number of uncharred macrofossils were identified to the nightshade family (Solanaceae), based on the seed thickness, shape and the surface pattern. Due to preservation or fragmentation further identification was not possible.

Solanaceae: *Alkekengi officinarum* Moench

N=25

Several uncharred seeds were identified physalis (*Alkekengi officinarum* Moench syn. *Physalis alkekengi*). These yellow flattened reniform seeds had a clear reticulate surface pattern. The seeds were larger than many other members of the Solanaceae family (e.g. *Hyoscyamus* and *Atropa*, Bogaard, 2010). No other species of *Alkekengi* or *Physalis* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). They compared very well to modern specimens from the reference collection.

Scrophulariaceae: *Verbascum* spp.

N=402 Figure 19 b

A large number of uncharred (and a few charred) macrofossils were identified as the seeds of mullein, *Verbascum*. These irregular seeds were obovoid with a strongly furrowed surface and rows of pits.

They varied somewhat in size and shape suggesting the presence of multiple species. Thirty-two species of *Verbascum* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The seeds compared well with modern material in the reference collection. Further identification was not attempted, due to a lack of sufficient comparative material and the morphological similarity of these species.

Typhaceae: *Typha* sp.

N=2

A couple of uncharred macrofossils were identified as the seeds of bulrush, *Typha*. These yellow-brown lustrous macrofossils were elongated ellipsoidal, with a long apex and darkened base. The macrofossils compared well with the modern material in reference collection and descriptions/images in Bojňanský and Fargašová (2007) and Cappers et al. (2012). Five species of *Typha* are known in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The macrofossils compared particularly well with images of *T. shuttleworthii* W.D.J. Koch et Sonder (Bojňanský and Fargašová, 2007). However, as there was insufficient comparative material to exclude all the other relevant species and given the small number of macrofossils, further identification was not made.

Urticaceae: *Urtica dioica* L.

N=141 Figure 19 c

A number of uncharred (and one charred) macrofossils were identified as the seeds of the common nettle, *Urtica dioica* L. These seeds/achenes were ellipsoid and flattish with a clear, slightly transparent margin. The seed tapered to the apex and to the base. Three species of *Urtica* are known to occur in the North Pindos and North Central regions of Greece (*U. dioica* L., *U. pilulifera* L. and *U. urens* L.; Dimopoulos et al. 2013). An identification was made to *U. dioica* L. based on the shape and size of the seeds after comparison with modern material in the reference collection.

Verbenaceae: *Verbena officinalis* L.

N=69 Figure 19 d

A number of uncharred seeds were identified as common vervain, *Verbena officinalis* L. These distinctive seeds were elongated fusiform in shape. One surface (dorsal) showed long striations and a netted pattern in a deep purple, while the other (ventral) was pale grey-brown. These seeds were invariably recovered whole. No other species of *Verbena* occur in the North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). The seeds compared well with modern material in the reference collection and images/descriptions in Bojňanský and Fargašová (2007).

Viburnaceae: *Sambucus* spp.

N=78

A number of uncharred macrofossils were identified as the seeds of elder (*Sambucus* spp.). These orange-brown seeds were obovoid to ellipsoid in shale with a rounded dorsal side and a slight angle on the ventral side. The hilum was small to the apex of the seed. The seed was hard, lustrous and slightly transparent, with a transversally furrowed surface (Bojňanský and Fargašová, 2007). Two species of *Sambucus* are known in the North Pindos and North Central regions of Greece – the broader and more obovoid *S. ebulus* L. and the narrower and more ellipsoidal *S. nigra* L (Dimopoulos et al. 2013). Comparison with accessions in the reference collection showed a lot of intra-species diversity. Some identifications of whole macrofossils were tentatively (signalled by cf.) made to species. However, many were left unidentified displaying features that were intermediate between the two species.

Viburnaceae: *Sambucus* cf. *nigra* L.

N= 25 Figure 19 f

Some of the *Sambucus* seeds were identified as *S. nigra* L. based on their thin, elongated shape. However, as comparison with accessions in the reference collection showed a lot of intra-species diversity, this identification was made tentatively (signalled by cf.).

Viburnaceae: *Sambucus* cf. *ebulus* L.

N= 8 Figure 19 e

Some of the *Sambucus* seeds were identified as *S. ebulus* L. based on their broad, oval shape. However, as comparison with accessions in the reference collection showed a lot of intra-species diversity, this identification was made tentatively (signalled by cf.).

Violaceae: *Viola* sp.

N=41 capsule fragments; n=34 small type; n=2 large type

A number of macrofossils were identified as violet, *Viola.* Capsule fragments were particularly distinctive being orange in colour with a broad 'M' shaped cross-section. Seeds were tear-drop shaped with a line running longitudinally from the apex to the base. Thirty-three species of *Viola* are known in North Pindos and North Central regions of Greece (Dimopoulos et al. 2013). Based on the preservation of the remains and the similarity between many *Viola* species, further identification was not attempted. Seeds were split into two types (large and small). The large seeds resembled *Viola alba* in the Maier (2001). However, insufficient reference material was accessible to exclude other species.

Vitaceae: *Vitis vinifera* subsp. *sylvestris*

N=226 seeds; n=4 pedicels Figure 19 g

A large number of macrofossils were identified as the seeds or pips wild grape *Vitis vinifera* subsp. *sylvestris*. These robust seeds were subglobose with a short apex and rounded base. The ventral face has two deep furrows creating a central rib. The cross-section of the seed wall had faint lateral lines. Many seeds were recovered whole. The size and shape of the seed, particularly the apex, led to the

identification as *Vitis vinifera* subsp. *sylvestris*. For the Late Neolithic, this is the expected form of *Vitis*. A few pedicels were identified as *Vitis* based on their size and presence of growths.

Vitaceae: *Vitis vinifera*

N=3 Figure 19 h

A few of the later Bronze Age *Vitis* pips were more pyriform in shape with an elongated apex and blunt base. These could be identified to another variety of *Vitis vinifera*.

Indeterminate bulb

N=11

A few charred specimens appeared to be fragments of bulb due to their size, density and presence of layers. The fragmentary state or poor preservation of these rare macrofossils inhibited further identification. Counting followed the principle of MNI (1=1 bulb), but it is hard to estimate the overall size of the bulb without further identification.

Indeterminate capsule

N=69

Some uncharred and charred specimens appeared to be fragments of capsules. They were hollow and appeared to have the capacity to hold seeds. Many types were included in this category. Further identification was attempted. These macrofossils did not match well with the capsules (available for comparison in the reference collection) of common seeds. Counting followed the principle of MNI (1=1 capsule), but it is hard to estimate the overall size of the capsule without further identification.

Indeterminate cupule fragment

N=262

This relatively common macrofossils type was consistent and likely all relates to the same taxa. They are flattened disks with a pedicel, or an attachment point and are woody. They are similar to acorn (*Quercus*) cupules but were not a sufficient to enable identification. Counting followed the principle of MNI (1=1 cupule), but it is hard to estimate the overall size of the cupule without further identification.

Indeterminate flower fragment

N=67

Several macrofossils were identified as fragments of flowers. A few types were included in this category, including a red, veined type and a yellow, soft type. Further work could permit the identification of some of these macrofossils. Counting followed the principle of MNI (1=1 flower), but it is hard to estimate the overall size of the flower without further identification.

Indeterminate fruit flesh

N=8

Some uncharred and charred macrofossils were identified as fragments of fruit flesh. This type resembled the fruit flesh identified as *Juniperus*, but further identification was not made due to preservation. Counting followed the principle of MNI (1=1 fruit), but it is hard to estimate the overall size of the fruit without further identification.

Indeterminate fruit skin/tissue

N=8

Some uncharred and charred macrofossils were identified as fragments of fruit skin/tissue. These fragments were generally thicker than other tissues. Counting followed the principle of MNI (1=1 fruit), but it is hard to estimate the overall size of the fruit without further identification.

Indeterminate "lichen"

N=1002

Some uncharred and charred macrofossils were tentatively identified as fragments of lichen. This common category was clearly one type (likely one taxa) of tissues with numerous spongey prickles/hairs. One fragment had layers of tissue with spongey growths/prickles/hairs in between the layers. The outer surface of *Galium* fruits was considered but excluded. Individual fragments were counted as it is hard to estimate the overall size without further identification.

Indeterminate nut kernel

N=3

A small number of charred macrofossils were identified as nut kernel due to their relatively large size, smooth shape and dense matrix. Further identification as not attempted. Counting followed the principle of MNI (1=1 kernel).

Indeterminate nutshell

N=4

A small number of charred macrofossils were identified as nutshell due to their relatively large size with a thin cross-section. *Pistacia, Amygdalus, Corylus* and *Quercus* are all possible identifications. Further identification as not attempted due to the poor preservation. Individual fragments were counted.

Indeterminate pedicel

N=32

Some uncharred and charred macrofossils were identified as pedicels. They did not have the characteristic bumpy irregular appearance of *Vitis* pedicels. It is likely that multiple taxa are present here as there is a range of sizes. Further identification was not attempted. Individual pedicels were counted.

Indeterminate pod

N=2

A couple of fragments of charred tissue appeared to be pods. They resembled the pods of Fabaceae but identification was not certain due to preservation. Individual pod fragments were counted.

Indeterminate seed coat

N=6

A few fragments of charred seed coat were identified. Further identification of these macrofossils was not possible due to fragmentation. Counting followed the principle of MNI (1=1 coat).

Indeterminate seed/fruit

N=291

Several charred and uncharred macrofossils resembled seeds or fruits. Many taxa/types are included in this category. For some macrofossils identification was attempted but was unsuccessful. For many macrofossils, further identification was not made due to preservation, fragmentation, or the rarity of types. Counting followed the principle of MNI (1=1 seed/fruit).

Indeterminate seed/fruit/bulb

N=11

Some charred macrofossils resembled seeds, fruits or bulbs. For this further identification was not possible due to preservation and fragmentation. Individual fragments were counted.

Indeterminate herbaceous stem

N=33

Some charred herbaceous stems were counted and possibly relates to taxa of interest. Further identification is possible. Individual herbaceous stems were counted.

Note: Unless otherwise stated all images are of uncharred seeds.



Figure 5: a. Alisma sp.; b. Chenopodium album L. group; c. Atriplex sp.; d. Polycnemum arvense L.; e. Pistacia terebinthus L. (nutshell); f. cf. Daucus sp.; g. Bifora cf. radians M.Bieb; h. Coriandrum sativum L. (partially charred/'browned'). All scale bars are 1 mm.



Figure 6: a. Carduus/Cirsium; b. Glebionis segetum Fourr.; c. Lapsana communis L.; d. Tordylium maximum L.; e. Carthamus lanatus L./dentatus (Forssk.) Vahl; f. Sonchus cf. oleraceus L.; g. Taraxacum sp. All scale bars are 1 mm.



CataFigure 7: a. Alnus glutinosa (L.) Gaertn.; b. Heliotropium europaeum L.; c. Capsella bursa-pastoris Medik.; d. Thlaspi arvense L.; e. Alnus glutinosa (L.) Gaertn.; f. Camelina microcarpa Andrz. ex DC.; g. cf. Neslia paniculata (L.) Desv.; h.-i. Corylus avellana L. All scale bars are 1 mm.



Figure 8: a. Campanula sp.; b. Valeriana coronata (L.) Mill.; c. Valeriana dentata (L.) All.; d. Scleranthus annuus L.; e. Stellaria media (L.) Vill.; f. Arenaria serpyllifolia L.; g. Petrorhagia sp.; h. Silene sp.; i. Silene sp. (capsule fragment, charred); j. Silene sp. (capsule fragment, uncharred). All scale bars are 1 mm.



Figure 9: a. Chara sp.; b. Cuscuta sp.; c. Juniperus cf. communis L.; d. Juniperus cf. oxycedrus L.; e. Cornus mas L.; f. Juniperus sp. (not communis or oxycedrus) g. Carex sp.; h. Euphorbia helioscopia L. (charred). All scale bars are 1 mm.



Figure 10: a. Fabaceae (small, charred); b. Medicago sp. (pod); c. Fabaceae (large, pod); d. Vicia ervilia (L.) Willd. (charred); e. cf. Pisum sativum L. (charred); f. Lens culinaris Medik. (charred); g. Vicia ervilia (L.) Willd. (detached hilum, charred); h. cf. Pisum sativum L. (detached hilum, charred); i. Lens culinaris Medik. (detached hilum, charred). All scale bars are 1 mm.



Figure 11: a. Trifolium sp. (flower); b. Quercus sp. (nutshell base); c. Hypericum perforatum L.; d. Mentha longifolia L.; e. Mentha aquatica L.; f. Origanum vulgare L.; g. Linum usitatissimum L.; h. L. usitatissimum L. (capsule fragment); i. Ajuga chamaepitys (L.) Schreb. All scale bars are 1 mm.



Figure 12: Figure 8: a. Malva cf. sylvestris L. (mericarp); b. Malvaceae; c. Ficus carica L.; d. Tilia cf. platyphyllos Scop. (exocarp); e. Papaver sp. (capsule); f. Fumaria officinalis L.; g.-h. Papaver somniferum L. (later Bronze Age seed, Late Neolithic seed). All scale bars are 1 mm.



Figure 13: a. Abies alba L. (needle), b. Pinus sp. (needle), c. Pinus sp. (cone scale, charred). All scale bars are 1 mm.



Figure 14: a. Plantago sp. (charred); b. Poa annua L.; c. P. cf. trivalis L., d. Poa sp. (charred), e. Bromus tectorum L., f. B. tectorum L. (charred); g. Poa/Phleum; h. Phragmites communis (Cav.) Trin. ex Steud.; i. Bromus arvensis L./hordeaceus L./secalinus L.; j. Bromus arvensis L./hordeaceus L./secalinus L. (charred). All scale bars are 1 mm.



Figure 15: a. Hordeum distichon L. (naked, rachis, charred); b. H. distichon L. (hulled, rachis, charred); c. H. vulgare L. (hulled, rachis, charred); d. H. vulgare L. (naked, rachis, charred); e. T. monococcum/dicoccum/timopheevii (spikelet fork); f. T. dicoccum Schrank (spikelet fork, 'browned'); g. T. timopheevii (Zhuk.) Zhuk. (spikelet fork, charred); h. T. monococcum L. (spikelet fork, charred); i. T. dicoccum Shrank (spikelet fork, charred). All scale bars are 1 mm.



Figure 16: a. Triticum spelta L. (glume base, charred); b. Triticum dicoccum Schrank. (terminal spikelet fork, charred); c. Triticum aestivum L. (two rachis segments, charred); d. Hordeum vulgare/distichon (bulgur, charred); e. straight, barbed awn (charred); f. twisted awn (charred); g. Hordeum vulgare/distichon (charred), h. Triticum dicoccum Schrank. (grain), i. Triticum aestivum/durum (charred). All scale bars are 1 mm.

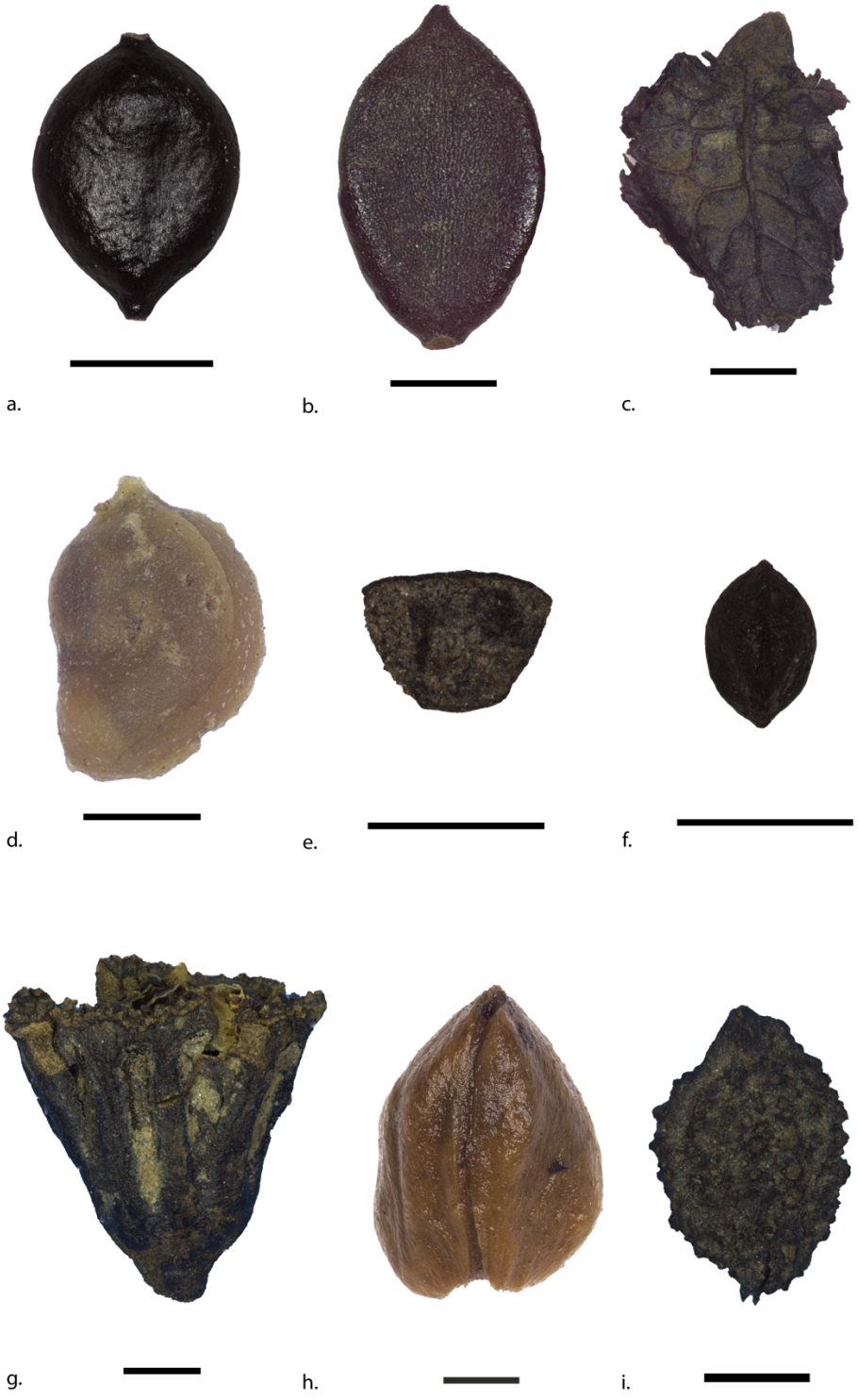


Figure 17: a. Persicaria lapathifolia (L.) Delarbre (charred); b. Fallopia convolvulus (L.) Á.Löve; c. Rumex sp. (perianth); d. Potamogeton sp.; e. Lysimachia arvensis (L.) U.Manns & Anderb. (charred); f. Rumex cf. acetosella L. (charred); g. Agrimonia eupatoria L. (exocarp); h. Rosa sp.; i. Sanguisorba minor Scop. (exocarp, charred). All scale bars are 1 mm.

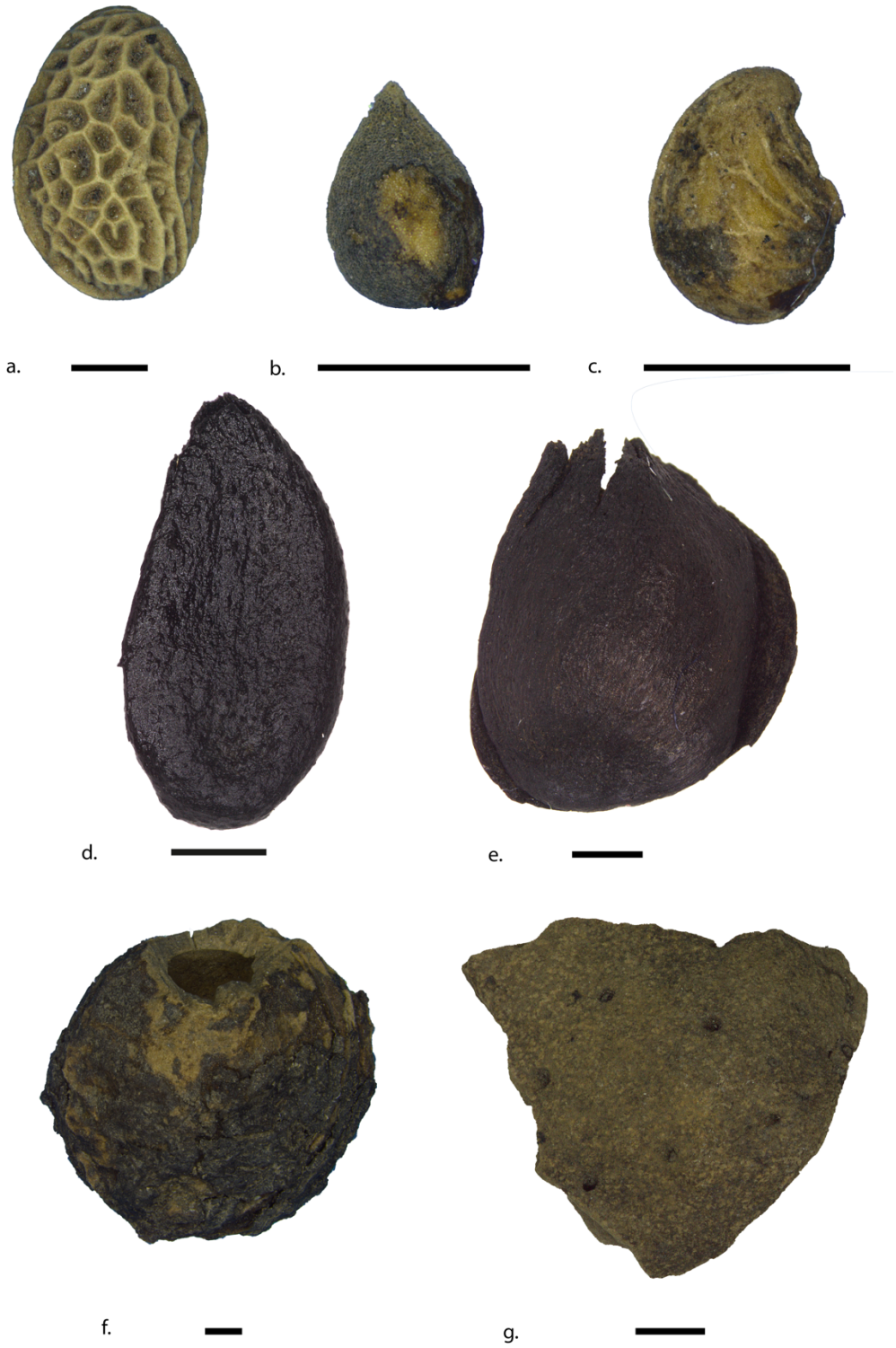


Figure 18: a. Rubus fruticosus agg.; b. Aphanes/Alchemilla sp.; c. Fragaria vesca L.; d. Pyrus/Sorbus; e. Malus sp.; f. Prunus spinosa L.; g. Prunus amygdalus Batsch. All scale bars are 1 mm.



Figure 19: a. cf. Acer sp.; b. Verbascum sp. (charred); c. Urtica dioica L. (charred); d. Verbena officinalis L.; e. Sambucus cf. ebulus; f. Sambucus cf. nigra; g. Vitis vinifera subsp. sylvestris (Willd.) Hegi (browned); h. Vitis vinifera (later Bronze Age). All scale bars are 1 mm.

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7.0 Appendix 3: Publication of preliminary results

The following paper presenting the preliminary archaeobotanical results from one of the cores has been accepted for publication.

Holguin, A., Antolín, F., Charles, M., Jesus, A., Martínez Grau, H., Soteras, R., Steiner, B.L., Stroud, S. and Bogaard, A. (*in press*). Archaeobotanical investigations at the mid-5th millennium BCE pile-dwelling site of Ploča, Mičov Grad, Lake Ohrid, North Macedonia. In Ballmer, A., Hafner, A. and Tinner, W. (eds.). Prehistoric Wetland Sites of Southern Europe. Archaeology, Chronology, Palaeoecology and Bioarchaeology. (Natural Science in Archaeology). Cham: Springer International Publishing.

ARCHAEOBOTANICAL INVESTIGATIONS AT THE MID-5TH MILLENNIUM BCE PILE-DWELLING SITE OF PLOČA, MIČOV GRAD, LAKE OHRID, NORTH MACEDONIA

Holguin, A., Antolín, F., Charles, M., Jesus, A., Martínez Grau, H., Soteras, R., Steiner, B.L., Stroud, S. and Bogaard, A.

7.1 KEYWORDS

Late Neolithic; Agriculture; Crop processing; Agrosystems; Functional plant ecology; Southwestern Balkans; Prehistoric pile-dwelling

7.2 ABSTRACT

Abundant, well-preserved, waterlogged macrobotanical remains were found in a thick cultural organic layer associated with the Late Neolithic pile-dwelling site of Ploča, Mičov

Grad, Lake Ohrid, North Macedonia. Located in a biogeographically transitional zone between mediterranean, alpine and continental regions, and on a topographically accessible link between imposing mountain ranges, the site presents a valuable opportunity to explore how, with the movement of people, plant foods and/or ideas, new subsistence strategies were established in the area. Here, we present the first archaeobotanical results from this lakeshore settlement to investigate changing subsistence strategies. We find that during a Late Neolithic occupation phase lasting an estimated 100 years, populations at the site of Ploča, Mičov Grad cultivated a range of cereals (particularly einkorn, emmer and barley), pulses (including lentil, pea and bitter vetch) and oilseed crops (flax and opium poppy), alongside a variety of collected fruits and nuts (such as almond, pistachio, blackberries and strawberry). Crop processing techniques are inferred from the partially charred glume bases consistent with singeing of cereal ears to remove awns before dehusking and from the weed seeds which resemble those found in fine-sieving by-products. Using functional weed ecology, we infer that the agrosystem at Ploča, Mičov Grad resembles high-input practices suggesting that cultivation was small-scale and labour-intensive. Such inferences are often not possible due to the preservation conditions of terrestrial assemblages, resulting in a lack of extensive weed datasets in the southwestern Balkans and southern Europe more broadly. Archaeobotanical research on wetland prehistoric sites from this region is currently limited. Our new work highlights the potential of such sites in this area for better understanding the spread of agriculture and patterns of plant food use during the Neolithic in the southwestern Balkans.

7.3 INTRODUCTION

The Neolithic (5th millennium BCE) and Bronze Age (2nd millennium BCE) pile-dwelling site of Ploča, Mičov Grad is located on the eastern side of Lake Ohrid, North Macedonia. A c. 1.7m thick organic cultural layer with abundant waterlogged organic remains was investigated through the sediment cores extracted from the area of the submerged settlement. Upon completion of the EXPLO project, this will be the first time that such a well-preserved organically rich waterlogged deposit is systematically investigated for plant macroremains in southeastern Europe. In this chapter, we present preliminary results from the archaeobotanical analysis of waterlogged macrobotanical remains from the Late Neolithic (calibrated 2-sigma ages 4600 to 4300 cal BCE) organic cultural layer (Hafner et al. 2021; see REFERENCE Chapter X in this book). The aim of this work is to investigate the spectrum of cultivated and collected plant foods from the site in order to better understand the adoption and adaptation of agriculture and other subsistence strategies in the Neolithic. The southwestern Balkans is a particularly important region for understanding the spread of agriculture due to its diverse landscape with mediterranean, alpine and continental biogeographical regions, each of which presents different challenges to plant cultivation (Figure 1). Despite this, the southwestern Balkans is an under-researched region. The site of Ploča, Mičov Grad presents an exciting opportunity to contribute to efforts to fill this research gap, due to the great inferential potential of the site's abundant and well-preserved waterlogged plant remains.

THE POTENTIAL OF WATERLOGGED ASSEMBLAGES FROM PREHISTORIC WETLAND SITES

Waterlogged archaeobotanical remains from prehistoric wetland sites offer a rich record of human subsistence. Plant parts, such as pods and leaves, that do not normally survive charring, the most common form of archaeobotanical preservation, can be well preserved in such anaerobic conditions. Waterlogging can also preserve fragile or oily seeds, such as poppy seeds (Papaver sp.), which are less likely to survive the charring process than more robust plant remains such as cereal grains (Jacomet et al. 1989; Märkle and Rösch 2008). Colledge and Conolly (2014, 199) found that charred assemblages only preserve approximately 35% of the range of wild taxa found in their waterlogged counterparts. Thus, waterlogged assemblages frequently have both a greater range of plant parts and a greater variety of plant taxa. This highlights the value of wetland sites with waterlogged assemblages for gaining a deeper understanding of the diversity and composition of plant assemblages at prehistoric sites (Jacomet et al. 1989; Brombacher and Jacomet 1997; Hosch and Jacomet 2004). In turn, such material promises great inferential power when investigating patterns of past cultivation and consumption of plant foods (Antolín et al. 2020).

THE IMPORTANCE OF PREHISTORIC WETLAND SITES IN THE LAKE OHRID BASIN

Several prehistoric sites with the potential for high levels of organic preservation thanks to waterlogging are known within the Lake Ohrid basin (see REFERENCE Chapter XX in this book). Accompanying Ploča, Mičov Grad, on the eastern side of the lake, is the pile-dwelling site Ohridati, one of the better researched prehistoric sites on the lakeshore. Recovered weights thought to be related to fishing nets and harpoons imply that lacustrine resources were important at the Middle-Late Neolithic site of Ohridati. The distribution of the wooden piles

suggest the site was comprised of individual dwellings (Westphal et al. 2011; Naumov 2020; Hafner et al. 2021; see REFERENCE Chapter X in this book). Both Ploča, Mičov Grad and Ohridati show extraordinary levels of organic preservation in the form of vertical wooden piles and so, have great archaeobotanical potential, but little research has centred upon the plant foods consumed in the area. Prehistoric sites in this region are of particular interest in investigating changing subsistence practices and understanding the adoption and spread of agriculture across the southwestern Balkans, and into central Europe, as the Lake Ohrid basin lies at a topographically accessible point between biogeographically and ecologically different regions.

The Galičica and Mokra mountain ranges, to the east and west of Lake Ohrid respectively, both have peaks higher than 2000m, making lowland pathways between the mountains particularly favourable. A prehistoric route crossing the mountain ranges, believed to date back at least to the Iron Age, known as the 'Candavian Road' (Kandaviski Pat), runs longitudinally through the Lake Ohrid basin at the northern side of the lake and acted as the predecessor of the Roman road, 'Via Egnatia' (Lolos 2007; Jovanova 2013; Mitrevski 2015; Weissová et al. 2018). The existence of these historically attested routes opens the possibility that the area was a similarly important link between western and eastern zones during earlier prehistoric occupations. The Black Drin River valley towards the northern part of Lake Ohrid further enabled movement between northern and southern regions through the basin (Kuzman 2017; Weissova et al. 2019). Similarities between Neolithic material culture recovered from sites in the Ohrid basin and from pile-dwelling and tell sites further north along the Black Drin River valley, south towards the Korče valley (Kuzman 2017) and to the east in the Pelagonia basin (Kuzman 2013; Naumov 2020) suggests the interconnectivity of the region, linking the earliest known settlements in the area. Thus, the prehistoric sites on

the shore of Lake Ohrid lay at a likely point of passage, enabling the movement of people, materials and ideas between adjacent areas, due to its topographic accessibility, on the flanks of challenging mountain ranges.

The southwestern Balkans is an area with notable ecological and biogeographic variability which likely influenced when and how different food practices and ideas could have been adopted and adapted (Figure 1). Lake Ohrid is situated within the Pindus Mountains mixed forest ecozone (European Environment Agency 2017a) and, alongside the rest of western North Macedonia, belongs to the 'alpine' biogeographical region of Europe (European Environment Agency 2017b). Regions to the south, such as southern Albania and Greece, are classed as 'mediterranean' biogeographical regions (European Environment Agency 2017b), featuring the Aegean and Western Turkey sclerophyllous and mixed forests, and the Illyrian deciduous forests ecozones (European Environment Agency 2017a). Areas to the north, such as Kosovo and Serbia, are considered 'continental' biogeographically (European Environment Agency 2017b), with Balkan mixed forests ecozones (European Environment Agency 2017a).

Environments within an area vary locally, and current ecological conditions may not accurately characterise the prehistoric landscape. Nevertheless, the influence of physical geographical factors such as geology, latitude and altitude, coupled with data indicating relatively unchanged climatic conditions in the region following the Rapid Climate Change event (6550-6050 cal BCE) (Krauß et al. 2018), suggest that biogeographic classifications remain relevant and useful for exploring broad patterns. Different biogeographic regions and ecozones likely fostered different subsistence strategies. Exploring how subsistence strategies at prehistoric sites in the Lake Ohrid basin compare with those at other contemporary alpine sites and sites located in the mediterranean and continental zones may afford insights into

how new ideas or foods were adopted and adapted in different areas, and suggest what balance of biogeographical, ecological and cultural factors influenced such changes. This is especially so given that the lake lies at this plausible point of connectivity, through which new ideas, people or foods could have travelled, between the north and south, and the east and west.

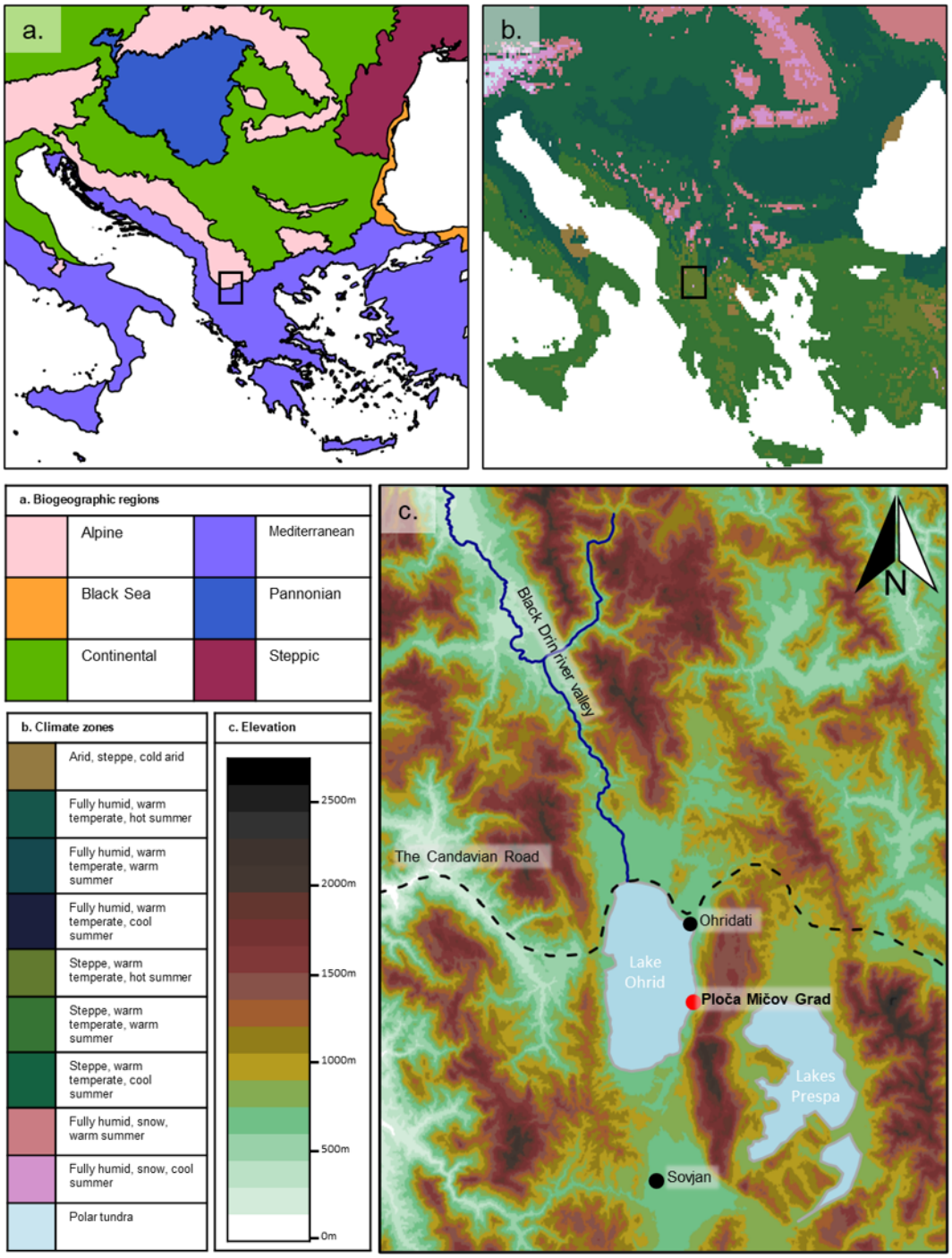


Figure 1: Location of Ploča, Mičov Grad. a. Biogeographic regions in the southwestern Balkans. b. Köppen-Geiger climate zones of the southwestern Balkans. c. Topographic map showing the location of the pile dwelling site of Ploča, Mičov Grad, the Black Drin River valley, the possible route of the Candavian Road/Via Egnatia and selected other sites mentioned in the text. Data for biogeographic regions from the European Environment Agency (© Council of Europe (CoE),

Directorate-General for Environment (DG ENV), European Environment Agency (2017b)). Köppen-Geiger climate classification after Kottek et al. (2006) downscaling after Rubel et al. (2017). © Climate Change & Infectious Diseases Group, Institute for Veterinary Public Health, Vetmeduni Vienna, Austria. Elevation data from USGS Global Multi-resolution Terrain Elevation Data. Possible route of Via Egnatia based on Filipović (2018) and https://www.viaegnatiafoundation.eu/ (last accessed 15/06/2021).

THE STATE OF RESEARCH OF PREHISTORIC WETLAND SITES IN THE LAKE OHRID REGION IN THE CONTEXT OF THE SOUTHWESTERN BALKANS

While prehistoric wetland sites in the Ohrid basin are numerous and have the potential for extraordinary levels of organic preservation, none of these sites have been the subject of a published comprehensive archaeobotanical study or extensive chronological investigation, and so such questions regarding prehistoric subsistence strategies in the area remain under-researched. This echoes the pattern more broadly seen in the southwestern Balkans. Many prehistoric sites are known on riverbeds and lakeshores across the region, such as on the ancient Lake Maliq (Albania), the Panonic Lake (Bosnia), Lake Orestia (Greece) and Great Lake Prespa (North Macedonia, Albania and Greece), but few are well researched, and doubtlessly many more remain undiscovered (Naumov 2020). Archaeological interest in wetland sites in this area has only recently grown during the last few decades. For comparison, the waterlogged prehistoric sites in the Alpine Foreland (Austria, France, Germany, Italy, Slovenia and Switzerland) have been researched for the past c.150 years (Menotti 2004) to the extent that, at present, nearly 1000 such sites have been identified, 111 of which are included on the UNESCO World Heritage list (UNESCO World Heritage Centre, 2021) Thus, extensive

excavations and new research projects are needed to fill this distinct gap in knowledge surrounding prehistoric wetland sites in the southwestern Balkans.

AIMS AND OUTCOMES OF PRELIMINARY ARCHAEOBOTANICAL RESEARCH AT THE SITE OF PLOČA, MIČOV GRAD

The research presented in this chapter derives from new excavations at the prehistoric site of Ploča, Mičov Grad, on the eastern shore of Lake Ohrid. Current excavations, beginning with a pilot study in 2018 and an extensive campaign in 2019, are part of the ERC Synergy project 'Exploring the dynamics and causes of prehistoric land use change in the cradle of European farming', known as EXPLO, a collaboration of the universities of Bern, Oxford and the Aristotle University of Thessaloniki, designed to investigate the adoption of agriculture at lakeshore sites in the southwestern Balkans. Recent extensive dendrochronological and radiocarbon analysis by the EXPLO team at the University of Bern suggest that the site reflects multiple settlement phases from the Late Neolithic (5th millennium BCE) to the Bronze Age (2nd millennium BCE) (Hafner et al. 2021; see REFERENCE Chapter X in this book). The Late Neolithic settlement phase related to the organic cultural layer, sampled through the lake sediment coring, is estimated to have lasted approximately 100 years based on tree felling dates (SEE REFERENCE CHAPTER IN THE BOOK.) Hence, the site offers the opportunity to explore changes to subsistence strategies through a well-defined occupation period. Here, we report the archaeobotanical findings from one of the lake cores from Ploča, Mičov Grad with plant remains dating to the Late Neolithic. The high levels of preservation and the abundance of the archaeobotanical material from this single core shows that the site has great promise for archaeobotany. We present preliminary inferences regarding the site's subsistence strategies and agrosystems and consider how this compares to researched food systems from

other lakeshore sites in the southwestern Balkans and southern Europe more broadly. Future work on further lake core samples and bulk samples from an underwater sondage at Ploča, Mičov Grad will enable us to consider intra-site variability, perhaps reflecting different activities across the site or different depositional/taphonomic processes, and to identify settlement-wide trends.

7.4 MATERIALS AND METHODS

THE SITE OF PLOČA, MIČOV GRAD, LAKE OHRID, NORTH MACEDONIA

Ploča, Mičov Grad (40.994°N, 20.798°E) lies on the eastern shore of Lake Ohrid, at an altitude of 693m asl. The Late Neolithic to Bronze Age site is now fully submerged, above which a modern museum is situated with pile-dwelling reconstructions (Figure 1). The lake measures approximately 30km in length (N-S) and 14km width (E-W), with an estimated total volume of 50.7km3 and a maximum depth of 293m. At its deepest point, sediment accumulation rates are estimated to be c. 0.5mm per year (Lacey et al. 2015). The Lake Ohrid basin is located on the border between present-day North Macedonia to the northern and eastern shores, and Albania to the southern and western sides of the lake. Within the Pindus Mountains mixed forest ecozone, this area is characterised by mixed broadleaf forest in lowland zones and coniferous forests at higher altitudes (1200-2500m) (Dinaric Arc and Balkans Environment Outlook, 2010) and a Mediterranean-type climate with hot summers (Kottek et al. 2006). Within the basin, the average annual rainfall is 907mm and temperature is 11.1°C, reaching heights of 31.5°C and lows of -5.7°C (Popovska and Bonacci 2007).

CORING, SAMPLING, AND PROCESSING OF THE SAMPLES

During the 2019 season, 14 cores were extracted using a Niederreiter coring system by the EXPLO palaeoecological coring team, led by Prof. André Lotter. These were arranged along two approximately perpendicular transects (north-south and east-west) centred on the main settlement area of the visible vertical piles (Figure 2). Plant macrofossil samples were taken for radiocarbon dating from the top and bottom of the visible organic layer from four of these cores, returning calibrated 2-sigma ages ranging from c. 4600 to 4300 cal BCE. Bayesian modelling of these dates alongside felling dates from dendrochronological analysis of the piles suggests that the organic layer present in the cores accumulated across approximately 100 years, between the start of the 45th and the middle of the 44th century BCE (Hafner et al. 2021; see REFERENCE Chapter X in this book). Eight bulk samples were also taken along a grid from an excavated underwater sondage within the settlement area and will be the subject of further archaeobotanical analysis. One of the four cores, QLM19 0, is the focus of this chapter.

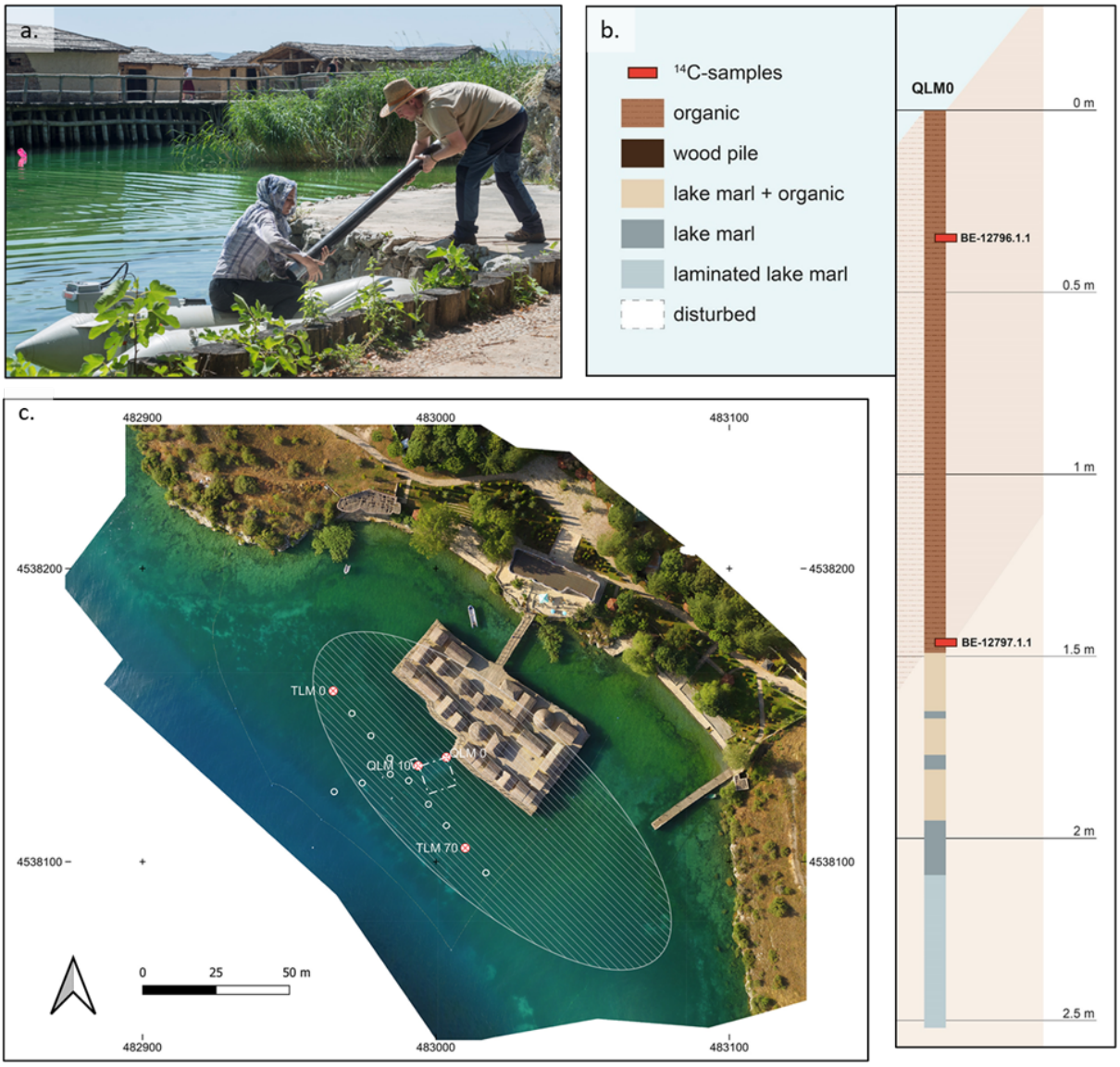


Figure 2: The prehistoric piledwelling settlement. a. Team members moving a core. (R. Soteras). Schematic diagram of drill core QLM19 0, showing key stratigraphic features and the radiocarbon sampling locations (A. Bieri, UBern, J. Reich and A. Ballmer EXPLO/UBern). c. An aerial orthophoto of the submerged site of Ploča, Mičov Grad with the area containing remains of wooden piles marked by a hatched oval. A modern museum is built above the remains of the site. White circles indicate the locations of core drillings, those with a red cross indicate the cores from which samples were taken for radiocarbon dating (J. Reich, EXPLO/University of Bern).

Core QLM19 0 was extracted in 3 parts. The top sub-core measured 60cm in length, the middle 90cm and the bottom 100cm (Figure 2). A thick organic layer was visible throughout the top and middle sub-cores. The bottom sub-core appeared to be largely lake marl and was left for future macrofossil and pollen analysis. In total the organic layer measured 1.7m in thickness.

28 samples were taken from the organic layer. A sample was taken from each distinct stratigraphic horizon. When layers were not apparent, samples were taken at regular intervals (average c. 6cm) based on depth. 17 samples were taken from the lower part of the organic layer in middle sub-core. These were originally labelled 0.1.1 to 0.1.17. For the purposes of clarity in this chapter, the samples have been renamed 1 to 17. A further 11 samples were taken from the upper part of the organic layer in the top sub-core, originally labelled 0.0.1 to 0.0.11 and renamed 18 to 28. Sample 1 is the lowermost sample and sample 28 is the uppermost.

The volume of each sample was measured before processing, by calculating the volume of water displaced when a sample was submerged in a beaker (Antolín et al. 2015). The sample volumes ranged from 30ml, to 200ml with an average of 93ml. The total volume of sieved sediment measured 2602ml. The organic and inorganic fractions of each sample were sieved through 2mm and 0.35mm meshed sieves using the wash-over method (eg. Steiner et al. 2015). The <0.35mm fraction was retained unanalysed. The 2mm fraction was analysed in full. If the 0.35mm fraction sample volume exceeded 14ml, it was randomly sub-sampled to a volume of approximately 10ml by grid sampling (eg. Steiner et al. 2017), No random sub-samples amounted to less than approximately a quarter of the total sample.

Identification and counting of botanical macroremains

Samples were sorted under a low powered microscope (x6.3-50). The 17 samples from the lower part of the organic layer (1-17) were sorted on site by AB, FA, HMG, ES and AJ. The upper 11 samples (18-28) were sorted at the Institute of Archaeology, University of Oxford, by AH. Identification was done through comparison with the seed reference collection in the Archaeobotany Laboratory at the Institute of Archaeology, University of Oxford, aided by images and descriptions in reference atlases (Körber-Grohne 1964; Berggren 1969, 1981; Anderberg 1994; Bojňanský and Fargašová 2007).

Items relating to fauna (for instance bones, dung, insects and fish scales), and some plant items, such as leaves, thorns, charcoal, stems and cereal bran, were counted semi-quantitatively on a 3-part scale from rare to abundant (following Antolín et al. 2017). All other crop material and seeds were recorded quantitatively.

Glume bases were counted if the whole glume base was present. Spikelet forks were counted as two glume bases. For rachis fragments, the upper part of the node (with glume attachment points) was counted. Fragments of apical and embryo ends of charred cereal grains were both counted, as they were rare; if fragments of comparable grains with both ends were present, they were counted together as one. Pulse pod and nutshell fragments were counted if they exceeded 12 mm^2, with the exception of acorn (Quercus sp.) fragments, for which the threshold was set at 25 mm2 owing to their large but fragmentary nature. Two pulse cotyledons were counted as one seed. Flax (Linum usitatissimum) capsules naturally break into ten segments or 'septa' (Diederichsen and Richards 2003); tips of these septa, or fragments containing two mid-ribs to which a tip could not be connected, were counted. The principle of minimum number of individuals (MNI) was applied visually when counting all

other seeds. Some crop items for which it was challenging to estimate an MNI, such as cereal awns and pulse stalks, were recorded as fragment counts.

In the text and figures, counts from sub-sampled fractions were multiplied to represent the absolute number in the full sample and rounded to a whole number. Counts from the 2mm and 0.35mm fraction were combined.

ANALYSIS OF COMPOSITION OF SAMPLES

Correspondence analysis was performed to explore compositional variation among the samples, using CANOCO 5. This ordination technique arranges samples along two axes based on the extent of their compositional similarity. The horizontal axis is the primary axis and captures the dominant trend in the sample compositions. The position of a sample from the origin reflects the degree of similarity between samples, based on taxon abundance and the combinations of taxa present in the sample. Only taxa occurring in at least 10 samples were included. In cases where the same taxa were represented in uncharred and charred form, they were entered separately into the analysis. In total, 27 taxon categories were included. A logarithmic transformation was used due to the very high numbers of certain taxa in some samples.

Discriminant analysis was performed to investigate how the weed/wild seed characteristics compare to those of known crop processing products and by-products. This approach uses three attributes (seed size, whether seeds are free or enclosed in a head, and whether seeds are easily blown by the wind) to assess the similarity of weed/wild seeds in the archaeobotanical samples to weed seeds in winnowing by-products, coarse-sieving by-products, fine-sieving by-products and fine sieving products of manually processed cereals documented on the island of Amorgos, Greece (Jones 1984, 1987). Following Jones (1984,

1987), the samples were classified as unknown cases in a discriminant analysis, using functions extracted to maximise the separation of ethnobotanical crop-processing groups using the 'leave one out' option (82% of modern ethnobotanical samples correctly reclassified in IBM SPSS Statistics 26). Results were plotted using R version 3.6.1 (R Core Team, 2019).

Discriminant analysis was also employed to explore how the functional ecological traits of the weed/wild seeds compared to those from different modern agricultural regimes, following Bogaard et al. (2016, 2018). This approach considers the specific leaf area, canopy diameter, leaf area per node: leaf thickness, and canopy height of each weed taxon to create a discriminant function distinguishing between weeds commonly found in low labour input agricultural 'fields' and those found in high labour input 'gardens.' This is based on modern survey datasets collected from present-day traditional systems managed under different intensities in Morocco, Spain, France and Greece (Bogaard et al. 2016, 2018). The presence or absence of weed species in different regimes was used to create a discriminant function that maximally separates out these high and low labour input systems. All archaeobotanical weed/wild taxa identified to species, or at least to a small number of ecologically comparable species (eg. Mentha aquatica/arvensis), were included in the analysis. This totalled 29 taxa. Two of the lower samples (2 and 6) were removed from the analysis since they contained less than 10 weed seeds included in the analysis. The samples were entered into the classification phase of the discriminant analysis, as unknown cases using a discriminant function, extracted using the 'leave one out' option (94% of modern agricultural plots correctly reclassified as 'low input' or 'high input' in IBM SPSS Statistics 26). Results were plotted using R version 3.6.1 (R Core Team, 2019).

7.5 RESULTS

OVERALL CORE

The organic layer was visually relatively homogeneous, lacking visible sterile layers interspersed between organic layers as commonly observed in Alpine Foreland lakeshore site stratigraphies (eg. Sipplingen, Bodensee (Kolb 1997)). Large fragments of pottery, bone, teeth, molluscs, burnt clay and stone were recorded within the organic layer, as well as some variation in macroscopic composition that we are continuing to assess in light of the archaeobotanical results.

The average density of fully quantified plant items per litre sediment throughout the organic layer was 8276. Sample 3, towards the bottom of the organic layer, had the lowest density of 1265 items/litre. Seven samples had more than 10000 items/litre, the greatest density being 16780 items/litre in sample 8 (Figure 3).

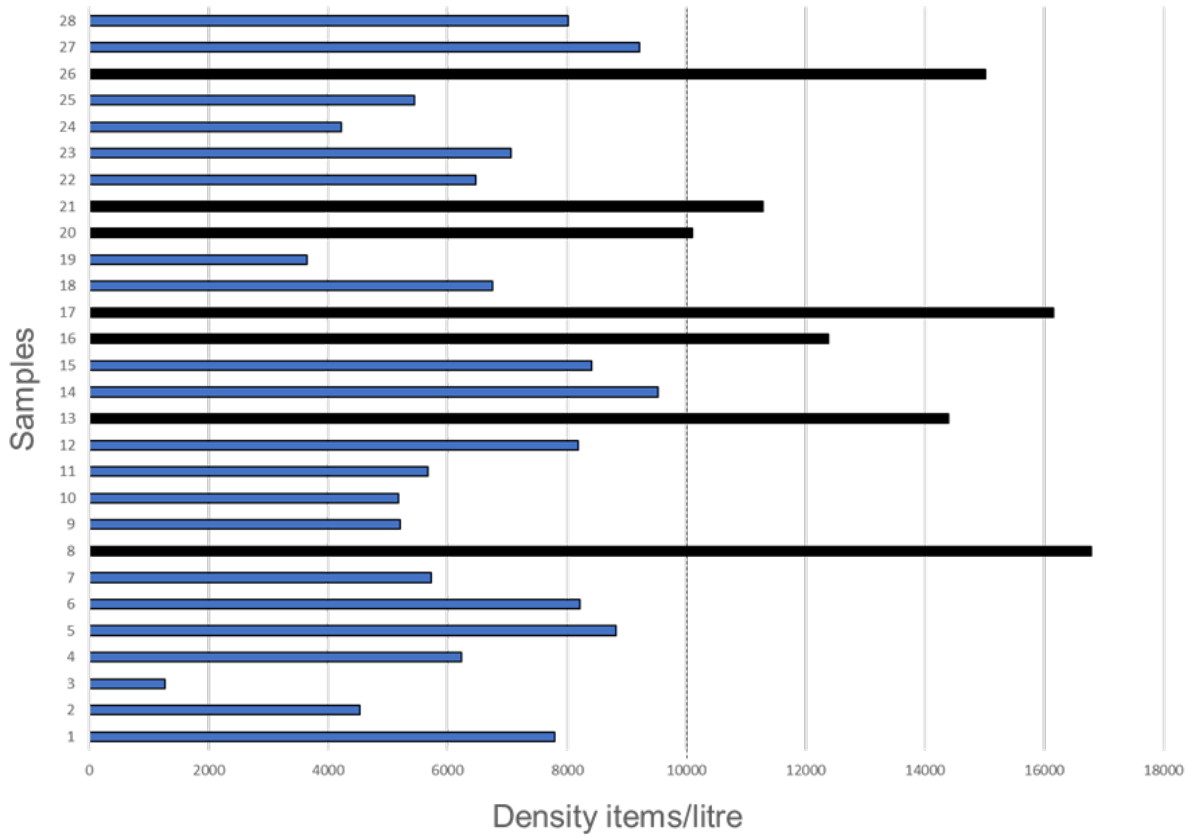


Figure 3: The density of each sample in items per litre. Samples are ordered on the y-axis following stratigraphic order, with the uppermost sample (28) at the top of the bar-chart. There are seven samples with over 10,000 items per litre indicated in black.

Crop material was the main botanical category found in the organic layer, comprising 57.8% of all items, followed by fruits and nuts (26.3%), weed/wild taxa (9.7%), oilseed crops (4.1%), wetland types (2.0%) and finally other wild items (0.4%) (Figure 4). The other wild taxa category largely comprised of arboreal seeds and needles such as fir (Abies sp.) and pine (Pinus sp.). Counts of wetland taxa (primarily Chara sp. and Najas sp.) were low throughout the organic layer, but increased notably to the top, making up 34.0% of the total items recovered in the uppermost sample (28). Rodent dung occurred in most samples but small ruminant dung only in a few. Other non-botanical organic remains included fish scales, fish bone and insect remains.

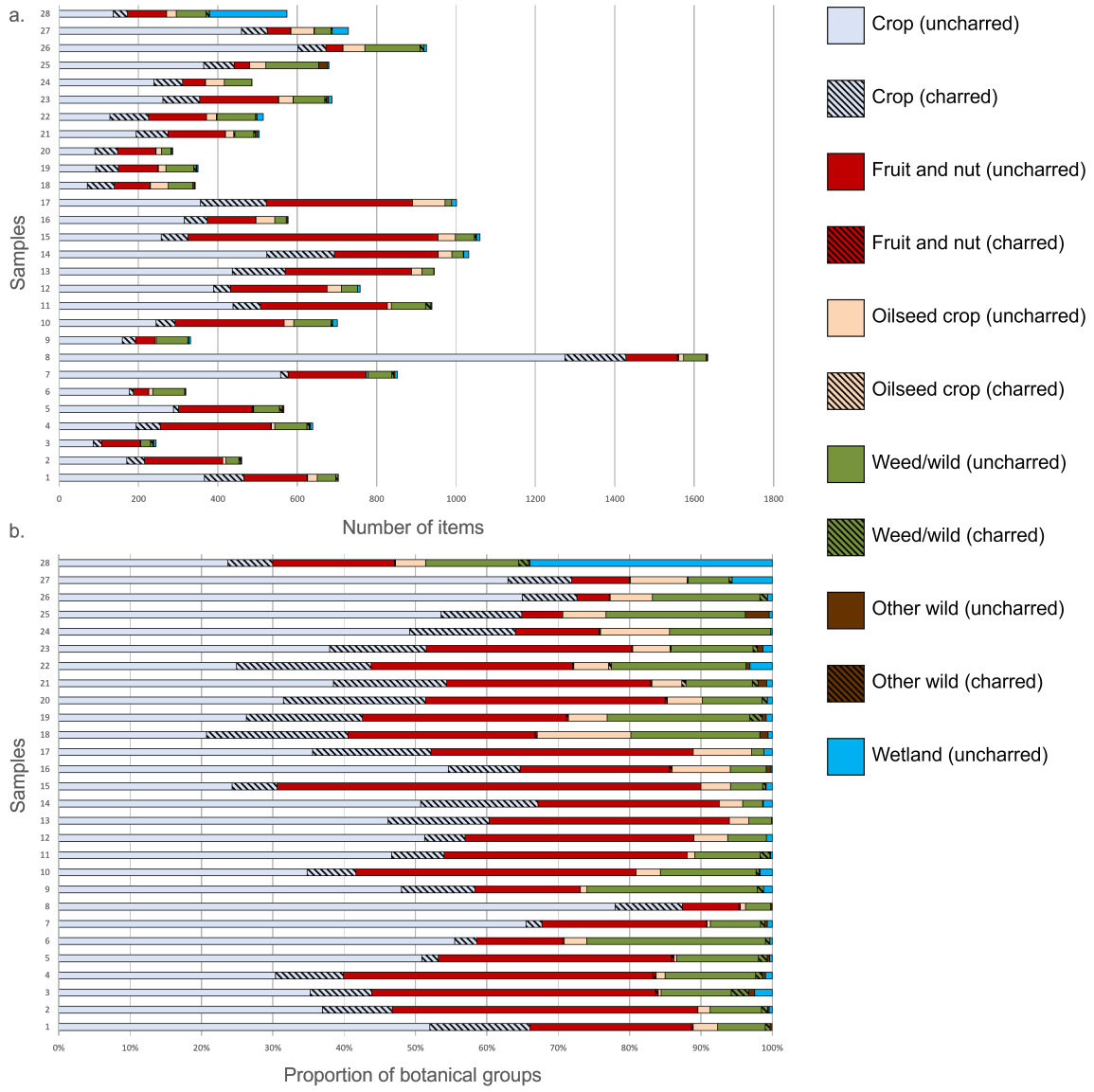


Figure 4: The composition of the samples. Bar-chart showing the absolute number of items in each major botanical category in each sample. b. The relative proportion of each botanical category in each sample. Charred material is indicated with a diagonal fill. The most abundant category is the crop remains which here refers to cereal and pulse crops. Counts of wetland taxa are very low, although they are notably most abundant in the uppermost sample (28), likely reflecting taphonomic process.

The waterlogged botanical remains were primarily preserved uncharred (88.8% of all items). However, charred material (11.2% of all items) was still present throughout the samples. All

of the main botanical categories discussed included some charred material, except for wetland taxa which were only found uncharred.

BOTANICAL CATEGORIES

The largest botanical category, the crop material, included cereal and pulse remains (Figure 5). Uncharred, and in lower numbers charred, cereal chaff items (particularly spikelet forks, glume bases and rachis) were recovered from all samples. The uncharred glume bases were by far the most dominant group, making up 83.1% of all crop material (Figure 6). These proved challenging to identify to species, as they were frequently distorted. Some uncharred glume bases appeared to be blackened and singed in places, and others appeared lightly charred ('toasted'), being brown in colour and soft (Figure 7). These singed (8.2% of glume bases) and brown (2.5% of glume bases) glume bases retained their original shape to a greater extent and so some of these, alongside some of the charred glume bases (7.0% of glume bases), could be identified to species as einkorn (Triticum monococcum, n=395), emmer (Triticum dicoccum, n=396) and New Glume Wheat (Triticum timopheevii group, n=13). Uncharred and charred rachis nodes were also found making up 3.2% and 1.1% of all crop material respectively. These were identified as barley (Hordeum distichon/vulgare, n=381) and free-threshing wheat rachis (n=43). Work is ongoing to identify barley rachis to species/variety. Across the chaff, einkorn, emmer, and barley were identified in similar numbers. However, 8826 glume bases were unidentifiable to species. The charred cereal chaff generally exhibited a good state of preservation. For example, many of the spikelet forks had a complete internode, and palea and lemma tissues were sometimes preserved still nestled within the spikelet forks. Charred cereal grains were comparatively few (n=108), often less well preserved and fragmented. Some cereal grain fragments (n=22) appeared to have been

broken before charring (Valamoti et al. 2021). Fragments of cereal bran were found in all samples.



Figure 5: Crop remains from Ploča, Mičov Grad. a. Uncharred glume base. b. Singed glume base. c. Brown Triticum dicoccum spikelet fork. d. Uncharred Hordeum sp. rachis. e. Charred Triticum monococcum spikelet fork. f. Charred Triticum dicoccum spikelet fork. g. Charred

Triticum timopheevii group (New glume wheat) spikelet fork. h. Charred Hordeum sp. rachis. i. Charred Triticum monococcum grain. j. Charred Triticum dicoccum apical grain fragment with a pre-charring break. K. Charred Hordeum sp. grain. l. Uncharred pulse pod fragment. m. Uncharred Linum usitatissum capsule fragment. n. Uncharred Linum usitatissum seed. O. Charred Vicia ervilia seed p. Uncharred Papaver somniferum seed q. Charred pulse pod tip fragment (R. Soteras and A. Holguin).

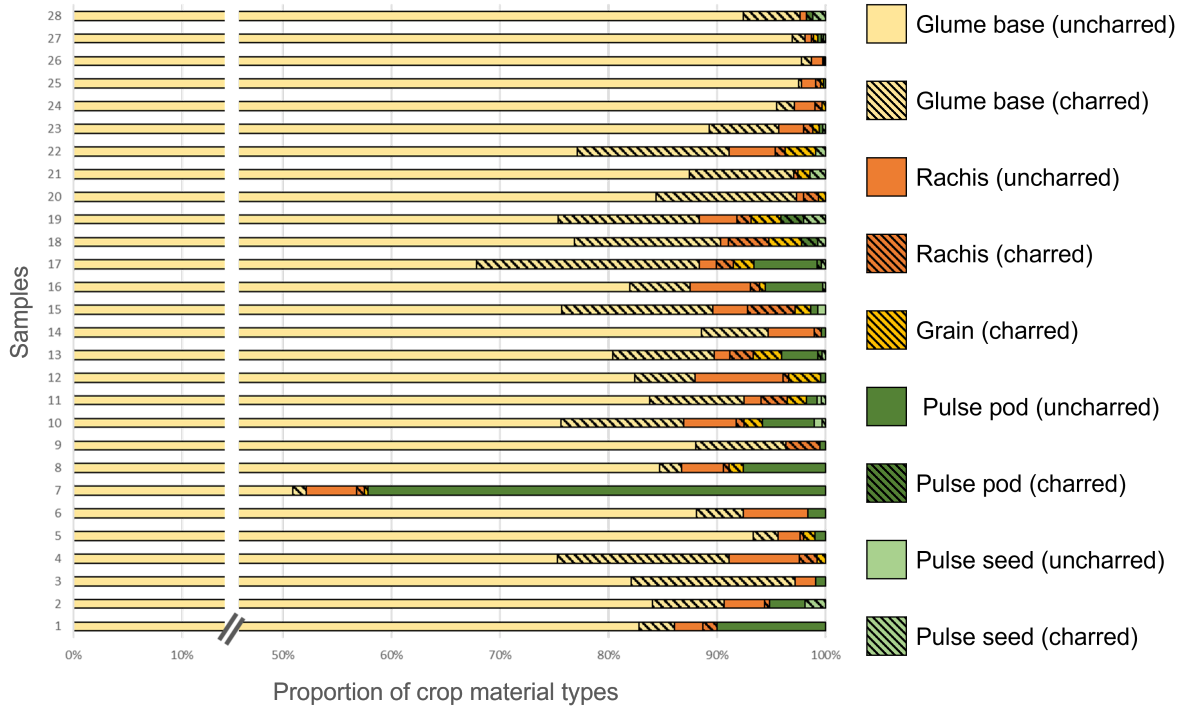


Figure 6: The relative proportions of crop material in each sample. Material relating to cereals is shown in yellows and oranges and those relating to pulses in green. Charred material is indicated by a diagonal fill. Uncharred glume bases are by far the most abundant crop remain, making up at least 50% of all samples; as such, there is a break in the x-axis.

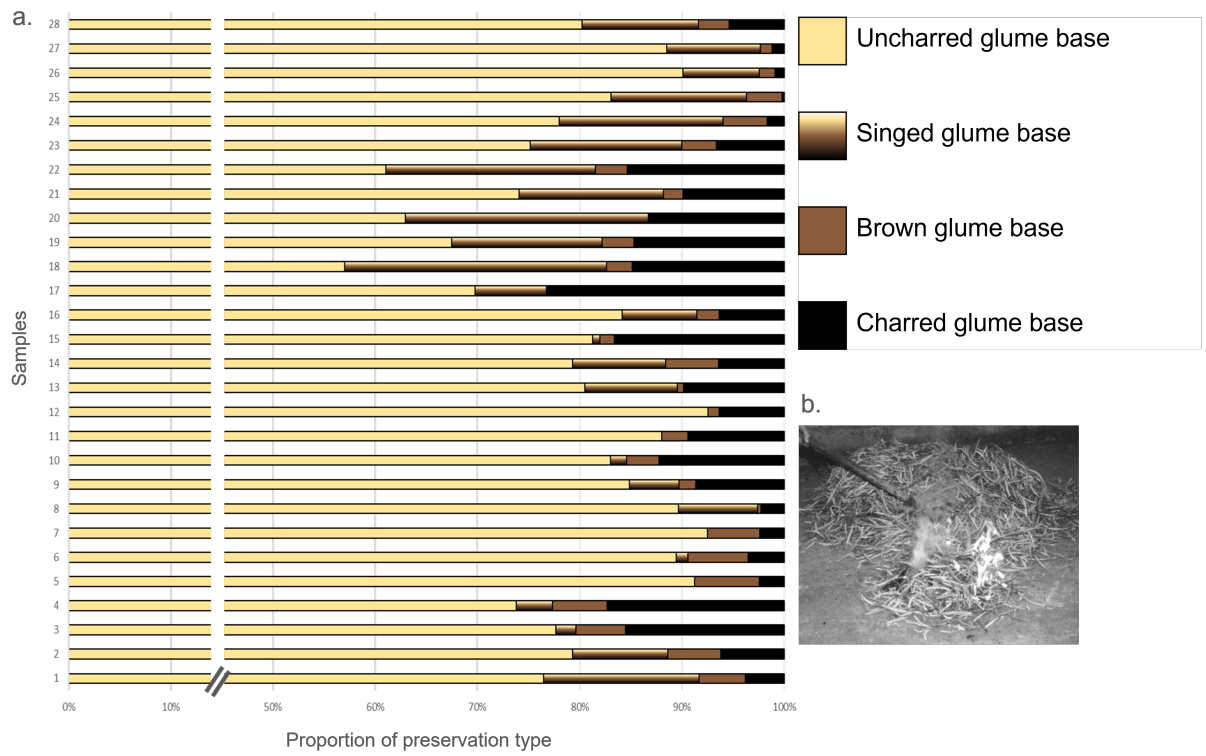


Figure 7: Preservation of glume wheat chaff. a. The relative proportions of glume bases in each sample according to preservation type. Glume bases were recovered in uncharred, singed, brown and fully charred form. Uncharred glume bases are by far the most abundant crop remain, making up at least 50% of all samples; therefore there is a break in the x-axis. b. The singeing of hulled wheats to scorch awns before or during dehusking in Asturias, Spain taken from Peña-Chocarro and Zapata (2003, Fig. 6).

Uncharred pulse pod was found throughout the organic layer, and comprised 4.7% of all crop material, with particularly high concentrations (n=237) in sample 7 in the lower quarter of the organic layer (Figure 6). A small amount of charred pulse pod (0.1% of all crop material) and charred pulse seed, hilum and testa (0.2% of all crop material) was recovered. The uncharred pulse pod was mostly found highly fragmented with little discernible shape; further taxonomic identification is ongoing. The charred pulse seeds were identified as bitter vetch (Vicia ervilia, n=3), lentil (Lens culinaris, n=2) and pea (Pisum sativum, n=2).

Oilseed crops were also found, 99.1% of which were uncharred (Figure 8). Uncharred opium poppy (Papaver somniferum) seeds were found in almost all samples, markedly increasing in the upper half of the organic layer. Sample 18 towards the middle of the organic layer had the largest concentration of seeds (n=41). Uncharred flax seeds (Linum usitatissimum) were present in most samples, although they were notably absent in the top 4 samples. The highest numbers could be found in samples towards the middle and at the very bottom of the organic layer. Uncharred flax capsule fragments were found in every sample, increasing in number towards the middle and the top of the organic layer. The number of flax seeds and flax capsules did not appear to strongly correlate with each other. A few charred poppy seeds and charred flax capsule fragments were recovered from samples near the top of the organic

layer.

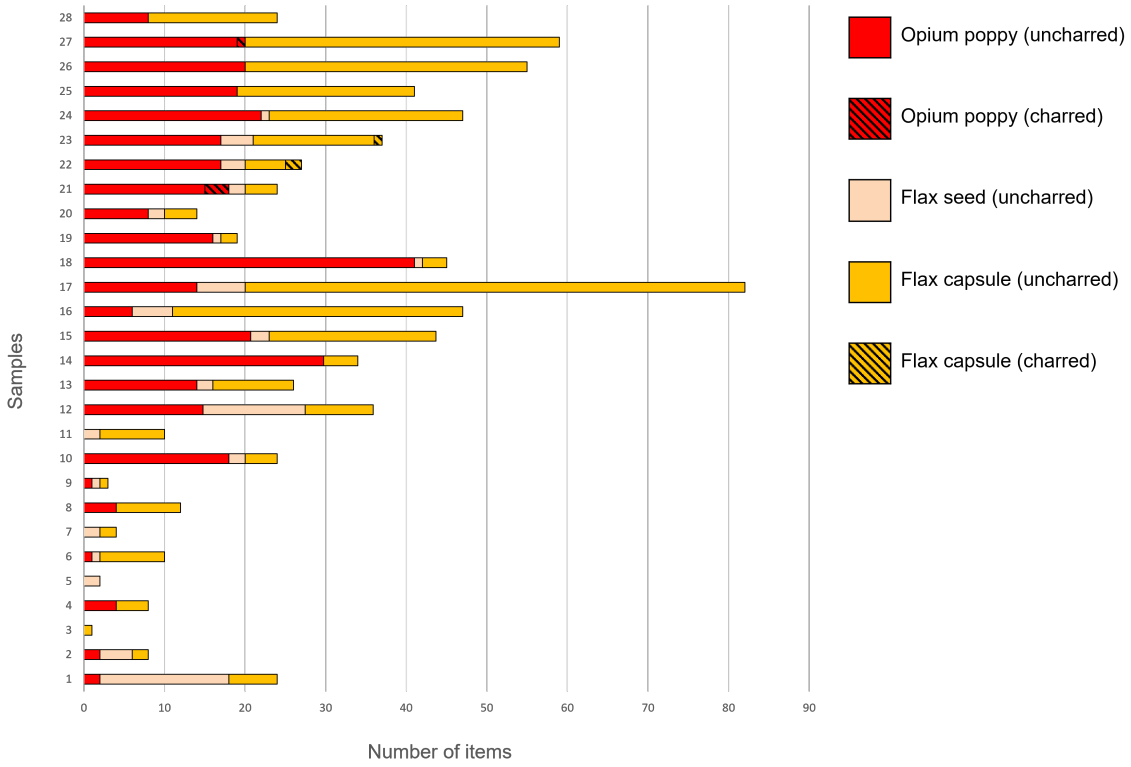


Figure 8: The absolute number of remains from different oilseed crops (namely opium poppy and flax seeds or capsule fragments in the sample) in each sample. Charred material is shown with a diagonal fill. It is however very rare in this category.

Uncharred blackberry (Rubus fruticosus agg.) seeds constituted by far the most abundant taxon in the fruits and nuts category. The greatest number of blackberry seeds (n=552) were found in sample 15 towards the middle of the organic layer. Almond (Amygdalus sp.), hazelnut (Corylus avellana), acorn (Quercus sp.) and pistachio (Pistacia atlantica/terebinthus) nutshell fragments were found, along with other fruit seeds including strawberry (Fragaria vesca), juniper (Juniperus sp.), cornelian cherry (Cornus mas), fig (Ficus carica) and elderberry (Sambucus sp.) (Figure 9). Items in this category were predominantly uncharred (99.5%), with a single charred elderberry and a few charred nutshell and blackberry seed fragments recovered.

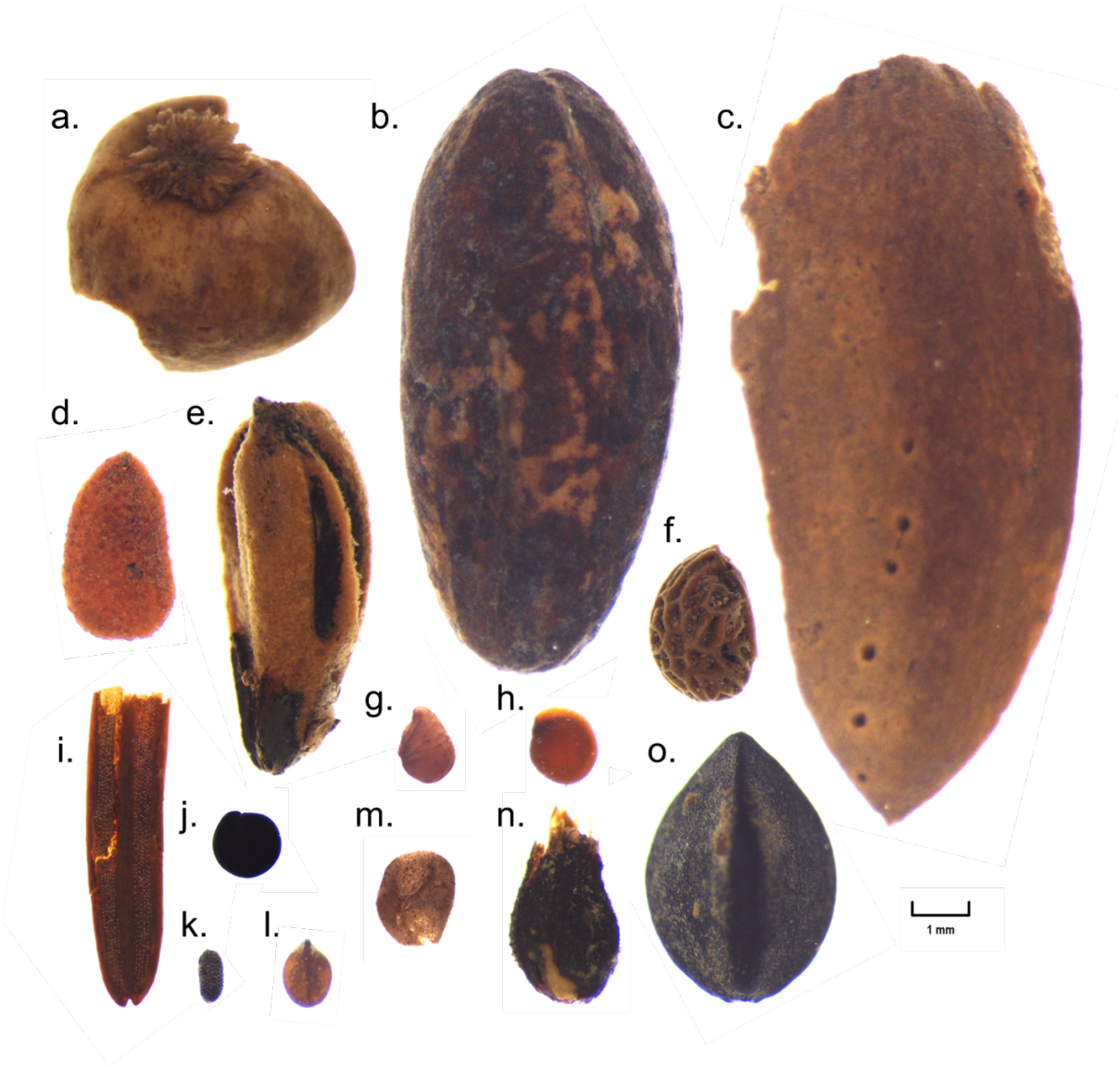


Figure 9: Collected and wild uncharred macrobotanical remains from Ploča, Mičov Grad. a. Pistacia atlantica/terebinthus nutshell b. Cornus mas. c. Amygdalus sp. nutshell. d. Sambucus sp. e. Juniperus sp. f. Rubus fruticosus agg. g. Fragaria vesca. h. Ficus carica. i. Abies sp. needle. j. Chenopodium album. k. Hypericum perforatum. l. Origanum vulgare. m. Cuscuta sp. n. Valeranella dentata. o. Polygonum convolvulus (R. Soteras and A. Holguin).

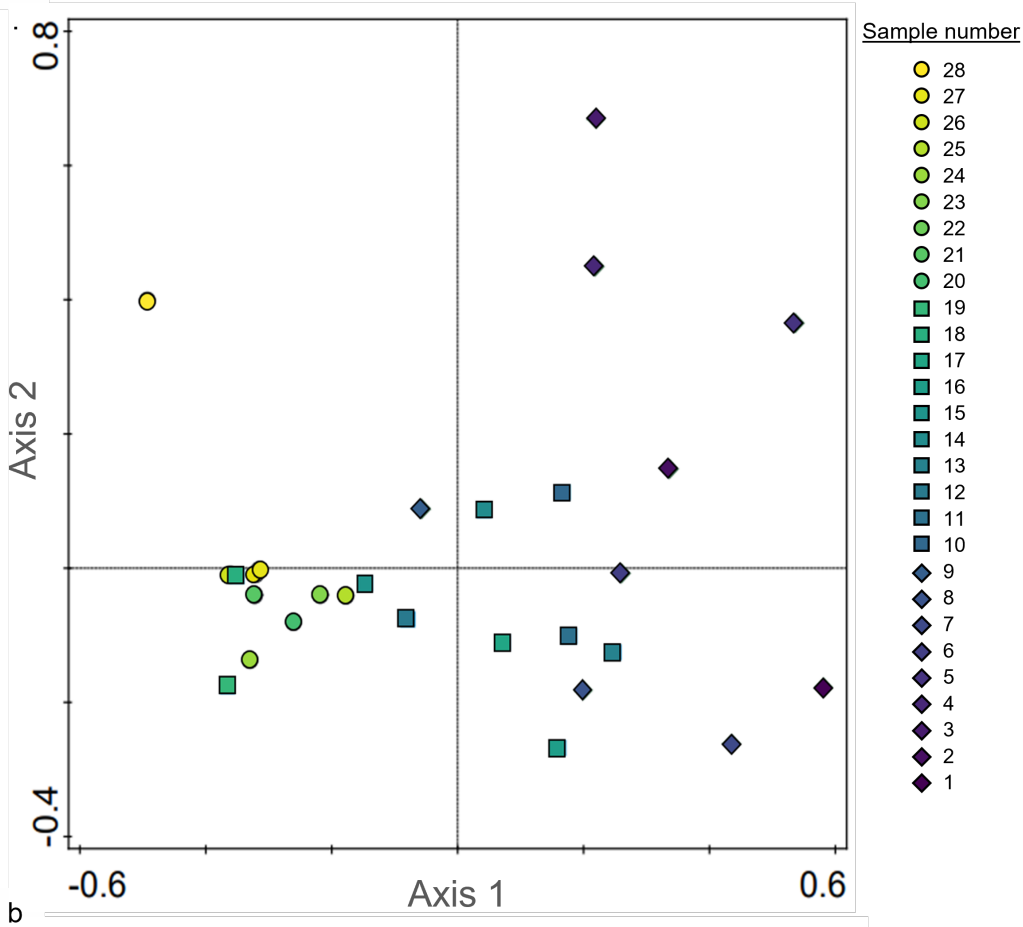
The majority of weed/wild seeds were uncharred (94.7%). The most numerous uncharred weed/wild seeds were St John's-wort (Hypericum perforatum), thyme-leaf sandwort (Arenaria serpyllifolia), dodder (Cuscuta sp.) fat-hen (Chenopodium album) and black

bindweed (Polygonum convolvulus). Charred weed/wild taxa included wild oat (Avena sp.), campion (Silene sp.) and St John's-wort (Hypericum perforatum). Some seeds such as lemon balm (Melissa officinalis), oregano (Origanum vulgare) and horse mint (Mentha longifolia) could have been collected as herbs. However, they are counted here as weed/wild seeds due to their low numbers, as they are also commonly found growing wild in the region. The weed/wild taxa in the assemblage notably include some autumn-germinating species (e.g. Valerianella dentata) as well as spring-germinating ones (e.g. Polygonum convolvulus), based on their flowering time (Bogaard et al. 2001).

CORRESPONDENCE ANALYSIS

Together axis 1 and 2 of the correspondence analysis accounted for 35.5% of the variance in the samples (Figure 10). The distribution of samples along axis 1 (the horizontal x-axis) roughly corresponds to their depth; samples towards the top of the organic layer are found further towards the left of the scatterplot and those towards the bottom are found further towards the right. Samples further towards the top of the organic layer (with the exception of the uppermost sample, 28) were positioned relatively close together along axis 2 (the vertical y-axis), whereas samples further towards the bottom are more dispersed vertically, reflecting greater variation between the compositions of the lower samples.

a


Sample number
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0.8
-0.4
Axis 2
-0.6
0.6
Axis 1

b

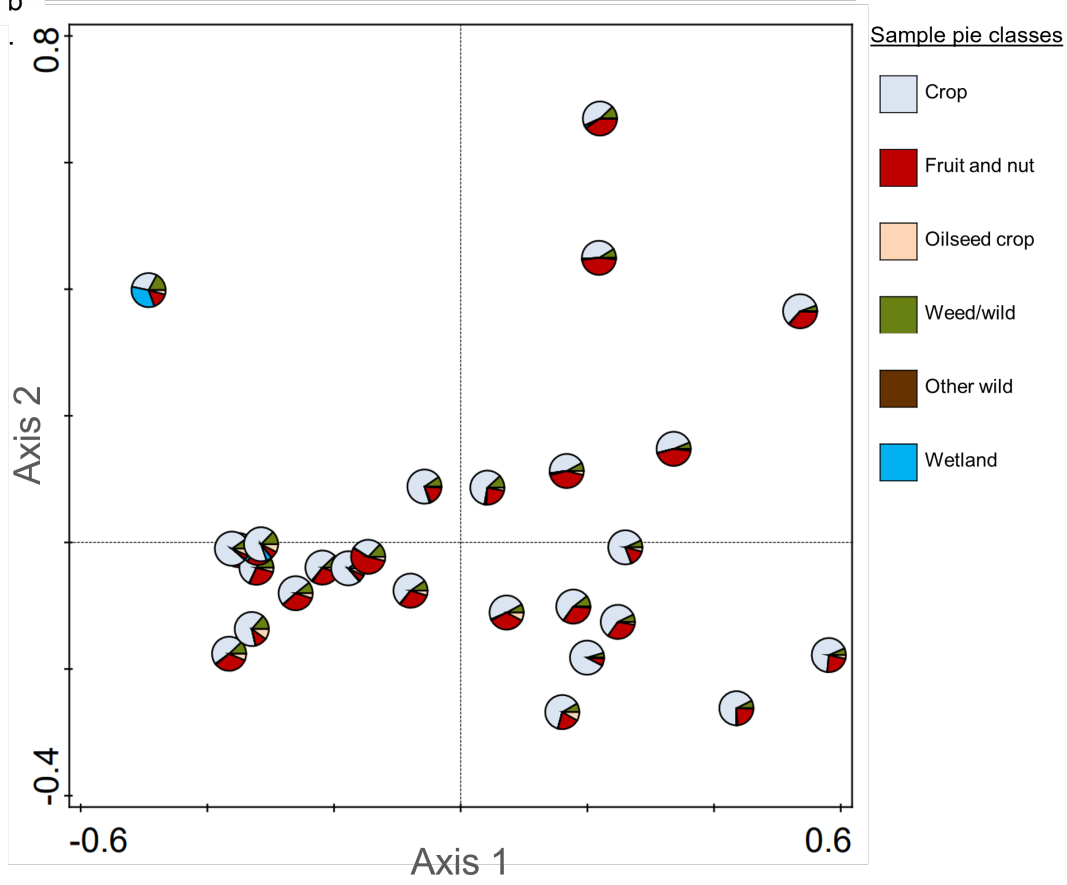

Sample pie classes
Crop
Fruit and nut
Oilseed crop
Weed/wild
Other wild
Wetland
0.8
-0.4
Axis 2
-0.6
0.6
Axis 1

Figure 10: Scatterplots showing the results of the correspondence analysis (axis 1 horizontal and axis 2 vertical). a. Samples are coloured according to depth with the uppermost sample (28) in yellow and the lowermost sample (1) in dark purple. b. Samples are shown as a pie-charts showing the relative proportions of the major botanical categories.

Proportions of uncharred and charred material per sample do not reflect trends along either axis. Uncharred material dominated all samples. The proportion of charred material fluctuated but did not reflect the position of samples on the axes. The proportions of different botanical categories, however, did approximately correspond to the position of the samples. Samples with greater amounts of fruits and nuts generally were positioned to the top right of the scatterplot and those with greater amounts of oilseed crops to the bottom left. The uppermost sample (28) is the only sample positioned high in the top left-hand corner of the

CROP PROCESSING DISCRIMINANT ANALYSIS

Almost all of the samples coincide in the discriminant function plot with the distribution of ethnobotanical samples from known crop processing stages (Figure 11). The archaeobotanical samples largely overlap with the fine-sieving by-product group. A few samples are positioned below this group. Some samples are placed in the region of the plot where fine-sieving products overlap with fine-sieving by-products and winnowing by-products. Samples show some grouping by depth.

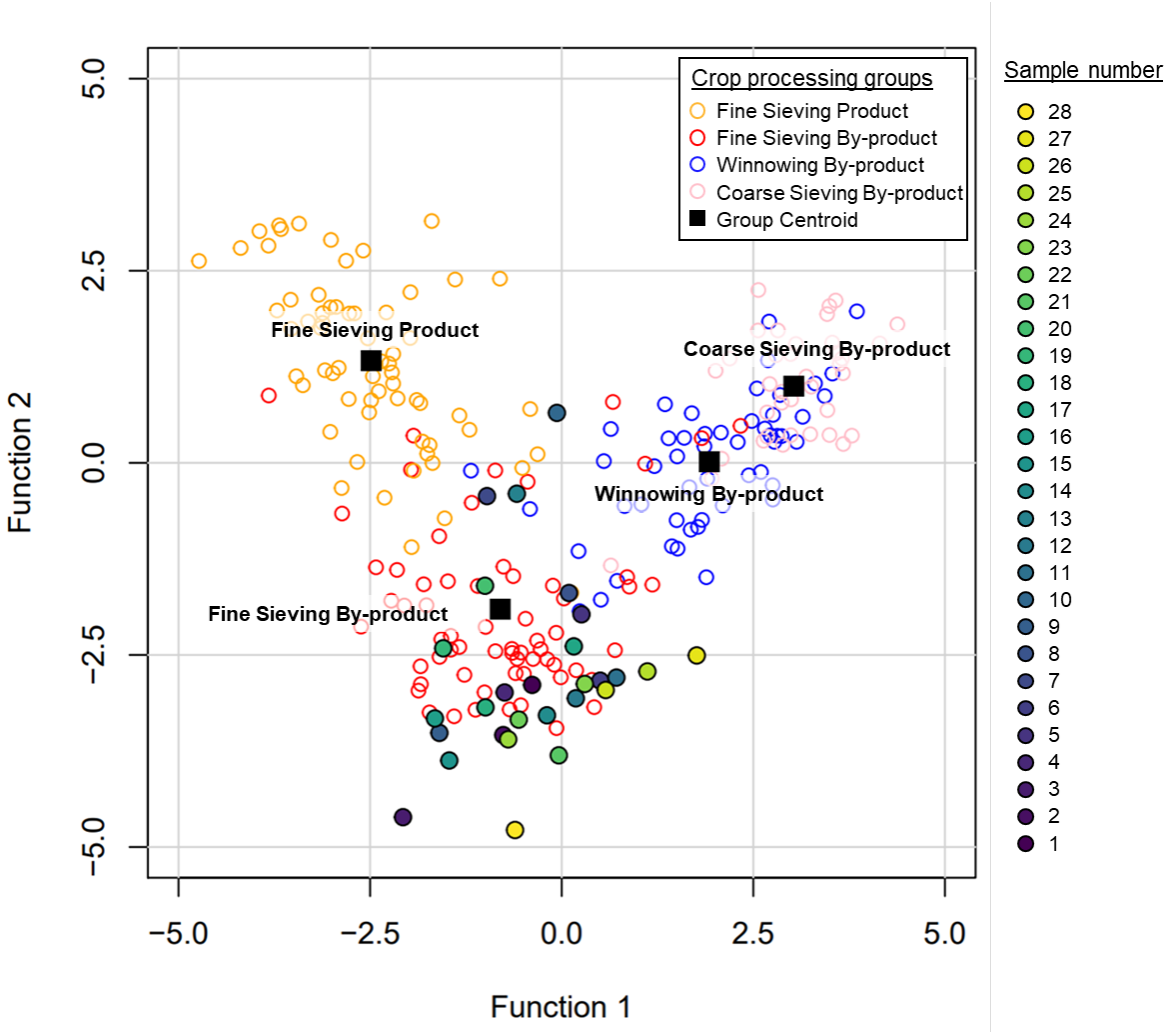


Figure 11: Scatterplot showing the distribution of the archaeobotanical samples from Ploča, Mičov Grad along two discriminant functions extracted to distinguish four modern ethnobotanical crop processing sample groups based on physical characteristics of weed seeds. Samples are coloured according to depth with the uppermost sample (28) in yellow and the lowermost sample (1) in dark purple.

WEED FUNCTIONAL ECOLOGY

The discriminant scores of the archaeobotanical samples, in comparison to modern high and low input agricultural plots are shown in Figure 12. Most of the samples are intermediate

between the low-input and high-input regimes, but mostly align with the lower end of the high input group. There is some grouping by depth, but no consistent trend.

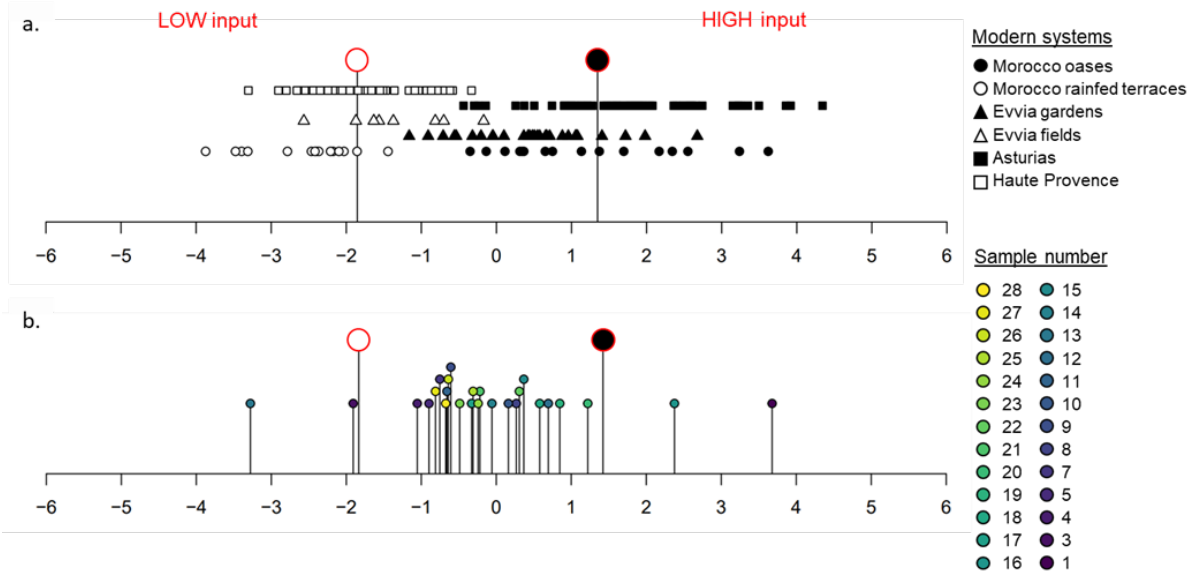


Figure 12: Functional weed ecology. . The results of a discriminant analysis separating modern low- and high-input fields on the basis of four functional attributes of the constituent weed taxa. b. The distribution of the archaeobotanical samples from Ploča, Mičov Grad when entered as unknown cases. The group centroids are shown with larger symbols with a red border.

7.6 DISCUSSION

Many samples showed a very high density of items per litre with 7 samples exceeding 10,000 items/litre. This is comparable to well-preserved organic cultural layers in lakeshore sites of the Alpine Foreland (Steiner et al. 2017). Such high densities mean that data at a high resolution can be collected from the samples and thus the core offers great inferential potential. The lack of sterile layers within the organic layer suggests that it resulted from likely relatively continuous accumulation of material. Loss of some material due to degradation is, however, probable. The thickness of the organic layer, the low number of wetland species,

the high number of crop remains and the finds of cultural artefacts such as pottery all strongly suggests that the organic layer is cultural in origin and reflects repeated activities in the pile-dwelling settlement.

Variation in the density and the exact compositions of samples shows that the organic layer is not perfectly homogeneous. The evident variation surrounds a continuous theme, with crop remains and gathered fruits and nuts overwhelmingly the most abundant items throughout. Thus, the slightly variable, but cohesive, densities and compositions suggest that the layer accumulated as a result of repeated plant-related activities, across an estimated 100 years, corroborated by evidence through the radiocarbon dates and tree felling dates through dendrochronological analysis (see REFERENCE Chapter in this book).

Glume wheats (einkorn and emmer) are the most abundant cereal taxa, followed by barley. The importance of glume wheats is particularly evident when unidentified glume bases are taken into consideration. Charred grains of einkorn, emmer and barley were all found. However, these are too few in number to make conclusions about the relative abundance of the different cereals. Emmer, einkorn and barley are consistently thought to be the most important crops throughout the Neolithic across Europe more broadly. In the Balkans this can be seen in charred assemblages from the Late Neolithic lakeshore site of Maliq, Albania (Xhuveli and Schultze-Motel 1995) and the Early-Middle Neolithic sites of Bâlgarcĕvo II, Bulgaria (Marinova and Popova 2008). The Early Neolithic site of Vrbjanska Čuka, situated in the Pelagonia Valley, North Macedonia show a similar spectrum of crops, but with a dominance of einkorn (Antolín et al. 2020). New Glume Wheat has been identified at some sites in the Balkans including the Middle-Late Neolithic site of Karanovo, Bulgaria (Kreuz et al. 2005).

The range of preservation conditions of glume bases, from uncharred to singed to lightly charred ('brown') to fully charred, is interesting in terms of crop processing methods. Some modern communities practising traditional crop processing methods have been known to singe glume wheats to scorch off awns prior to, or during, dehusking (Peña-Chocarro 1999; Peña-Chocarro and Zapata 2003). Such crop processing practices could explain why we find notable amounts of partially charred glume bases and some charred cereal awns. In terrestrial assemblages only fully charred material would survive. This gives us a more complete understanding of the contexts or conditions under which cereal chaff may become charred, than could be inferred from the charred assemblage alone.

Lentil, bitter vetch and pea are commonly found at prehistoric sites in southeastern Europe including Vrbjanska Čuka, North Macedonia (Antolín et al. 2020). Bitter vetch is valued for its low soil fertility requirements and drought tolerance, making it particularly attractive in areas with winter rain and hot summers, as is found in parts of the southern Balkans (Kreuz and Marinova 2017). Both pea and lentil appear important crops at Linearbandkeramik sites since the Early Neolithic. However, bitter vetch is not present at such sites until the Bronze Age. This perhaps relates to a climatic barrier preventing the adoption of certain crops in central Europe, and a lesser need for drought tolerant crops in temperate regions (Colledge and Conolly 2007; Kreuz and Marinova 2017). Kreuz and Marinova (2017) also note that Vicia species may have been a less desirable crop as many require additional processing than for instance peas and lentils, due to the poisonous testa which needs to be removed prior to consumption. Fragments of testa and detached pulse hila, closely resembling those of bitter vetch, were recovered from the samples, and these remains plausibly relate to food processing.

The numbers of charred oilseed crops, fruits and nuts and weed seeds are all too few to compare between the composition of the charred and uncharred components in each category. Thus, we are unable as yet to explore if there is a taphonomic or cultural bias relating to preservation type creating different proportions of different taxa, or to investigate the possible scenarios that resulted in these remains being charred. These lines of enquiry will become more feasible as additional cores are analysed.

While flax is known from many other sites in southeast Europe, such as at the Early Neolithic sites of Slatina and Kapitan Dimitrievo, western Bulgaria (Marinova 2007), no finds of opium poppy seeds are known in the area during the Neolithic period (Salavert et al. 2020). Other sites in the region, such as Vrbjanska Čuka have not yielded evidence for oilseed crops to date (Antolín et al. 2020). However, this absence may be due to a taphonomic bias, as oilseed crops, particularly poppy seeds, are unlikely to be preserved by charring (Märkle and Rösch 2008). Opium poppy seeds have been found in abundance in uncharred contexts in Neolithic sites in the pre-alpine (eg. Isolino Virginia, Italy (Banchieri et al. 2004) and northern alpine Foreland lake dwellings (eg. Zurich KanSan Schicht 2 (Bromacher and Jacomet, 1997; Jacomet, 2006), and from southwestern Europe, such as the Early Neolithic lakeshore site of La Draga, Spain (Antolín 2016; Salavert et al. 2020).Recent developments in geometric morphometric analysis may enable classification of the poppy seeds from Ploča, Mičov Grad as domesticated or wild subspecies (Jesus et al. 2021) and therefore contribute to a better understanding of the economic role of the plant at the site.

Many of the gathered fruits and nuts found at Ploča, Mičov Grad are well-known from other Neolithic sites in the Balkans and other parts of Europe. In the southwestern Balkans, such gathered fruits and nuts were similarly recovered from charred assemblages from the Early

Neolithic Macedonian site of Vrbjanska Čuka (hazelnut, blackberry, elderberry, strawberry and apple) (Antolín et al. 2020) and the Early Bronze Age phase of Sovjan, Albania (blackberry, fig, elderberry, cornelian cherry and physalis) (Fouache et al, 2001). However, there was a far greater range and number of collected taxa at Ploča, Mičov Grad. This may be due to preservation biases, as found by Colledge and Conolly (2014), that results in less diverse and numerous wild taxa surviving in charred assemblages.

A preliminary inference of the presence of autumn- and spring-germinating weed/wild taxa is that there was at least some autumn sowing, though additional spring sowing cannot be excluded. Similar observations have been made for the Early Neolithic Macedonian site of Vrbjanska Čuka (Mazzucco et al. in press).

The correspondence analysis suggests that there is a trend based on the depth of the samples in the core. However, the proportion of uncharred-versus-charred remains does not explain this pattern. Instead, the composition of the samples, particularly relating to proportions of fruits and nuts and oilseed crops, appears to explain the variation seen in the samples. Those to the top of the organic layer contain a larger proportion of oilseed crops, while those towards the bottom have higher proportions of fruits and nuts. The increase in oilseed crops towards the top of the organic layer particularly relates to an increase in opium poppy seeds and flax capsules, but not flax seeds, which are present in greater numbers in samples towards the bottom. These results will be compared to the three other lake cores and the bulk samples to assess whether these trends are representative of the whole settlement or specific to this core.

The results of the crop processing analysis suggest that the weed/wild taxa have similar attributes to those associated with fine sieving by-products. This fits with the high amount of

glume bases recovered from the samples, as such material would also be removed at this stage with the weed seeds (Hillman 1984; Jones 1984, 1987). This compatibility between the predominant crop and weed/wild composition of the samples suggests that the latter represent the arable weed flora associated with the glume wheats rather than originating from another source such as animal dung (cf. Charles 1998). Though rodent dung was ubiquitous in the samples, larger fragments of possible ruminant dung was a rare occurrence. Some of our samples are positioned below that of the fine sieving by-product. This finding is similar to that of other sites in central Europe such as the Early Neolithic site of Vaihingen, Germany (Bogaard 2011) and in southeast Europe such as the Late Bronze Age site of Assiros Toumba, northern Greece (Jones 1987). A possible explanation for this is given by Bogaard (2011) who suggests that different crop fields with different proportions of weed seed types could result in samples positioned outside the main group.

We carried out a functional ecological analysis of the weed/wild assemblage given the likelihood that the weed/wild seeds are arable weed seeds. The samples showed variable scores along the discriminant function, again highlighting variability through the core. The samples broadly align with the lower end of high-input regimes suggesting that the agrosystem at Ploča, Mičov Grad resembles modern agrosystems, that are relatively small-scale and labour intensive. High-input regimes, resembling gardens or cultivated patches, rather than typical modern fields, are associated with higher soil fertility and mechanical disturbance, due to labour intensive practices such as weeding, tillage and manuring. Sites from the Neolithic in southwestern Balkans, and southern Europe more broadly, generally do not have a wealth of weed data. As such, a major aim of this project is the collection of weed data for the reconstruction of the agroecology at Ploča, Mičov Grad. However, this means that, at present, it is hard to compare these results to contemporary and spatially proximal

sites. Variable discriminant scores, reflecting medium to high intensity conditions, can be seen at other Neolithic sites in central Europe such as the forementioned Vaihingen (Bogaard et al. 2016), the Early Neolithic Körös site of Ecsegfalva, Hungary (Bogaard et al. 2007; Bogaard et al. 2016) and Neolithic Çatalhöyük, Turkey (Green et al. 2019). A range of discriminant scores is not surprising, as this likely reflects the variability typically found in 'real' agrosystems with limited labour and thus shows the expected flexibility and pragmatism involved, influencing when and where labour is focused in such agrosystems (Bogaard et al. 2016).

The degree of similarity between samples shown by these initial analyses will be considered when assessing whether or not to amalgamate adjacent samples taken according to depth rather than visible variation in compositions. This decision will only be taken after analysis of archaeobotanical samples from a further three cores which appear to possess the same organic layer, in order to discern the stratigraphic relationship between samples and between cores. Ongoing work on these samples, including additional cores, aims to further increase our understanding of plant-related activity during the Late Neolithic at the site of Ploča, Mičov Grad, providing further data to explore trends in the diversity and abundance of different plant taxa, and strengthen inferences regarding crop processing techniques and agrosystems.

7.7 CONCLUSIONS

Waterlogged plant remains from a thick cultural organic layer relating to the lakeshore pile-dwelling site of Ploča, Mičov Grad, Lake Ohrid in North Macedonia, offer evidence for repeated plant-related activities during the Late Neolithic across an estimated 100-year occupation from the mid-5th millennium BCE. A range of cereal, pulse and oilseed crops were cultivated, together with a collection of varied fruits and nuts. The spectrum of cultivated and

collected plants is similar to others in the southwestern Balkans, but notably includes a greater number and range of collected plants and oilseed crops than many terrestrial sites, likely reflecting the broader preservation of waterlogged assemblages. These results will be compared to ongoing work on three further lake core samples and bulk samples from Ploča, Mičov Grad to explore intra-site and whole settlement trends. Evidence relating to crop processing techniques comes from partially charred glume bases and the characteristics of the weed/wild seeds, which resemble the arable weeds found in fine-sieving by-products. The results of the functional weed ecological analysis suggest that the agrosystem at Ploča, Mičov Grad was small-scale and labour-intensive. This aligns well with results from other Neolithic sites from southern and central Europe. Comparison to contemporary sites from the southwestern Balkans is limited due to little archaeobotanical research in this region and a lack of large weed datasets. The work presented here alongside ongoing work on further samples from Ploča, Mičov Grad and other EXPLO sites aims to contribute to efforts to fill this research gap in the southwestern Balkans, emphasising the potential of prehistoric wetland sites in this area to better understand the adoption and adaptation of agriculture and patterns of plant food use during the Neolithic.

7.8 ACKNOWLEDGEMENTS

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8.0 Appendix 4: Co-authorship statements

Following the article-based thesis route, I will be submitting three papers framed by a unifying introduction and discussion/conclusion for my DPhil assessment in lieu of a single monograph. Submission of an integrated thesis was approved by the Director of Graduate Studies on 17th October 2023. As part of a large and interdisciplinary project (ERC-synergy EXPLO project), the papers are co-authored by several colleagues to recognise their contributions to this work.

This first paper of my thesis presents the archaeobotanical dataset from the site of Ploča Mičov Grad. As such it is appropriate to recognise the contributions of many members of the EXPLO project. The paper will be co-authored by the following colleagues (ordered by role within the project):

- Amy Bogaard (supervisor)
- Michael Charles (supervisor)
- Elizabeth Stroud (advice regarding data analysis)
- Ferran Antolín (data collection, fieldwork and supervision of poppy seed analysis)
- Raül Soteras (sample processing, data collection and photography for poppy seed analysis)
- Stefanie Jacomet (primary data collection of one sample)
- Rachel Ballantyne (contributions to primary data collection methodology)
- Müge Ergun (contributions to primary data collection methodology)
- Rachel Wood (co-investigator on NEIF radiocarbon grant and advice on radiocarbon analysis)

- Andres Lotter (fieldwork)
- Johannes Reich (fieldwork)
- Goce Naumov (fieldwork)
- Willy Tinner (fieldwork and PI EXPLO project)
- Albert Hafner (fieldwork and PI EXPLO project)

I confirm that I conducted the vast majority of data collection and data analysis, prepared the figures and drafted the manuscript.

The second paper of my thesis is a synthesis of the archaeobotanical data with previously published palaeoecological data with analyses to investigate prehistoric land-use. It will be co-authored by the following colleagues:

- Amy Bogaard (supervisor)
- Michael Charles (supervisor)
- Lieveke van Vugt (palaeoecological data collection, analysis and interpretation)
- Sarah Brechbühl (palaeoecological data collection, analysis and interpretation)
- Erika Gobet (palaeoecological data analysis and interpretation)
- Elizabeth Stroud (advice regarding data analysis)
- Albert Hafner (fieldwork and PI EXPLO project)
- Willy Tinner (fieldwork and palaeoecological data analysis and interpretation).

I confirm that I conducted the vast majority of data analysis, prepared the figures and drafted the manuscript.

The third and final paper of my thesis will evaluate evidence for prehistoric pulse processing and pests. It will be co-authored by the following colleagues:

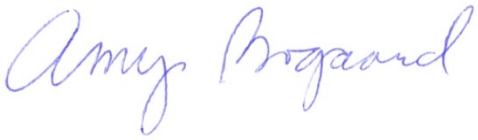
- Amy Bogaard (supervisor)
- Michael Charles (supervisor)
- Eva Panagiotakopulu (entomological data collection).

I confirm that I conducted the vast majority of data collection and data analysis, prepared the figures and drafted the manuscript.

Sincerely,



Amy Holguin



Amy Bogaard (supervisor)



Mike Charles (supervisor)

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,
Elizabeth Stroud

Date: 11/03/2024
Contact email: Elizabeth.stroud@arch.ox.ac.uk

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,



Ferran Antolín
Contact email: ferran.antolin@unibas.ch

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

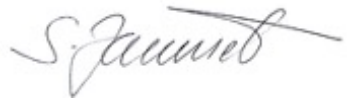
Sincerely, Raul Soteras

Contact email: raulsoteras_portraits@hotmail.com ; raul.soteras@dainst.de

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,



Date: 1 march 2024
Contact email: stefanie@jacomet.ch

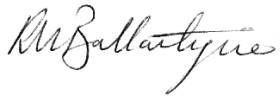
Dr Rachel Ballantyne
School of Archaeology
University of Oxford
1 South Parks Road
Oxford OX1 3TG

11th March 2024

To the Graduate Studies Committee,

I am writing as co-author of one of the papers, *Living by the lake: diverse plant foods of a prehistoric pile-dwelling in North Macedonia*, included in the DPhil thesis of Amy Holguin to confirm that she contributed the majority of the work in the preparation of this article.

Yours faithfully,



Contact email: rachel.ballantyne@arch.ox.ac.uk

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,



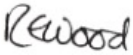
Müge Ergun

Contact email: muge.ergun@arch.ox.ac.uk

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,



Dr Rachel Wood

Contact email: rachel.wood@arch.ox.ac.uk

To the Graduate Studies Committee

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,



PD Dr. André F. Lotter

Date: 7 March 2024
Contact email: andre.lotter@unibe.ch

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of the article on the archaeobotanical assemblage of the site Ploča Mičov Grad, North Macedonia.

Sincerely,

Johannes Reich

Contact email: johannes.reich@unibe.ch

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,
Asst. Prof. Goce Naumov

Date: 12.03.2024
Contact email: gocenaumov@gmail.com

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,

Date: 7 March 2024
Contact email: willy.tinner@unibe.ch

UNIVERSITÄT
BERN

Philosophical-Historical Faculty

Institute of Archaeological Sciences
Prehistoric Archaeology

Oeschger Centre for Climate Change Research OCCR

Prof. Dr. Albert Hafner

Bern, 6. März 2024

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,

Date: March 6th, 2024
Contact email: albert.hafner@unibe.ch

Albert Hafner



Prof. Dr. Albert Hafner
Director
Institute for Archaeological Sciences
Prehistoric Archaeology
Mittelstrasse 43
CH-3012 Bern/Switzerland

Secretary +41 31 684 58 20
Direct +41 31 684 58 25
albert.hafner@unibe.ch
www.iaw.unibe.ch

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,
L. van Vugt

Date: 7/3/24
Contact email: lieveke.vanvugt@unibe.ch

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,

Sarah Brechbühl

Date: 03-14-2024
Contact email: sarah.brechbuehl91@gmail.com

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,
Erika Jobet

Date: 7. 3. 24
Contact email: E. Jobet

To the Graduate Studies Committee,

I am writing as co-author of one of the papers included in the DPhil thesis of Amy Holguin to confirm that she contributed to the majority of the work undertaken in the preparation of this article.

Sincerely,

Eva Panagiotakopulu



Contact email: eva.p@ed.ac.uk