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Food for Thought: An Analysis of the Robenhausen Botanicals at the Milwaukee Public Museum

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FOOD FOR THOUGHT: AN ANALYSIS OF THE ROBENHAUSEN BOTANICALS AT THE MILWAUKEE PUBLIC MUSEUM

by

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ABSTRACT

FOOD FOR THOUGHT: AN ANALYSIS OF THE ROBENHAUSEN BOTANICALS AT THE MILWAUKEE PUBLIC MUSEUM

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Under the Supervision of Professor Bettina Arnold

Museum collections excavated from archaeological sites represent an intersection of disciplines and provoke innovative approaches to the study of these material aspects of culture. Botanical collections of food remains in particular, provide an opportunity to interrogate the way in which culinary practices in the past are understood. The circum-Alpine lake dwelling complex of central Europe includes hundreds of archaeological sites dating to the Neolithic, Bronze, and Iron Age; many of these sites are known for exceptional preservation of organic material due to a waterlogged, anaerobic environment. Robenhausen, located in eastern Switzerland was one of many lake dwellings discovered in the 19th century when these sites first became known to the archaeological community and the general public. Because of this early discovery date combined with a variety of other circumstances, material culture from this site and many others was part of an artifact diaspora which scattered objects from Robenhausen throughout museums in the U.S. and Europe. Artifacts from this site were rediscovered in the Milwaukee Public Museum's permanent collection in the early 2000s and include over 8000 plant and food remains, most of which are carbonized and have remained intact for over a century since their removal from the site in Switzerland. This thesis uses a combination of

approaches including scientific reporting, macrobotanical identification, experimental archaeology, and theoretical interpretation based in foodways research to interpret this collection of botanical remains. In addition, this project digitally reunites the food and botanicals from Robenhausen with those scattered throughout other museum collections and contributes to our understanding of the complex nature of foodways at the Robenhausen site during the Late Neolithic and Bronze Age.

This Thesis is Dedicated to:

My daughter Elora, for your love, laughter, and smiles

and for inspiring me to continue on this journey

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Chapter I Introduction

1.1 Thesis Background

Sometime between 3900 and 1000 BC there were six periods of occupation at a site in what is now Switzerland on the shore of a lake, by a river. These settlement periods each lasted for several decades and at least one ended in a catastrophic fire, the flames of which engulfed many components of material culture including large quantities of stored foods, primarily cereal grains and crab apples. When these occupations ended, rather than disintegrating, the pieces of material culture and remains of this small settlement were preserved due to their carbonization by fire and the anaerobic, alkaline environment created by the peat bog that covered the site. Robenhausen in west-central Europe was one of many sites inhabited by Neolithic, Bronze, and Iron Age peoples who lived on raised platforms over and along lakeshores in the circum-Alpine region and are known as pile or lake dwellers. What is left of these people now are the remains of more than one thousand settlements spread across six countries and a series of collections in museums across the globe where they were frequently separated by material category, providing a window into this culture and the daily lives of these lake dwellers.

The Milwaukee Public Museum (MPM) Robenhausen botanical collection is part of a larger whole that includes other artifact categories. In a broader sense, the objects at the MPM represent one subset of a greater Robenhausen collection, found in museums primarily but not exclusively in Europe and the U.S. However, the scattered and disjointed situation in which these collections exist does not prevent comprehensive analysis or interpretation of the material. In fact, many similar lake dwelling sites have undergone modern excavations, yielding so many ecofacts and artifacts that they require teams of specialists working for years in order to examine

and document everything. In the case of the MPM botanical collection, this small subset of the larger body of objects from the Robenhausen site provides the opportunity for careful examination and should be viewed as a boon rather than a hinderance. One important goal of this thesis was to make this data available to other researchers and to provide written and digital access to the collection. The other main focus of this project was the assessment of the MPM Robenhausen botanical material in order to understand the people for whom these were not just datasets of plant species and food remains, but rather meals, stores of food to survive the winter, and a deeply imbedded aspect of their culture and way of life.

The circum-Alpine lake dwellings of central Europe spanned the late Neolithic through the Early Iron Age from 4300 to 800 BC. While many cultures in Europe primarily relied on agriculture during this period, the people of this cultural complex based their subsistence on a mixture of domestic plants and animals while also exploiting wild resources. In addition, while the small villages that they inhabited were often occupied repeatedly, individual periods of occupation usually only spanned a few decades at a time. They disposed of their dead in what is called the invisible rite, since there is minimal evidence of any mortuary practice and human skeletal remains are only rarely found. These cultures are known for excellent wood and textile craftsmanship, linear iconography without representations of people, and the unstratified communities in which they lived. Their strategic location during the European Bronze Age was especially significant because they were at the center of a continent-wide trade network that linked the far reaches of Europe and dealt in tin, copper, and exotic materials.

Robenhausen was a lake dwelling settlement occupied during the Late Neolithic and Bronze Age between 3900 and 1000 BC. The Robenhausen site is located on the shores of Lake Pfäffikon near the modern town of Wetzikon about 20 kilometers east of Zürich. The site itself

is known for its excellent organic preservation even for a lake dwelling, which is due to the peat bog on the south shore of the lake where the settlement was located and to the carbonized state of some of the material culture that is primarily the result of two site-wide fires. One of the most prevalent interpretations of Robenhausen is that it was a lake dwelling specializing in flax production and textile manufacture (Altorfer 2010, 2000; Barber 2000; Leuzinger and Rast-Eicher 2011; Lillis 2005). This is due to the large quantities of linen found at the site, some of which were preserved due to charring, while others disintegrated when they were removed from the peat bog. The location was found a few years after the initial lake dwelling site discovery at Obermeilen, in 1858, by a farmer called Jakob Messikommer. The circum-Alpine lake dwellings captured the spirit of the time and their discovery coincided with nascent museum development. This led to a diaspora of cultural material from lake dwelling sites to museums in the U.S. and Europe as a burgeoning antiquarian-collector exchange system took root. As a consequence, material from Robenhausen is part of many 19th century museum collections including the Milwaukee Public Museum, where the collection under study is located. The botanical material presented here is one component of a larger collection including textiles (Lillis 2005), bone and antler (Johnson 2006), tools, pottery, wood implements, and stone tools.

1.2 Theoretical Background

Foodways are defined as the activities, rules, contexts, and meanings that reflect, construct, and challenge norms through the mediums of food production, harvesting, processing, consumption, preparation, storage, service, and discard (Graff 2018: 306; Peres 2017: 423; Twiss 2012: 358). While food itself is a biological necessity, the regularity and repetition of these acts make it inextricable from its cultural significance (Twiss 2012: 360). As such, foodways are part of what Bourdieu defines as *habitus* or the reproduction of society through the actions of

individuals (1977). While daily and special or ritual consumption are often considered distinct, the foodways perspective considers everything consumed by an individual or community (Peres 2017: 422). Taking a unified approach to food allows for other comparisons to be made including temporal, spatial, and cultural differences (Peres 2017: 423). The study of food in archaeological contexts often relies on the premise that differences in diet and food related activities are equivalent to inter- and intra-societal divisions and that changes in foodways are indicators of negotiations related to social difference (Twiss 2012: 358, 367). The archaeology of foodways can be subdivided into two specialties in archaeology: zooarchaeology and paleoethnobotany, the latter of which is biased toward the by-products of food processing rather than the end-products, which are generally consumed (Peres 2017: 424). Foodways can be understood by using these two methods separately or in coordination, applied to direct and indirect evidence (Graff 2018).

One aspect of foodways research focuses on subsistence strategies, defined as the dominant mode of food acquisition (Peres 2017: 423). From this perspective, individuals and groups can be seen to engage with food in an evolving trajectory over time (from hunting and gathering to raising animals and growing crops to trade and acquisition) and through systematic activities that occur in a certain order (in the case of grain processing: threshing, winnowing, course sieving, parching and pounding, fine sieving, and storage, for example)(Figure 1.1)(Twiss 2012: 361-362). The application of the concept of *chaîne opératoire* helps to disentangle the web of activities involved in the process that begins with raw materials and ends with a meal (Graff 2018: 309; Twiss 2012: 362). These operational sequences are often lengthy and complex because, while fresh food is considered valuable, some foods can only be eaten after some degree of processing and many foods require multi-step processing and cooking prior to

consumption (Fuller and Carretero 2018: 110; Hastorf 2017: 91). Staple foods, especially grains, usually belong to this latter category and have been the object of many ethnoarchaeological studies focused on the types of archaeological remains that result from certain processing activities. These studies examine the distribution of grains within a structure (Dennell 1972), the percentages of different components in an assemblage after the performance of a specific processing activity (Dennell 1974; Jones 1990, 1996) or how weed types and percentages can be used as an indication of the time of year that an assemblage was harvested (Bogaard 2004; Bogaard et al. 2005). The steps needed to process many foodstuffs, including grain, are often split into two groups: post-harvesting activities and pre-consumption or cooking activities (Twiss

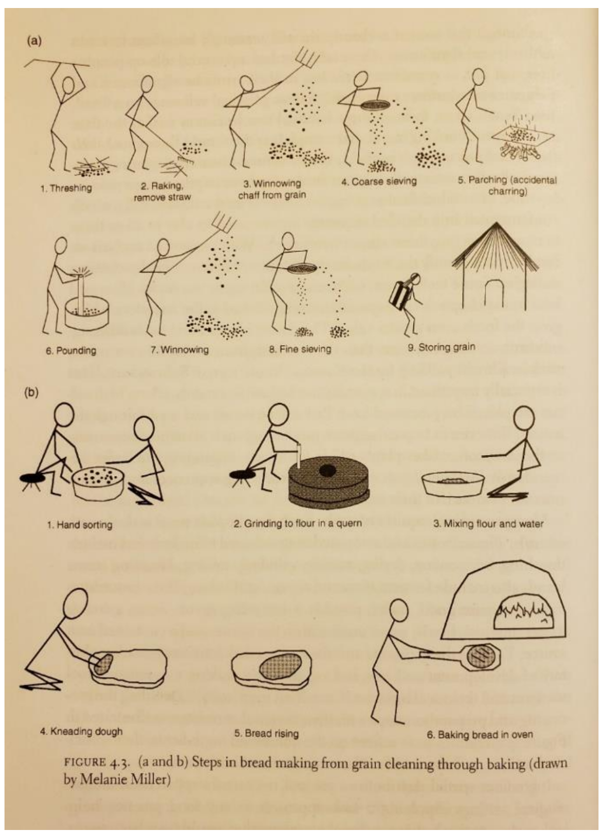

Figure 1.1: Steps involved in grain processing and breadmaking (after Hastorf 2017: Fig. 4.3).

2012: 362). Foodways approaches also examine the relationship between food and craft production related to food by focusing on whether the same individuals produce food and the craft goods related to it (Graff 2018: 318). Other important aspects of food related material culture are the tools used to harvest grain, including analyses of post-processing plant parts in archaeological assemblages, which can illuminate not just the equipment used, but also the actions of the individual (Hillman 1973).

The Neolithic has long been known for the development of domestic plants and animals, and more recently for the introduction of complex cooking techniques and production based luxury foodstuffs, including cereal products (Fuller and Carretero 2018; Hayden 2003). The idea that an associated set of tools and activities accompanies each new plant adopted as a food source suggests the idea of parallel regional Neolithic transitions called *Neolithicities* (Fuller and Carretero 2018). An example of this is the adoption of bread as a staple food in the Pre-Pottery Neolithic Near East while porridge was the primary form of cereal grain consumption in East Africa, where pottery, specifically the bowl, preceded the adoption of cereal domestication (Haaland 2007). This is just one example of the types of distinct regional *Neolithicities* that might have linked communities and influenced consumption patterns, processing techniques, the character of food, and the ability of these things to shape the way that culture is constructed (Fuller and Carretero 2018). Stemming from this is the concept of cuisine, which is affected by the soil and climate of a region and can be described using the term *terroir* (Peres 2017: 423). The food signature of a group can also be reflected in the sensory qualities of food that don't leave an archaeological signature, for instance, the smell of a particular dish, which is often an important ethnic signifier (Twiss 2012: 380).

The theoretical perspective of foodways provides many specific insights that can be applied to small-scale farming. One aspect of this is storage, which can illuminate both privatization of resources and the economic autonomy of household units (Twiss 2012: 370). When incorporating storage data into interpretive models, one key insight is that material remains may only represent one component of the sum total of a household or settlement's total capital since live animals, unharvested fields, and reciprocal relationships are also forms of food resources (Twiss 2012: 370). Another important aspect of small-scale farming is represented by the decision-making processes of the individual and whether these are based on practical considerations or cultural mores and traditions (Kardulias 2008:110). Temporally speaking, agriculture and specifically the daily, repeated, and seasonal, activities encompassed by a yearly routine, combine time and the landscape in an interplay of habitual action (Bogaard 2004: 3). This interplay creates and reproduces social identities and helps form institutions that make up and differentiate cultures and societies (Bogaard 2004: 3).

Applications to the study of lake dwellings using the foodways framework indicate the importance of understanding depositional processes and preservation factors (Twiss 2012: 375). For example, carbonization acts as a preservative of floral remains when it occurs to a specific degree, except in cases of anerobic preservation (Twiss 2012: 375). All areas of archaeological study are impacted by food and food security, which creates a cultural atmosphere in which people can pursue other creative aspects of life such as art, construction, and experimentation (Peres 2017 445). At the same time, foodways research explores catastrophic events, which interrupt food resources (Peres 2017: 445). When large amounts of edible plant material are preserved at a settlement, this is often indicative of an accident, since this material was brought to that location in order to be consumed whereas quantities of plant by-products are more likely

to indicate that normal activities took place without interruption (Twiss 2012: 376). In addition, low levels of plant diversity are more commonly associated with short term occupations and don't necessarily reflect a restricted diet compared to a long-term occupation that often appear to exhibit higher plant diversity (Twiss 2012: 378).

1.3 The MPM Robenhausen Collection

The process of analyzing the Robenhausen collection at the Milwaukee Public Museum began in the early 2000s when Curator of Anthropology, Dawn Scher Thomae was conducting a collections inventory and located a box labelled French Paleolithic/Swiss Neolithic in basement storage. She contacted Bettina Arnold, UWM Anthropology Professor and Adjunct Curator of European Archaeology for the MPM. Dr. Arnold recognized the significance of the Robenhausen material because it is found throughout museum collections in the U.S. and Europe. She became interested in the documentation and analysis of these collections as a means of recovering context information about the site, supervising two theses on textiles (Lillis 2005) and bone and antler tools (Johnson 2006) from the site. The ceramic material is currently being studied by another UWM Anthropology Masters student (Annis, forthcoming), while the lithics and wood implements, still await study. The botanical material and food remains from the site that are the focus of this thesis include carbonized apples, carbonized cereal grains, carbonized bread, and hazelnuts.

Most of the material from Robenhausen outside Switzerland lacks context due to the nature of the excavation methods used when it was removed from the site during the second half of the 19th century (Altorfer 2010; Arnold 2013). For example, Jakob Messikommer, the original excavator of Robenhausen used a raft fitted with a pump system to recover artifacts from the peat bed of the Aa River that bisected the site and brought many objects to the surface without noting

their provenience (Altorfer 2010: 27). This method was lamented by the excavator himself at the time; however, the high cost of other excavation methods was bankrupting both his family and the Zürich Antiquarian Society (Altorfer 2010: 27). In addition, the botanical material is only a small part of the total material retrieved from the site due to the dispersal that occurred between 1858 and 1917, the longest Swiss lake dwelling excavation in history (Atorfer 2010: 24). During this period, Messikommer sold material from the site to many different collectors and museums in order to pay for the ongoing excavations at the site.

All of this background information combined to raise the question of what the most relevant analytic approach for this botanical material would be, keeping in mind that the MPM collection is only a small part of a larger collection and comes from different occupation periods and different parts of the Robenhausen settlement. In addition, the material was sourced by three collectors and became part of the MPM collection at different dates in the early 20th century. As a result, the material under study for this project does not comprise a cohesive collection. Furthermore, because these objects had not been studied since they were first removed from the site in the late 19th century, they had not been subjected to modern analytical techniques. Finally, due to a variety of factors, there are inaccuracies in the catalogue descriptions of the botanical material.

1.4 The Lake Dwelling Diaspora

Although the 150th anniversary of the discovery of the lake dwellings took place in 2004, in the 21st century U.S. there is little interest in or awareness of the prehistoric circum-Alpine cultural complex (Arnold 2013). This lack of public awareness is a recent phenomenon, however; in fact, during the first half of the 20th century the central European lake dwellings were well known and were the subject of exhibits at many large U.S. museums. One such

exhibit at the MPM was removed from display in 1982 (Dawn Scher Thomae, pers. comm., 2018) and another at Harvard was removed from display in 1984 (Bettina Arnold, pers. comm., 2018). In addition, lake dwellings were once the subject of advertisements, children's books, and many other aspects of popular culture (Figure 1.2)(Arnold 2013: 877; Schöbel 2004: 221). More specifically and for a variety of reasons, the Robenhausen site has also become less prominent in terms of lake dwelling interest considering its high esteem in the eyes of early lake dwelling experts (Altorfer 2000: 1).

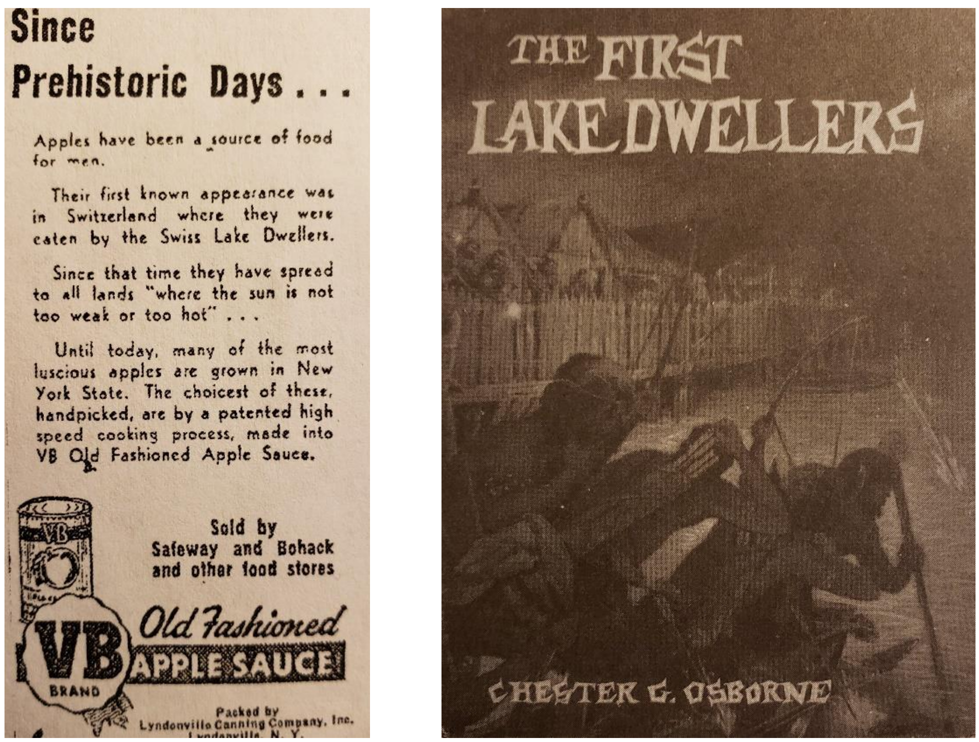

Figure 1.2: An ad for apple sauce (left)(*New York Times* 1944) and the cover of a children's book (right)(Osborne 1958, after Arnold 2013: Fig. 52.4).

Lake dwelling sites have been linked to museums since their discovery and there are a number of reasons for this. First, the discovery of the lake dwellings coincided with nascent museum development and a burgeoning antiquarian-collector industry (Arnold 2013). Second,

the underwater locations of many sites prevented the possibility of *in situ* preservation of material culture, meaning that lake dwelling artifacts could not be kept in their original locations for public display (UNESCO). Finally, the zeal with which the discovery of lake dwelling cultures was greeted by the public required the display of artifacts at accessible locations especially in Europe (Schöbel 2004: 222-225). Between 1860 and 1930, lake dwelling sites were treated as a plentiful resource for archaeological remains where both individual collectors and museum curators could acquire objects (Pétrequin and Bailly 2004:36-37).

The lake dwelling artifact diaspora was different from other material culture collecting sprees for a number of reasons. One difference was that, in the late 19th century, individuals defined as antiquarians or collectors were in some cases more comparable to looters by today's standards (Arnold 2013: 876). Another distinction is that this diaspora involved material culture related to daily life in Europe rather than exotic objects from ancient civilizations such as Egypt (Arnold 2013: 876). In addition, this process took place while burgeoning institutions were building their collections during what can be considered a defining period of growth for U.S. and European museums (Arnold 2013: 876). At the close of this developmental phase at the end of World War I, every large institution on either side of the Atlantic had a lake dwelling collection that had passed from excavators to museums through the hands of a complex network of antiquarian-collectors (Arnold 2013: 876). This material was then used to fuel public interest and provide general information about Neolithic daily life which carried through the middle of the 21st century (Pétrequin and Bailly 2004: 37). Unfortunately, during this period of time, little attention was paid to specific details of daily life or chronology (Pétrequin and Bailly 2004: 37). Another issue unique to the lake dwelling material is that the removal of cultural items from Switzerland was conducted by people of western and central European descent, complicating

questions of repatriation and ethics (Arnold 2013: 876-877). Finally, while large quantities of lake dwelling material are part of the collections of many museums in the U.S., in most cases, this material has not been exhibited or studied in the last few decades (Arnold 2013: 877).

Due to the artifact diaspora described above, many museums, primarily but not exclusively in the U.S. and Europe, have material from the Robenhausen site in their collections. Some of these museums include the Ortsmuseum Heiden, the Museum Wetzikon, the Landesmuseum in Zürich, the Musée des Antiquités Nationales in St. Germain-en-Laye, the Heimatmuseum am Pfäffikersee, the Rosgarten Museum Konstanz, the Historisches Museum Bern, the Museum der Kulturen Basel, the Historisches Museum St. Gallen, the Münzkabinett und Antikensammlung der Stadt Winterthur, the Museum zu Allerheiligen Schaffhausen, the Musée d'Art et d'Histoire Genéve, the Museum für Vor- und Frühgeschichte der Staatlichen Museen Berlin, the Abbey Museum in Australia, the Milwaukee Public Museum, the Smithsonian National Museum of Natural History, the Chicago Field Museum, the Oxford Archaeology Museum, the British Museum, the Berlin Museum, the Peabody Museum of Archaeology and Ethnology, the Museum of Archaeology and Anthropology at the University of Pennsylvania, the Cambridge Archaeological Museum, and the Ashmolean and Pitt Rivers Museums at Oxford University (Altorfer 2010; Jackson 2006).

1.5 Milwaukee Public Museum Robenhausen Botanical Collection Donors

The MPM Robenhausen botanical material was donated to the Milwaukee Public Museum by three individuals: Charles Dörflinger, Adolph Meinecke, and J.A. Renggly (Renggli). All three of these men were European immigrants to the U.S. who lived in Milwaukee and were involved in the early years of the Milwaukee Public Museum in different ways and to varying degrees. Charles Dörflinger was the MPM's first director and is known to

have travelled personally to Switzerland where he visited the Robenhausen excavation site in 1893; his name appears in the logbook kept by the excavator, Jakob Messikommer (Arnold 2013: 881). The material that he brought back from the site was first loaned, then eventually sold to the MPM in 1913 (MPM Archives). Dörflinger's contributions to the MPM Robenhausen botanical collection include five catalogue numbers containing a carbonized hazelnut shell, uncarbonized whole hazelnuts, carbonized apples, and charred cereal grains.

Adolph Meinecke, also a German immigrant and a member of the MPM's first board of directors, visited Europe and brought back artifacts that he donated to the MPM in 1901. His contributions to the MPM Robenhausen botanical collection include four catalogue numbers containing carbonized apples and cereal grains. J.A. Renggly is the most mysterious of the three men: it is unclear whether mentions of Renggly and Renggli in the MPM archives refer to the same person. There is information about a man called Renggly who was a veterinarian in Switzerland but appears to have advertised himself as a medical doctor when he emigrated to the U.S. However, there are also mentions of a faunal expert in Europe who worked with the lake dwelling material and it is unclear if this was the same person. Renggly gifted lake dwelling material to the MPM in 1901, including carbonized bread, carbonized apples, and charred cereal grains. Each of these three collectors also donated non-botanical material from Robenhausen to the MPM and there are several other donors who contributed additional objects, but not botanical material, from the site to the museum (Table 1.1).

1.6 The Possibility of Forgery

As discussed in the previous section, the MPM Robenhausen collection includes material from J.A. Renggly (Renggli), a somewhat mysterious character involved in the early days of the Milwaukee Public Museum. The material donated by Renggly includes all of the carbonized

Table 1.1: MPM Robenhausen botanical collection donor and catalogue information.

Catalogue Number	Catalogue Date	Accession Type	Donor/Seller	Collected By	Date Collected	Catalogue Description
10128	1901	Gift	Renggly			Charred Bread
10129	1901	Gift	Renggly			Charred Cultivated Apples
10130	1901	Gift	Renggly			Charred Wheat and Barley
10131	1901	Gift	Renggly			Charred Wild Apples
10158	1901	Gift	Meinecke			Charred Barley
10159	1901	Gift	Meinecke			Charred Wheat
10161	1901	Gift	Meinecke			Charred Wild Apples
10672B	1903	Gift	Dörflinger			Hazelnut
15046	1913	Purchase	Dörflinger	Messikommer	1892	Charred Wheat and Barley
15047	1913	Purchase	Dörflinger	Messikommer	1892	Charred Crab Apples
15048	1913	Purchase	Dörflinger	Messikommer	1892	Hazelnuts (Well Preserved)
15049	1913	Purchase	Dörflinger	Messikommer	1892	Lot of Charred Grain (*Triticum*)

bread fragments, the majority of the carbonized apples, and more than half of the cereal grains discussed in this thesis. During the lake dwelling diaspora, there was a period of pastiche artifact manufacture, when lake dwelling objects and material were used to create composite tools and implements (Arnold 2013: 878). Because representative collecting was one of the main drivers of continued lake dwelling acquisition by museums, creating new artifact classes ensured continued sales for collectors who were willing to engage in such dubious practices. In the case of the MPM Anthropology collection, several objects, mainly lithics, donated by J.A. Renggly and attributed to the central European Neolithic were discovered to be objects from the Scandinavian Bronze and Iron Ages (Bettina Arnold, pers. comm., 2018). Because of this and

combined with the possibility that Renggly falsified his educational credentials to become a doctor in the U.S. when he was trained as a veterinarian in Europe, the Robenhausen botanical material which he gifted to the MPM in 1901 is called into question. Early attempts in the course of this thesis research sought to radiocarbon date the materials that Renggly contributed in order to verify their temporal attribution, but funding for this part of the project was not forthcoming. During the course of this research, the botanical material donated by Renggly was examined for any indications that they might have been falsified in some way, but none were found. In addition, since Renggly donated this material rather than selling it, there would have been no financial benefit to forging the botanicals. Finally, many objects donated by Renggly to the MPM have been verified as legitimate artifacts (Bettina Arnold, pers. comm., 2018). Since throughout the course of this project, no methods of analysis indicate forgery, all botanical materials in the MPM Robenhausen collection including those specimens donated by Renggly, can be assumed to be legitimate. The succeeding chapters will discuss all botanical materials from Robenhausen without caveat and assume that a straightforward approach to the MPM collection is warranted.

1.7 Terminology Choices and Important Definitions

The Robenhausen site on Lake Pfäffikon in Switzerland is the source of this study of lake dwelling material at the MPM. However, some modern sources, including UNESCO documentation, refer to it as Wetzikon-Robenhausen, because Robenhausen is a locality in the town of Wetzikon and many lake dwelling sites are given hyphenated names based on their locality and a modern, civic affiliation. For this thesis Robenhausen will be used to refer to the site for the purposes of simplicity and because it is the name used to refer to this collection in all associated MPM documentation. Another choice of terminology for this thesis was the use of

the terms “lake dwellings” and “lake dwellers”. However, pile dwellings and pile dwellers, terms that are more common in Europe, are also used in some cases. Pile dwelling tends to be used more frequently in Europe because *Pfahlbau*, which is the German term, translates as pile or post, dwelling. Since this thesis involves a collection in a U.S. museum and because this material is referred to as a lake dwelling site in all MPM documentation, this is the primary term used for this thesis.

As described above, in most cases, the terms “lake dwelling” and lake dweller” were used to describe Robenhausen and other sites in the region. For the purpose of clarification, it must be stated that there are many different modern and prehistoric lake dwellings around the world, within Europe, and even within central Europe. For example, the country of Benin in West Africa is home to a group of lake dwellers with populations on some large lakes numbering in the tens of thousands (Pétrequin and Pétrequin 1984) and during the Iron Age in Scotland, people built artificial islands called crannogs in the center of lakes and lived on them (Coles and Coles 1989). Even within central Europe during the Middle to Late Bronze Age, a group called the Terramare lived in the Po Valley in northern Italy in houses built on raised platforms that were sometimes surrounded by water or built near lakes. However, the lake dwelling culture that is the subject of this thesis is different from any of these groups, despite being proximal and contemporaneous to the latter.

A final note of clarification must be included here related to the contents of the Robenhausen botanical collection, specifically the material described in the catalogue as charred bread. There are fourteen fragments of this material and in subsequent chapters these will be divided into categories and described in greater detail. Beginning with Hansson (1994), archaeological materials initially described as bread were reexamined and often reassigned to

other categories such as porridge after analysis. Bread in prehistory was defined differently than modern bread since it often included other elements, such as weed seeds. Recent examinations of bread from central European lake dwelling sites have found non-seed elements such as celery pericarp as a constituent using SEM identification (Heiss et al. 2017). Recent studies also question the assignment of prehistoric foods to modern categories and suggest that the continuum along which such materials exist includes many different types that can be defined separately (Valamoti et al. 2019). This last assertion was corroborated by the findings discussed later in this thesis. The most recently published analysis of this type of material discusses the importance of unified terminology in the literature regarding food made from primarily cereal grains (Heiss et al. 2019). Based on the recommendations presented in this discussion, the terms cereal preparation and cereal product will be used to refer to objects described as bread in the MPM catalogue. This helps to avoid assumptions that a certain chain of operation occurred in the post-harvest and pre-consumption production process (Heiss et al. 2019).

1.8 History of Robenhausen Botanical Studies

The plant material from Robenhausen and other lake dwelling sites was first studied by Swiss botanist Oswald Heer, who recognized the significance of the assemblage (Figure 1.3). Heer’s 1865 monograph *Die Planzen der Pfahlbauten,* which was included in Keller’s 1866 volume *The Lake Dwellings of Switzerland and Other Parts of Europe,* is still relevant to lake dwelling plant studies today. In this initial catalogue of the species from Robenhausen, Heer listed 82 different plant species (Appendix A)(Altorfer 2010:104). He was the first to identify *Triticum antiquorum* or small lake dwelling wheat, which he described as a separate species similar to *Triticum durum.* Small lake dwelling wheat is now extinct and was apparently unique

Figure 1.3 Swiss botanist Oswald Heer (1809-1883).

to the lake dwelling region (Jacomet and Schlichtherle 1984). The pioneering work by Heer was followed by two botanists who examined specific components of the Robenhausen collection: Jakob Jaggi, who wrote a treatise on water chestnut (*Trapa natans*), and Carl Hartwich, who studied the opium poppy (*Papaver somniferum*)(Altorfer 2010: 104). The next Robenhausen plant studies were conducted by Carl Schröter, a professor in Zürich, and Fritz Netolitzky, who studied coprolites from the site (Altorfer 2010: 104). Ernst Neuweiler described the plants from Robenhausen, including 113 taxa in his 1905 botanical overview (Altorfer 2010: 104). It is interesting to note that eight years later, Heinrich Messikommer, the son of the Robenhausen excavator Jakob Messikommer, produced a list composed of only 90 plant species (Altorfer 2010: 104). Most recently, W.H. Schoch and Renata Huber, the latter of whom studied plant material recovered from a scuba diving recovery in 1999, generated an updated list which was the basis for the table in Appendix A and included 136 taxa (Altorfer 2010: 107).

1.9 Thesis Goals

This thesis had five primary goals, some of which address the entirety of the collection while others focused on specific components. The first three goals focused on the research utility of the collection, while the last two represent archaeological and museological professional contributions, as follows:

1) To identify the cereal grains in the collection to the species level where possible and rehouse this material to reflect this new organization.
2) To determine whether the cereal products and crab apples described in the collection have been correctly identified and assess variations between lots using experimental techniques.
3) To interpret the information from the above methods using an interdisciplinary theoretical framework to demonstrate its significance within the broader spectrum of Robenhausen and lake dwelling botanical studies and make this information available to other scholars.
4) To document the current state of the collection, including photographing, housing, and labeling all organic material.
5) To rehouse the collection to improve accessibility and prevent degradation of the material.

1.10 Chapter Summaries

This thesis provides a multifaceted history, analysis, and discussion of the MPM's Robenhausen botanical collection, situates the collection regionally, temporally, and contextually within a broader research framework, and describes the collection in terms of its anthropological,

museological, and botanical significance. Chapter I begins with a description of the thesis background and the impetus for conducting this research. This is followed by a definition and description of foodways theory, which was used to approach this analysis of lake dwelling plants and food remains. The next section describes the MPM Robenhausen collection, followed by three sections that discuss the background of lake dwelling museum collections and the historical environment in which this collection developed, the donors of the MPM's Robenhausen material, and some potential issues related to one of these donors. This chapter also provides a series of explanations and definitions for some of the terminology used in this thesis. The next section briefly describes the history of Robenhausen botanical studies, and the chapter concludes with a summary of the goals of the research project.

Chapter II focuses on the background of the lake dwellings and the Robenhausen site and is divided into five main sections. The first part describes the geography, climate, flora, and fauna of the Alpine Region that is home to Robenhausen and the lake dwelling cultural complex. The next section presents the broader regional and temporal context of the site, including the time periods in central European prehistory spanning the Mesolithic to the Bronze Age with a focus on the adoption of domestic plants during the Neolithic. These sections are followed by a description of the circum-Alpine lake dwelling cultures, their main characteristics, and their discovery. The next section narrows in scope, surveying Robenhausen, its artifacts, and focusing on the particular qualities of the site and its botanical assemblage. The final section of this chapter describes excavations at lake dwellings including a brief overview of botanical studies and the process through which some of these sites became a UNESCO world heritage site.

Chapter III outlines the methods used to approach the Robenhausen botanical material in this thesis research project, beginning with a brief discussion of the significance of Robenhausen

within the context of paleoethnobotany. The next section describes the process of scientific documentation starting prior to any work being done on the botanical material and concluding after all analyses were complete. This part of the chapter includes an abbreviated version of the expected flora table found in Appendix A, including the plant species which occur at Robenhausen and some of the museum collections that house specimens of each species. The following section includes species accounts of each of the major plant and food categories in the MPM Robenhausen collection with some basic botanical and archaeological information. Floral identification was an important goal of this thesis and the subsequent paragraphs describe the process used to identify the different species of cereal grains, seeds, and organics in the collection. The final part of this chapter describes the process of building a comparative collection and the experimental methods used to interpret the cereal products and apples in the Robenhausen collection.

Chapter IV describes the results achieved based on the application of the various analytical methods discussed in the previous chapter, beginning with a summary of the initial state of the collection including the housing of the botanical materials and followed by a description of the results of the scientific documentation of the botanical remains. The heart of the analysis chapter includes individual sections which address the major botanical categories beginning with cereal grains, followed by miscellaneous seeds that were discovered during the course of this project, apples, and finally cereal product. The following section of this chapter is a description of the results of the experimental archaeology used to help identify the species of apple and types of grain product analyzed. The next section makes comparisons between MPM Robenhausen material and collections from this site housed in other museums. The chapter

concludes with an interpretation of the Robenhausen botanical material based on the theoretical model of foodways which was described at the start of the thesis.

The last chapter of this thesis provides a discussion of the nature of agriculture at the Robenhausen site during the Neolithic and Bronze Age. This discussion highlights the combined subsistence strategies used at the site, the way the products of these strategies might have complimented one another to form a distinct culinary package, and the nature of subsistence related choices at lake dwelling sites. This is followed by a series of suggestions for the study of other 19th century botanical collections housed in museums. The next section describes some suggestions for future research that are primarily based on the experimental studies conducted as part of this project. The final section of the closing chapter connects the interpretation of the MPM Robenhausen botanical material in the context of early agriculture to the recent history of this locality in Switzerland.

Chapter II Background

2.1 Introduction

This chapter provides an overview of the time periods and region associated with the circum-Alpine lake dwellers and describes the general environment of Robenhausen, located in east-central Switzerland. This chapter begins with a description of the geography, climate, flora, and fauna of the region followed by a brief description of the general characteristics of the Mesolithic, Neolithic, and Bronze Ages in central Europe. Plants and agriculture are important components of this thesis and they are discussed with additional information about animals as the accompanying component of domestication. The next section provides an overview of lake dwellings, their defining characteristics, and a summary of each of the major cultures. This is followed by a description of the rediscovery of lake dwelling sites by archaeologists in the middle of the 19th century, including a discussion of the Robenhausen site, its physical description, how it was discovered, significant artifacts, and excavation history including botanical analyses. The final parts of this chapter present the lake dwellings from a modern perspective with sections describing the infamous *Pfahlbau* problem, lake dwellings as symbols of everyday life in prehistory and as national symbols, and a brief summary of excavation methods and history over the past 165 years culminating in the creation of the lake dwellings as a UNESCO World Heritage site complex.

2.2 Geography, Climate, Flora, and Fauna of the Alpine Region

The Alpine region of Europe is a 1200 km area of land that runs from east to west with a width of between 100 and 150 km, covering 200,000 km^2 (Menotti 2001: 1). Regions of France, Germany, Italy, Switzerland, Austria, and Slovenia are part of the Alpine chain and are also

home to the lake dwelling cultures of central Europe (Menotti 2001: 1). This region has many assets, the most important of which is the massive reserve of fresh water found in glaciers, lakes, springs and rivers (Figure 2.1)(Menotti 2001: 1). Switzerland is located to the north of the western Alps and confined by the Jura Mountains to the west and Rhine River to the north and east (Sakellaridis 1979: 1). The northern part of Switzerland is known as the Alpine Foreland and is characterized by a series of lakes (Coles and Coles 1989: 17). There are three types of lakes in the Alps: border, mountain, and valley lakes. Border lakes are the largest and lie on the periphery of the mountain chain while mountain lakes are small and located at higher elevations; valley lakes fall somewhere in between the other two types (Menotti 2001: 2). The border lakes have elongated basins and were the primary locations chosen for lake dwelling settlements in the Neolithic, Bronze, and Early Iron Ages (Menotti 2001: 2).

The temperate climate of the Alpine Region is an effect of the combined proximity to the Mediterranean Sea to the south and the continental climate to the north (Menotti 2001: 3). Between 6,000 and 4,000 BC, the climate is believed to have been more temperate than today (Whittle 1985: 73). The Younger Atlantic (4,000 – 2700 BC), Subboreal (2700 – 1700 BC), and Subatlantic (1700 – Present) phases (Menotti 2001: 3-4) are the three periods during which the lake dwelling cultures flourished in this area. The Younger Atlantic was characterized by instability and fluctuations between colder and more temperate periods (Menotti 2001: 3). The Subboreal period featured a lengthy stretch of moderate temperatures followed by a colder stretch and higher levels of precipitation (Menotti 2001: 4). A brief period of general climatic improvement was followed by cooler conditions which continued to the beginning of the historic period, distinguishing the Subatlantic phase (Menotti 2001: 4). In general, these three periods impacted different regions of the Alps in different ways and the variation in climate between

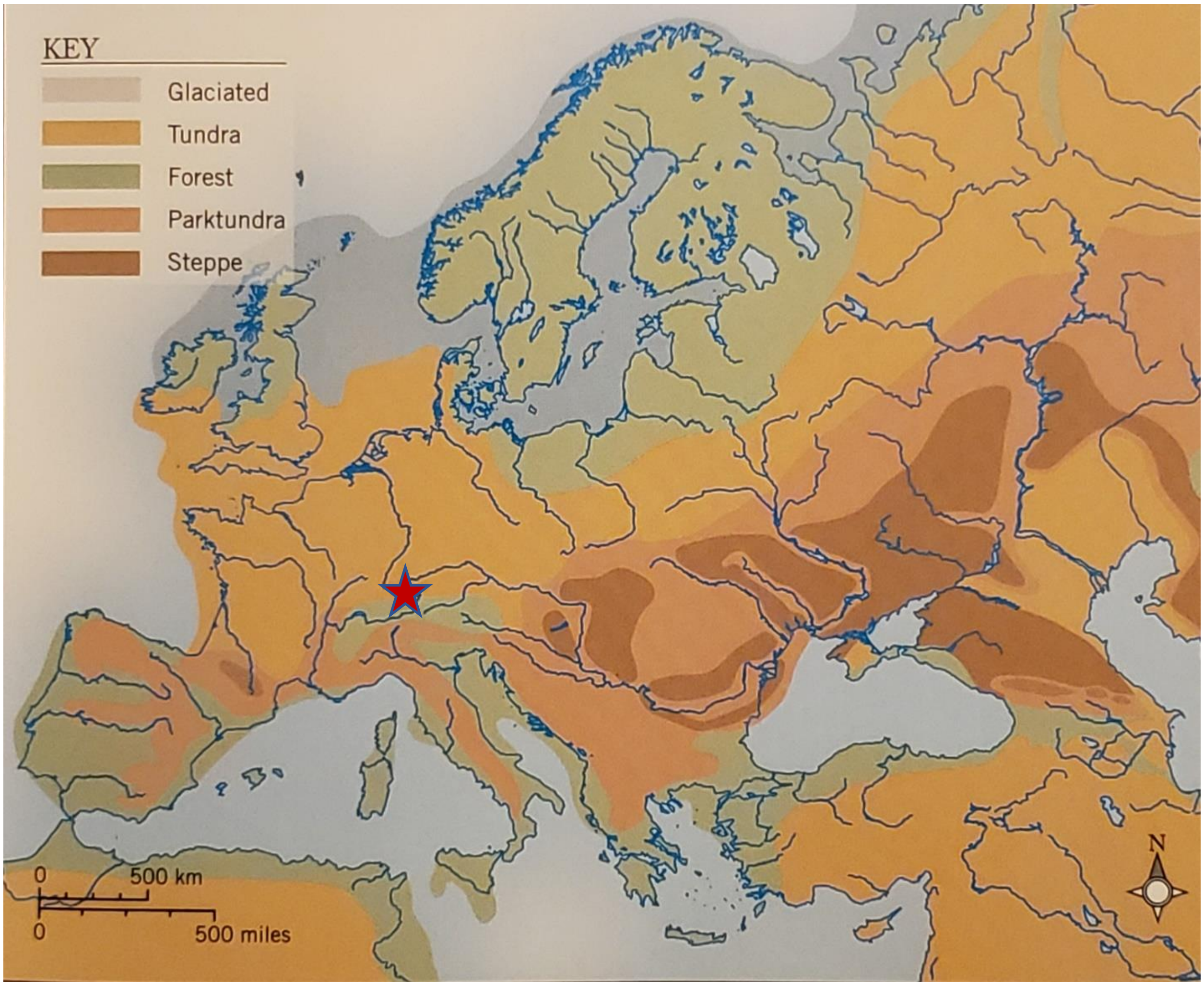

Figure 2.1: Map of Europe in the Holocene. This map shows the different terrain types of Europe, including the mountainous region running along the center of the continent from east to west; the Alps is part of this region The star indicates the location of the Robenhausen site (modified from Cunliffe 2008: Fig. 2.3).

these periods was much less significant than the seasonal variations that occurred throughout the year at any specific location (Menotti 2001: 4).

The flora and fauna of the Alpine Region are distinct from the rest of central Europe. The flora in particular are markedly distinct for a number of reasons (Menotti 2001: 4), including, the extreme temperature fluctuations and the large quantities of rainfall, particularly in

the foothills of the Alps, both of which have profound effects on regional ecology (Henfrey 1852). The variation in temperature within the region is equivalent to the variation between the Mediterranean and northern Europe, and the humidity from the sea coming into contact with the snow covered mountains produces the precipitation (Henfrey 1852). While the climate on the northern side of the mountain chain is more similar to that of central Europe, the climate to the south is characteristically Mediterranean. At the same time, different elevations feature different plant communities, but there are no distinct boundaries and the different groupings mix with one another (Henfrey 1852). The combination of northern and southern influences, different elevations, temperature variation, and the mixture of the two different climatic zones is what makes this a unique part of the European continent (Henfrey 1852).

Between 6,000 and 4,000 BC the vegetation in the Alpine Region was dominated by climax closed woodland (Whittle 1996: 149, 1985: 73). The Younger Atlantic featured fir, beech, spruce, and oak forests in different areas (Menotti 2001: 5). These broadleaf, mixed forests dominated regions with high levels of precipitation, whereas open woodlands flourished in areas with lower precipitation levels (Milisauskas 2002: 155). This period was the first to have been impacted by human agricultural activity, which consisted of cleared woodlands making way for agricultural spaces in some areas (Menotti 2001: 5). During the Subboreal phase, the human impact on the flora as a consequence of agriculture spread across the entire Alpine Region. This human impact increased even more in the final phase and the first part of the Subatlantic shows evidence of increases in pine, alder, beech, and oak trees, all of which were utilized by the people who lived there (Menotti 2001: 5). Alpine fauna during these three phases include native species as well as animals that relocated due to climate fluctuations and human migration (Menotti 2001: 5). Prevalent species include marmot, ptarmigan, lemming,

fieldfare, bats, marten, wild pigs, chamois, red deer, wild goat, wolves, bison, various bear species, lizards, vipers, asps, ravens, crows, blackbirds, starlings, sparrows, robins, owls, goshawks, falcons, and eagles (Menotti 2001: 5-6). The lacustrine environments in the region feature frogs, salamanders, trout, pike, perch, salmon, wild ducks, water hens, and herons (Menotti 2001: 6).

2.3 The Setting

Mesolithic Central Europe

The beginning of the Mesolithic Period is marked by postglacial climatic conditions and the start of the Holocene around 8300 BC (Jochim 2002: 115). However, there is a great deal of continuity with previous Paleolithic cultural trends and technologies since the reforestation and warming of Europe began during the Pleistocene (Figure 2.1)(Jochim 2002: 115; Mithen 1994: 79). In terms of technology, the characteristic tool of the Mesolithic is the microlith, a retouched blade made to be inserted into a wood or bone haft (Jochim 2002: 118; Mithen 1994: 93-97). Subsistence during the Mesolithic relied on elk, aurochs, bison, ibex, wild pig, red and roe deer, chamois fish, small game, birds, and gathered plant resources (Jochim 2000: 18, 2002: 122; Sakellaridis 1979: 6). Mesolithic foragers in central Europe preferred locations by open water and in valleys – both of which attracted game – and exhibited a preference for camp sites on sandy soils (Milisauskas 2002: 155; Whittle 1996: 153). During this period, people lived in caves, rockshelters, and open-air sites. A high level of mobility, shifting residences, and a base camp-collector model characterized these earlier inhabitants of the region (Whittle 1996: 153). By the late Mesolithic, innovations included trapezoidal microliths, regular blade technology, and skillful antler-working (Jochim 2000: 183). Evidence suggests that during this period, Mesolithic hunter-gatherers began to occupy the circum-Alpine region of central Europe

(Schlichtherle 2004: 30). Agriculture based subsistence strategies, permanent settlements, and, in most cases, pottery characterize the end of the Mesolithic and the beginning of the Neolithic (Jochim 2002: 115).

Neolithic Central Europe

The transition from Mesolithic mobility, hunting and gathering, and undifferentiated society to Neolithic sedentism, domestication, pottery, and social complexity is not a distinct boundary, but a gradual process during which the two distinct lifestyles became interwoven (Mithen 1994: 79). As such, Neolithic farming societies developed in Europe over a 3,000-year period, beginning around 7,000 BC (Whittle 1994: 136). The process of Neolithization was long and domestic plants and animals were not the dominant food resources in central Europe until around 4,000 BC (Whittle 1994: 136). Even after this point, the next thousand years would see a balance between the two subsistence strategies with periodic returns to a primary reliance on hunting and gathering (Schibler 2004). Evidence also suggests that people in the broader region spread out in smaller groups in the winter and gathered in larger communities in the summer (Whittle 1985: 75).

The development of agriculture in Neolithic Europe is a process which is still being investigated. The archaeological evidence indicates that people gathered wild plants and processed them for thousands of years and that varying degrees of human intervention eventually led to full-scale agriculture (Ucko and Dimbleby 1969: xx). This transition from hunting and gathering to agriculture and domestication was one of the most significant developments in human history (Ammerman and Cavalli-Sforza 1984: 9; Price 2000: 1). The foundational crops and animal domesticates that initiated this change were developed from wild counterparts indigenous to Asia Minor around 10,000 BC (Price 2000:3). These plants, termed the Neolithic

Package, included eight founder crops: barley, emmer and einkorn wheat, lentils, chickpeas, beans, bitter vetch, and flax (Weiss and Zohary 2011: 237).

Whether the first farmers in Europe were locals who adopted domestic plants and animals from the Near East or people from the east colonizing Europe and bringing staples with them remains heavily debated (Whittle 1994: 137). Some evidence supports continuity of indigenous communities (Whittle 1985: 74), some suggests an influx of migrants (Milisauskas 2002: 153; Whittle 1996: 149), and some suggests a more complex picture of what occurred during this period. This mosaic perspective indicates that a mixture of migration by farmers and the gradual incorporation of farming by preexisting hunter-gatherer communities took place and that the latter often relied simultaneously on the two subsistence strategies to varying degrees and for long periods before eventually practicing full-blown agriculture (Ammerman and Cavalli-Sforza 1984: 45-49; Cunliffe 2008: 105; Jochim 2000: 186; Price 2000: 3). No matter what role was played by the movement of people, there is no doubt that a group of plants and animals that had been domesticated in Asia Minor were brought into Europe and became a primary food source that people relied on. In terms of domestic animals, this transformation included sheep, goats, cattle, and pigs, although it is unclear whether the latter two were domesticated from wild animals indigenous to Europe or imported from Asia Minor (Whittle 1994: 136-137). During the Neolithic, many other social changes also took place, including the development of a sedentary lifestyle accompanied by food and raw material storage, and a focus on kin, ancestors, and lines of descent (Whittle 1994: 137). Another important lifestyle change during this period was the development of social differentiation reflected in mortuary practices (Whittle 1985: 73).

In central Europe, agriculture arrived later than in areas to the south (Whittle 1994: 154). This is primarily due to geography and the ease of travel along the Mediterranean coast which

connected parts of southern Europe to the Near East. When farming finally entered central Europe beginning around 5500 BC, it spread quickly across the Hungarian Plain and other adjacent areas (Whittle 1994: 155). By 5300-5000 BC, the earliest Neolithic sites are found in south-central Switzerland and by 4500 BC the Cortaillod Culture had spread throughout most of the region (Milisauskas 2002: 157). Movement into the Alpine region inhabited by the lake dwellers was likewise slowed by the geography of the region, which included rugged mountain terrain and as a result, a Mesolithic mode of subsistence lasted longer in this region than in other parts of central Europe.

Table 2.1: Chronology of periods in European prehistory. Dates are approximate and some overlap as they represent vast geographic regions (Cunliffe 1994; Menotti 2001).

	Early Neolithic	**Middle Neolithic**	**Late Neolithic**	**Early Bronze Age**	**Middle Bronze Age**	**Late Bronze Age**
Western Switzerland	5500 – 4200 BC	4000 – 2800 BC	3000 – 2300 BC	2000 – 1650 BC	1650 – 1300 BC	1300 – 800 BC
Eastern Switzerland	5300 – 4700 BC	4500 – 3000 BC	3000 – 2300 BC	2000 – 1550 BC	1550 – 1250 BC	1250 – 800 BC
Central Europe	5500 – 4500 BC	4500 – 3000 BC	3000 – 2000 BC	1800 – 1600 BC	1600 – 1200 BC	1200 – 800 BC

Between 5500 and 5000 BC, a cultural group known as the Linearbandkeramik or LBK spread from eastern Europe into central Europe (Ammerman and Cavalli-Sforza 1984: 42-43; Cunliffe 2008: 105; Jochim 2000: 185; Whittle 1996: 146). The LBK culture was characterized by a distinctive style of incised pottery (Cunliffe 2008: 105; Whittle 1996: 146; Whittle 1985: 76-77), part of a cultural complex that probably originated on the Hungarian Plain and marked by longhouses and agriculture (Ammerman and Cavalli-Sforza 1984: 42-43; Cunliffe 2008: 106; Jochim 2000: 185; Whittle 1985: 77). In terms of agriculture, members of the LBK culture planted emmer and einkorn wheat, barley, peas, lentils, flax, and poppy in the fertile loess soils

of the region (Cunliffe 2008: 106; Jochim 2000: 186; Whittle 1996: 146, 1985: 87). Of these domesticates, emmer wheat was the dominant crop (Whittle 1996: 146). The LBK farmers brought at least 12 non-indigenous weed species into central Europe and raised domestic animals including sheep, goats, cattle and pigs (Jochim 2000: 185-187) while continuing to exploit wild resources such as bromegrass (*Bromus secalinus)* and hazelnuts (*Corylus avellana*)(Whittle 1985: 87). LBK cemeteries suggest social differentiation by gender, competition for land, social hierarchy, and land access based on descent, as evidenced by the importance of jewelry and weapons as signifiers of social demarcation (Whittle 1985: 90).

The region of central Europe under LBK influence was vast and gave rise to several groups in different subregions between 4500 and 3500 BC (Whittle 1996: 146, 1985: 186). In the Alpine Foreland, the earliest lake dwelling cultural complexes, Egolzwil-Rössen and Pfyn-Cortaillod, developed around 4000 BC (Figure 2.2)(Whittle 1996: 148; 1985: 187). This split occupation was followed by a primarily Cortaillod phase beginning around 3700 BC, a Horgen cultural period around 3000 BC and a Corded Ware stage which started around 2700 BC (Whittle 1996: 148; 1985: 187). The Alpine region and period are associated with at least twenty-four different cultures (Menotti 2001: 7) although some of these are defined based on small quantities of pottery. In general, the central European Neolithic began around 4300 BC and ended around 2400 BC (Ebersbach 2004)(Table 2.1). While many groups dissolved and disappeared during the Bronze Age, new ones formed and took their places so that the lake dwelling cultural phenomenon of central Europe continued into the Early Iron Age (Menotti 2001: 7).

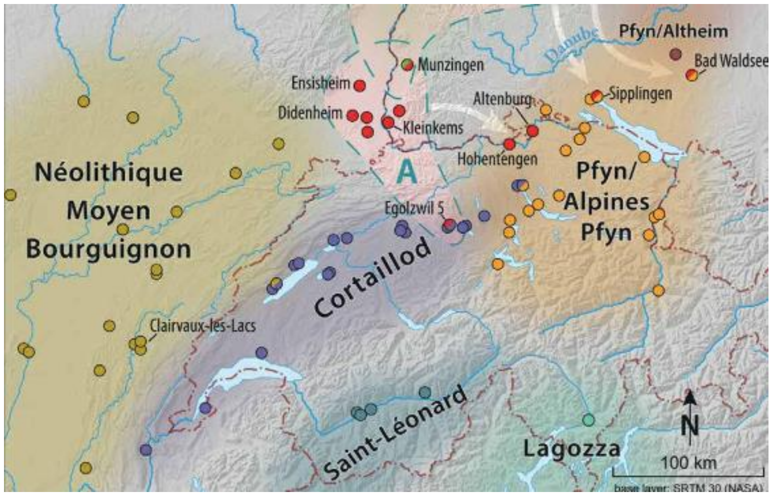

Figure 2.2: Map of Alpine Neolithic cultures. This map shows cultures in the region during the 4th millennium BC (after Jammet-Reynal 2017: Fig. 9).

Bronze Age Central Europe

The Bronze Age in Europe began in Greece around 3000 BC and lasted until 200 BC in parts of northern Scandinavia (Harding 2002: 272). However, in central Europe, the Early Bronze Age began around 2200 BC and was characterized by inhumations in cemeteries and material culture including axes, daggers, halberds, pins, and large arm-rings (Harding 2002: 273). The Middle Bronze Age lasted for about 200 years from 1500 BC to 1300 BC and is known as the Tumulus Phase because inhumation burials under barrows dominated cemeteries (Harding 2002: 273). In terms of Bronze Age weapons and jewelry, this period is characterized by rapiers and swords, spearheads, palstaves, arm- and leg-guards, pins, pendants, and spiral rings (Harding 2002: 273). The Late Bronze Age began around 1300 BC, continued to 750 BC, and is commonly referred to as the Urnfield Phase because of the almost universal change in mortuary program to cremation and burial of ashes in urns (Harding 2002: 273). This period is characterized by cultural homogeneity supported by extravagant elite displays, especially the use of four-wheeled wagons in funerary rites and burial assemblages (Cunliffe 2008: 267). This last

segment of the Bronze Age is further characterized by large quantities of bronze tools such as sickles and axes, weapons including swords, spears, and arrowheads, sheet bronze vessels such as buckets, cups, and cauldrons, armor, and a variety of personal ornaments (Harding 2002: 273). The Bronze Age exhibited a higher degree of uniformity than previous periods because tin and copper used to make bronze were only available in certain, often remote, regions and required long-distance trade and cultural connectivity in order to obtain them (Sherratt 1994: 244-246). Some of the cultures that characterized Europe during the Bronze Age include the Bell-Beaker, Corded Ware, Tumulus, and Unétice (Sherratt 1994: 246-247).

2.4 Lake Dwelling Cultures and Characteristics

Mesolithic hunter-gatherers first settled around the lakes of the circum-Alpine region in the fifth millennium BC (Schlichtherle 2004: 22-35). The Alpine pile dwelling cultures of central Europe proliferated between 4300 and 800 BC (Leuzinger & Rast-Eicher 2011: 535-542). Over 450 sites in the period from 4300 to 800 BC have been found in Switzerland alone (Figure 2.3)(Leuzinger & Rast-Eicher, 2011: 535-542). In this region, the groundwater level has remained above the stratigraphic cultural layers, creating a preservative anaerobic environment (Schibler et al. 1997: 554). These waterlogged conditions preserved seeds and fruit, including large quantities of dried apples, cereal remains, timber, houses, a great variety of bone and wood implements, textiles, and the raw material and the tools used to make them (Leuzinger and Rast-Eicher 2011: 535-542). Prior to the discovery of the Alpine pile dwellings, the complexity of the central European Neolithic and the variety of material culture had not been fully grasped. Although it is expected that regional and local variations in objects and patterns of plant use varied among Neolithic communities, based on the degree and complexity of organic finds from

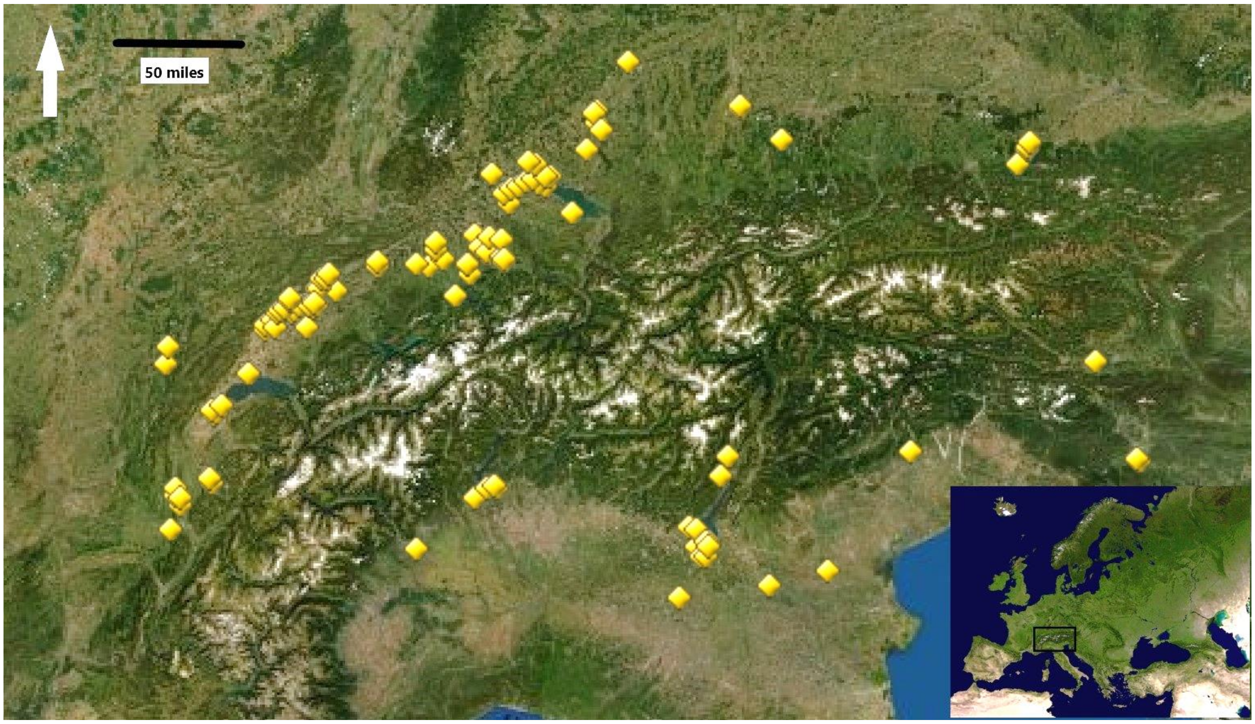

Figure 2.3: Lake dwelling sites around the Alps. Sites which appear to be in non-lacustrine locations are in the proximity of small lakes not visible due to the scale of the map which was selected to show a large number of sites (adapted from UNESCO 2019).

lake dwelling sites such as ornate wood carvings and textiles made using sophisticated weaves, a comparable degree of complexity and variety of organic mediums can be assumed for sites throughout the continent without the benefit of waterlogged preservation (Barber 1991).

Lake Dwellers

A large population chose to live on the shores of lakes in and around the Alpine Foreland beginning in the Late Neolithic and continuing through the Bronze Age and into the Early Iron Age (Figure 2.4). Although there were periodic lapses in this occupational span, especially during the Middle Bronze Age (Menotti 2001), there was nonetheless an apparent commitment to this lifestyle. These cultures may have originated in the western Mediterranean based on earlier occupation of lake dwelling sites in this area, similarities in sickles to other cultures in

this region, and the predominance of *Triticum turgidum/durum* or naked wheat at both circum-Alpine lake dwelling sites and western Mediterranean Cardial pottery culture sites (Schlichtherle 2004: 30). The use of wood technology is exemplified by lake dwelling cultures, which specifically feature skilled construction methods using vertical posts and long horizontal planks as well as smaller components such as wood chips and twigs (Figure 2.4)(Favre and Jacomet 1998: 167). Certain species of wood appear to have been utilized with greater frequency than others, including hazel (*Corylus avellana)*, yew (*Taxus baccata)*, and silver fir (*Abies alba*)(Favre and Jacomet 1998: 167).

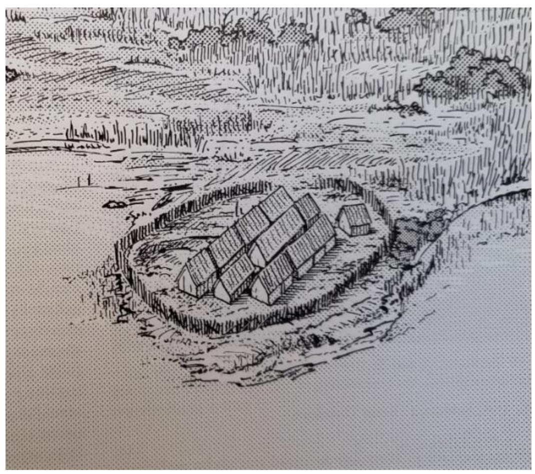

Figure 2.4: Artist's recreation of a lake dwelling settlement (after Gross et al. 1987: Fig. 102).

While huge quantities of material culture exist, with few burials, minimal iconography, and no contemporary written sources, our current understanding of the intricacies of lake dwelling society and beliefs is limited. Some general patterns can be ascertained from multidisciplinary regional studies such as craft specialization that defined different settlements and trade between sites, which was a key component of this cultural complex (Menotti 2001: 8). The site of Horgen Scheller on Lake Zürich, Switzerland, which was occupied between 3080 and 3030 BC, may have been a specialized yew timber settlement (Favre and Jacomet 1998), while

copper beads are characteristic of the Cortaillod Cultural Period and may have been a form of ornamentation linked to prestige that was traded to neighboring regions (Ottaway and Strahm 1975). The importance of the inter-site trade networks is further evidenced by long-distance trade routes that crisscrossed Europe through the Alpine region (Bellintani 2011; Menotti 2001: 8). These trade routes may have existed during the Neolithic and certainly proliferated in the Bronze Age, during which they were used to transport large quantities of amber, glass, bronze objects, and faience beads (Bellintani 2011). Another related observation based on detailed excavations is that in most cases, individual houses within settlements were self-contained economic units (Jacomet and Brombacher 2005: 82). This suggests that while trade and crafts were important between communities, within settlements individual households produced a variety of different forms of material culture rather than specializing.

In terms of site locations, part of the attractiveness of living on the lakeshore may have been access to communication and transportation networks (Whittle 1988: 83). In addition, the land around each settlement was certainly fertile and well-irrigated for agriculture (Müller-Beck 1961: 140). Arguments have been made that since the lakes were rich in fish, they would have provided a food source when agriculture faltered, but this has been questioned since the degree to which lake fish were utilized as a food source is unclear (Pétrequin and Bailly 2004: 39). Detailed analyses using more refined excavation techniques are required to better understand the exploitation of fish at lake dwelling sites (Schibler et al. 1997: 566). This environment would also have posed many challenges for construction since the soil was soft and would not have provided solid support for buildings (Müller-Beck 1961: 140). Besides this there were many other drawbacks, such as mud, periodic flooding, and distance from agricultural fields, pasturelands, and woodlands that supplied timber for construction (Pétrequin and Bailly 2004:

40). It is important to note that contemporaneous settlements are also found on dry land away from lacustrine, riverine, and fluvial environments (Whittle 1988: 83). Because of the existence of concurrent settlements away from lakes and the challenges of the lake dwelling lifestyle, some argue that living on the lakes may have been a cultural adaptation rather than a practical decision (Schlichtherle, 2004, 22-35). Others have suggested that lake dwellings were the equivalent of hilltop fortified settlements in terms of defensibility since both were inhospitable to potential invaders (Pétrequin and Bailly 2004: 40). This is corroborated to an extent by the building style since many sites were built directly over peat bogs or other damp soils and there is often an entire substructure composed of wood (Whittle 1988: 41). For example, in addition to houses with wood flooring, there are paths connecting houses and providing access to the area outside of settlements, and fences or palisades encircling settlements (Figure 2.4)(Whittle 1988: 41).

Lake Dwelling Cultures

During the Neolithic in Switzerland, the main cultures included Egolzwil, Cortaillod, Pfyn, Horgen, Corded Ware, Lüscherz, and Bell Beaker (Table 2.2)(Ebersbach 2004; Menotti 2001: 8). The Cortaillod Culture in western and central Switzerland was concentrated around Lake Neuchâtel with sites as far north as Lake Zürich (Ottaway and Strahm 1975: 307). This phase was preceded by the Egolzwil culture and followed by the Lüscherz culture (Ottaway and Strahm 1975: 307). By the Middle Neolithic, animal domestication had spread throughout Switzerland, yet hunting was still a primary subsistence strategy at different points within this period. For example, at some Cortaillod sites in Switzerland, wild animals constitute between 60% and 75% of the faunal material (Milisauskas and Kruk 2002: 213; Ottaway and Strahm 1975: 308). Population estimates suggest that villages consisted of fifty individuals who lived in

Table 2.2: Neolithic cultures of Europe and Switzerland discussed in this chapter with associated radiocarbon (where available) and standard date ranges (Manning et al. 2014; Ottaway and Strahm 1975: 307).

Culture	**Radiocarbon Range**	**Standard Range**	**Associated Region**
Western Cardial	6574 - 3849 BC	5600 - 4950 BC	Western Mediterranean
Linearbandkeramik	5719 - 4127 BC	5500 - 4900 BC	Northern France to Poland
Egolzwil		4300 – 4100 BC	Western Switzerland
Cortaillod	4503 - 2963 BC	4100 - 3400 BC	Western Switzerland
Pfyn	4251 - 3138 BC	3850 - 3400 BC	Eastern Switzerland
Horgen	3540 - 2525 BC	3500 - 2750 BC	Eastern Switzerland
Luscherz		2900 – 2650 BC	Western Switzerland
Corded Ware	3251 - 1901 BC	2800 - 2050 BC	Western Germany to Volga River
Bell Beaker	3040 - 1607 BC	2500 -1800 BC	Portugal to Poland, British Isles

rectangular houses with wood floors built on damp soil along small lakes (Ottaway and Strahm 1975: 308). Thin-walled pottery was incised with geometric designs and strips of white birch-bark were sometimes attached using birch-bark tar (Ottaway and Strahm 1975: 308).

The Pfyn Culture of northern Switzerland extended from Lake Zürich to Lake Constance (Ottaway and Strahm 1975: 307). This period was characterized by a gradual transformation in subsistence strategy, possibly based on preference rather than resource availability. This is demonstrated by a fluctuating faunal bone record, which reflects groups of people vacillating between a reliance on domestic animals and hunted wild game (Ebersbach 2004; Schibler 2004). Copper objects, especially flat axes made using crucibles, also distinguish this cultural phase (Ottaway and Strahm 1975: 308). The Pfyn period is noted for an increase in both the number of sites and the size of the settlements (Whittle 1988). During the Horgen Culture, which is identified by a characteristic type of pottery and dates from between 3400 to 2800 BC, flax was utilized more than in any other Alpine period (Jacomet 2004: 162-177). This cultural phase is also noted for an increased reliance on pigs, indications of open grazing land, and the use of the

plough (Ebersbach 2004: 291). The Horgen-Corded Ware transition is further characterized by larger villages than in previous periods and longer occupation spans for individual sites (Ebersbach 2004: 291).

Corded Ware Culture dendrochronology dates in Switzerland fall between 2750 and 2400 BC and represent the middle period for this culture in surrounding regions of Europe where sites are dated between 3000 and 2000 BC (Włodarczak 2009: 738). Flax initially continued to be one of the most important plants into the Corded Ware period, beginning in 2800 BC, then became less common as time went on (Jacomet, 2004: 162-177). There was an increase in domestic cattle during the Corded Ware Period as domesticated animals in general finally came to dominate subsistence (Ebersbach 2004: 291). The Bronze Age archaeological record exhibits increases in the numbers of sheep, an increase in the age of the animals when killed, and the first appearance of bone needles and buttons all of which, in terms of textiles, indicate a transition from flax to wool production (Schibler, 2004:144-161).

<u>Lake Dwelling Plants and Food</u>

As previously described, the LBK cultures were among the earliest farmers in Europe and by around 5500 BC, some of these groups occupied the northern Alpine region where they primarily grew einkorn (*Triticum monococcum)* and emmer (*Triticum dicoccum)* wheats, and peas (*Pisum sativum*)(Jacomet 2007: 233). Small quantities of naked wheat (*Triticum aestivum/turgidum /durum*), millet (*Panicum miliaceum*) and rye (*Secale cereal*) as well as lentils (*Lens culinaris*) and a few instances of bitter vetch (*Vicia ervilia*) are also documented during this period (Jacomet 2007: 233). Flax (*Linum usitatissimum*) was found in large quantities, while opium poppy (*Papaver somniferum*) occurs with less frequency (Jacomet 2007:

236). In terms of wild plants, hazelnuts (*Corylus avellana)* are found in large numbers, while crab apples (*Malus sylvestris*) and sloes (*Prunus spinosa*) are found at only a few sites (Jacomet 2007: 236).

In the Middle Neolithic, between 5000 and 4300 BC, emmer and einkorn were still the primary cereals, while quantities of naked wheat increased (Jacomet 2007: 236). During this period barley (*Hordeum vulgare*) was more commonly exploited and spelt (*Triticum spelta*) was introduced, while lentils and flax were present in small quantities (Jacomet 2007: 236). By the Late Neolithic, between 4300 and 3500 BC the grain distribution was similar except for the reintroduction of millet (Jacomet 2007: 236). Peas, flax, and poppy were also found alongside previous wild representatives such as hazelnuts; the first stores of wild apples were found at Ödenahlen and Aldingen Halden II during this period (Jacomet 2007: 236, 243). The Pfyn cultural phase is dominated by einkorn and naked wheat, while emmer increased in prominence during the Horgen period, followed by an absence of naked wheat in the Corded Ware Culture (Herbig 2008: 1280). Acorns *(Quercus robur)*, wild strawberry (*Fragaria* sp.), raspberries and blackberries (*Rubus* sp.), wild turnip *(Brassica rapa)*, and goosefoot (*Chenopodium album)* were all found for the first time at a number of sites in Eastern Switzerland during the Late Neolithic (Jacomet 2007: 243). During this period in Upper Swabia, lentils, celery (*Apium graveolens),* and dill (*Anethum graveolens*) were found, and at the site of Alleshausen-Grundwiesen, a large store of flax was also discovered (Herbig 2008: 1280). At the site of Parkhaus Opéra, in Zürich, additional gathered plants included wild rose fruits (*Rosa* sp.*)*, beech nuts (*Fagus* sp.), and wayfaring tree fruits (*Viburnum lantana*)(Antolín et al. 2015). In Slovenia, the spectrum of wild plants included wild grapevine (*Vitis vinifera)* in addition to plants found at Swiss lake dwelling sites, such as water chestnut (*Trapa natans),* goosefoot, and wild turnip (Tolar et al. 2011).

In the Eastern Alps during the Early and Middle Bronze Age barley was the dominant grain crop, followed by emmer and spelt (Stika and Heiss 2013: 356). Einkorn and naked wheat were less dominant during this period, and small quantities of broomcorn millet, rye, and oats were also grown (Stika and Heiss 2013: 356). By the Late Bronze Age, barley production was reduced in favor of broomcorn millet and rye production increased (Stika and Heiss 2013: 356). Throughout the Bronze Age the garden pea was the most prevalent pulse, while some field beans and lentils, and small quantities of bitter vetch, were also grown (Stika and Heiss 2013: 357). In the western Alps during the Early and Middle Bronze Age, barley was the dominant cereal, with emmer and spelt as secondary crops (Stika and Heiss 2013: 357). Naked wheat and einkorn were also present during this period, as were broomcorn millet, oats, and rye in very small amounts (Stika and Heiss 2013: 357). By the Late Bronze Age broomcorn millet had become more important and foxtail millet also became a significant crop (Stika and Heiss 2013: 357). During this period, hulled barley remained dominant, with spelt and naked wheats as significant runners up (Stika and Heiss 2013: 357). Unlike the East Alpine region, in the west the field bean was more dominant than the garden pea throughout the Bronze Age (Stika and Heiss 2013: 357). Flax and opium poppy were also common during this time, with significant increases of the latter toward the end of the Bronze Age (Stika and Heiss 2013: 357).

Plant and food processing activities are indicated at a number of lake dwelling sites. At Chalain Station 3 during the Horgen phase, there is evidence of winnowing activity on a balcony-like area outside a housing structure; this area would have been utilized while the wind was blowing, causing an accumulation of chaff under the house, which was raised on piles (Jacomet and Brombacher 2004: 80). The same type of chaff accumulation was found at Arbon Bleiche 3 (Jacomet and Brombacher 2004: 80), suggesting that this might have been an

intentional method to facilitate winnowing of grains rather than an isolated circumstance where the wind expedited processing activities. One example of hearths in lake dwelling contexts is at the Aichbühl site, where ovens were found (Whittle 1988: 43). At the site of Horgen-Scheller, dating to the Horgen Culture and located on Lake Zürich, hearth structures produced large quantities of carbonized plant material (Jacomet and Brombacher 2004: 80). At Chalain Station 3, Concise-sous-Colachoz, and Ens 2 high densities of carbonized material and lower densities of uncarbonized material indicate that the hearth areas were cleaned regularly (Jacomet and Brombacher 2004: 80). Evidence of cereal cooking in a hearth area was found at the site of Alleshausen-Hartöschle near Maier in Germany (Jacomet and Brombacher 2004).

Discovery of the Lake Dwellings

Although the discovery of the circum-Alpine lake dwellings of Europe is often dated to the mid-19th century, some sites were known prior to the 1800s. For example, the settlement of Nidau on Lake Bienne in Switzerland was described in 1472 and mentioned again by A. Pagan in 1767 (Menotti 2001: 319). Other documentation of the lake dwellings from the 16th century onward include sites at Lake Constance in Germany, Lake Garda in Italy, and in the Salzkammergut Region of Austria (Menotti 2001: 320). These settlements were primarily indicated by wood piles, palisades, and structures emerging from the shallows along lakeshores as well as isolated discoveries of bronze weapons on Lakes Luissel and Sempach (Menotti 2001: 320). As late as 1851, a harbor on Lake Garda in Italy was dredged and workers found bronze objects and the remnants of piles without realizing their significance (Coles and Coles 1989: 21). Despite these early indications, the majority of the lake dwelling sites were not discovered until the second half of the 19th century when their interpretation as houses built over open water

(Keller 1866; Menotti 2001) captured the imagination of antiquarians, burgeoning collectors, and the general public (Leckie 2013).

The lake dwelling phenomenon was brought to the attention of the archaeological community during the winter of 1853-1854, when an unusually dry and cold season led to a decrease in lake levels in the Alpine region (Coles and Coles 1989: 9; Keller 1866: 10; Menotti 2001: 320). One morning, a school teacher named Johannes Aeppli was walking on the shore of Lake Zürich and noted unusual wooden structures poking out of the lakeshore (Coles and Coles 1989: 19; Menotti 2001: 320, 2015: 1). Thinking that what he saw might be the remains of a very old bridge, Aeppli contacted the Antiquarian Society in Zürich and its president, Ferdinand Keller, soon visited what became known as the lake dweller site of Obermeilen (Coles and Coles 1989: 19; Menotti 2001: 320, 2015: 1-2). This initial discovery led to a massive search that uncovered many more lake dwelling archaeological sites in the region (Altorfer 2000: 1; Menotti 2001: 320, 2015: 2). This included Robenhausen, a settlement on the southern shore of Lake Pfäffikon where the Aa River enters the lake (Altorfer 2000, 2010; Keller 1866: 38). By 1860, only six years after the rediscovery of the first site, known lake dwellings numbered in the hundreds (Coles and Coles 1989: 20).

2.5 Robenhausen

Site Background

The site of Robenhausen on Lake Pfäffikon near Zürich (Figures 2.5, 2.6, and 2.7) was discovered a few years after the initial discovery of Obermeilen in 1854 (Ruoff 2004: 11). The land along the Aa River belonged to peasant farmers and was divided into plots which were individually owned (Munro 1888: 111). One of these farmers, Jacob Messikommer, discovered

the remnants of lake dwellings on the land owned by his family in January 1858 and put all of his efforts into excavating the site (Keller 1866: 38: Munro 1888: 111). This circumstance ensured an important place for the Robenhausen site in lake dwelling research due to Messikommer's interest in botany and scientific inquiry (Altorfer 2000, 2010; Keller 1866: 38).

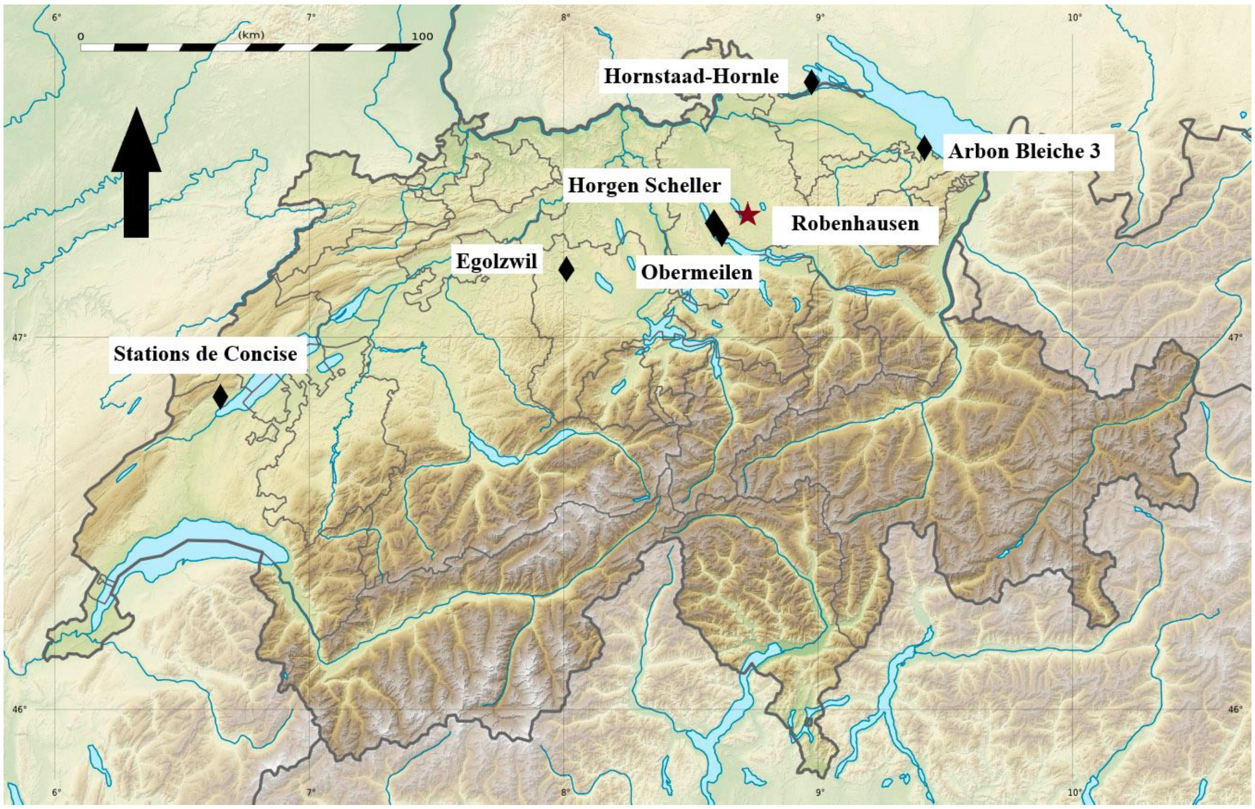

Figure 2.5: Location of Robenhausen and other lake dwelling sites.

Messikommer's excavations were innovative in terms of their attention to the recovery and identification of botanical remains as well as the conservation of artifacts (Altorfer 2010) and he was awarded an honorary doctorate by the University of Zürich for these achievements (Ruoff 2004: 12). Robenhausen is considered one of the best-preserved lake dwellings due to the peat bog which encompasses much of the habitation area (Altorfer 2000: 22; Coles and Coles

Figure 2.6: Lake Pfäffikon and the modern village of Robenhausen. The white arrow in the foreground indicates the location of the prehistoric lake dwelling Robenhausen settlement (after Altorfer 2010: Fig. 16).

1989: 26; Keller 1866: 38; Munro 1894: 107). Artifacts recovered from Robenhausen are unusual for a number of reasons: in addition to the excellent preservation conditions, excavating in peat is considered easier than excavating in mud, improving the object recovery rate (Coles and Coles 1989: 26). Robenhausen yielded a large quantity of material during the decades when it was explored by Messikommer and later researchers, including wheat, barley, flax, woven cloth, berries, nuts, cereal products, apples, animal bones, fish scales, stone celts, projectile points, and pottery (Figure 2.8)(Altorfer 1999, 2000; Keller 1866: 40). Textiles from Robenhausen are particularly impressive and have been used as evidence that the site was

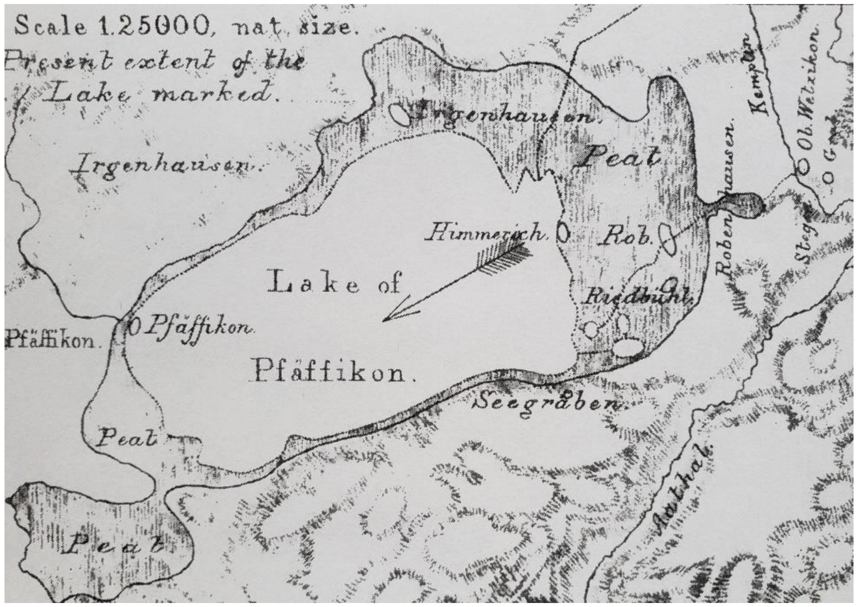

Figure 2.7: Early map of the Robenhausen site on Lake Pfäffikon (after Keller 1866: Plate 6).

focused on linen production, which may have been a trade commodity (Lillis 2005). Among the more remarkable finds at the site during early excavations were two long bows, a decorated wood door, and a 12-foot-long canoe made from a single tree (Altorfer 1999; Keller 1866: 41).

Site Description

Robenhausen is located in the Canton of Zürich, about 20 km east of the city of Zürich (Altorfer 2000: 15; Ruoff 2004: 11; Sherratt 2004: 270)(Figure 2.7). The site covers a 2.5 square kilometer area on the shore of Lake Pfäffikon, which was once larger but was reduced in size during the modern era (Altorfer 2000: 15; Coles and Coles 1989: 26). What remained of the once much larger lake consisted of a peat bog divided by the Aa River (Altorfer 1999: 217, 2000: 15; Coles and Coles 1989: 26). Initial excavations performed in the late 19th century revealed a three acre area with the remains of a large wood structure (Keller 1866: 39). Keller interpreted Messikommer's discoveries as a wood platform that sat on top of this structure and suggested

Figure 2.8: Artifacts from the original Robenhausen excavations (after Keller 1866, Plate 11).

that the huts on the platform were surrounded by a wattle and daub wall which may have served a defensive purpose (1866: 39). Keller also argued that a platform had supported the houses built over the lake and that the Aa River, which was 27 feet wide, bisected the Robenhausen settlement (1866: 39). This platform was made up of wood piles that were between ten and eleven feet long and made of split beams of oak, beech, and fir (Keller 1866: 39). At the time of its discovery, the entire Robenhausen site was covered by piles with a bridge that was thought to connect the main platform to the shore (Coles and Coles 1989: 26).

The location of Robenhausen was probably selected for settlement because of the bed of marl underlying that part of the Aa River, which would have provided a stable foundation for construction (Altorfer 2010: 21). The settlement area on the eastern side of the river appears more extensive than that on the west (Altorfer 2010: 21). However, it remains unclear whether this was due to 19th century peat harvesting which also removed cultural artifacts, or whether the

modern extent of the site resembles its Neolithic and Bronze Age iterations (Altorfer 2010: 21). The foundation of the first settlement layer at Robenhausen appears to have been laid after an extensive area of shallow water on the southern portion of Lake Pfäffikon dried up, but the exact location of the lakeshore in relation to this occupation is unclear (Altorfer 2010: 23).

While Messikommer and Keller believed that there were three periods of occupation at Robenhausen, more recent excavations have revealed at least six settlement layers (Altorfer 2000, 2010). The earliest two occupations are attributed to the Pfyn Culture, which dates to between 3900 and 3500 BC. Based on the ceramic material from the site, the earliest of these two layers is associated with the period from 3900-3775 BC (Altorfer 2010: 123). However, the classic Pfyn Culture period from 3700-3500 BC is better represented and it is to this period that the majority of the ceramics belong (Altorfer 2010: 123). The third occupation dates to between 3500 and 2700 BC and is associated with the Horgen Culture (Altorfer 2000, 2010). The fourth occupation is associated with the Corded Ware or Schnurkeramik Culture, which proliferated in the region between 2800 and 2050 BC. The final two phases of occupation at Robenhausen date to the Early and Late Bronze Age, respectively (Altorfer 2000: 124-125). The Early Bronze Age settlement phase at Robenhausen is characterized by a scarcity of ceramic finds and is dated to before 1600 BC based on the lack of ornate pottery decoration (Altorfer 2010: 125).

During the course of the occupations of Robenhausen, there were at least two significant fires that would have been devastating for its inhabitants (Altorfer 2000: 122). However, the stratigraphy of the site is complex and while one fire is thought to have occurred at the end of the second occupation period, around 3500 BC, it is difficult to determine at what point in time the second fire took place (Altorfer 2000: 123-124). The pre-fire occupation periods associated with the Pfyn Culture are also associated with the majority of the textile finds at the site, while the

food related botanical materials occur during all six phases (Altorfer 2000: 124). These occupations were also the longest during the life of the Robenhausen site and account for more than half of the stratigraphic layers containing cultural material (Altorfer 2000: 125). To underscore the complexity the settlement, it was estimated by the excavators that the entire site was supported by over 100,000 piles (Keller 1866:41).

2.6 Lake Dwellings in the Modern Era

Lake Dwellings as Archaeological Debates

One of the most famous debates over the interpretation of the lake dwellings is the *Pfahlbauproblem* (Coles and Coles 1989; Leckie 2013; Menotti 2001, 2004; Müller-Beck 1961; Munro 1894; Pétrequin and Bailly 2004; Ruoff 2004; Schöbel 2004). This was essentially a scholarly dispute over whether the sites were built on piles over water, on platforms over marshland, or on lakeshores. It began shortly after the first lake dweller site at Obermeilen was discovered, when the excavator, Ferdinand Keller, attempted to interpret the site (Menotti 2001: 320). At Obermeilen, Keller had observed three layers of mud with wood piles protruding and noted that only the middle layer was filled with artifacts, while the wood piles were anchored in the bottom layer (Coles and Coles 1989: 19). Keller interpreted the middle layer as a midden in the area of open water surrounding the houses and the bottom layer as the ancient lake floor, while more recent excavations suggest that the middle layer consisted of the floors of ancient dwellings (Müller-Beck 1961: 138). Since his observations were made on Lake Bienne and Lake Constance, which are both larger lakes, Keller assumed that water levels would not have been easily affected by climatic fluctuations (Menotti 2001: 320; Pétrequin and Bailly 2004: 36).

Based on these observations, Keller determined that the piles had originally supported platforms above open water on which multiple dwellings comprising small villages were built (Coles and Coles 1989: 19). This notion was supported by Arnold Escher, a geologist and scholar who studied limnology in Switzerland (Menotti 2001: 320). Keller's interpretation was also influenced by ethnographic descriptions of Malaysian cultures that built houses over water and had recently been documented by westerners (Leckie 2013: 217-218; Menotti 2001: 320, 2001: 11; Müller-Beck 1961: 138; Pétrequin and Bailly 2004: 36; Ruoff 2004). In addition, other antiquarians supported the interpretation of lake dwellings built over open water based on comparisons with the crannogs of Iron Age Scotland (Munro 1894: 105-106). The idea of "life on the lake" captured the Zeitgeist and without much evidence, every subsequent circum-Alpine archaeological settlement discovered within the proximity of a lake was tied to this phenomenon, while Keller was described as the "father of the lake dwellings" (Menotti 2001: 320-321; Pétrequin and Bailly 2004: 36).

As more lake dwellings were discovered, some sites were found to have been built on wooden floors rather than on piles, however, there was not enough evidence to overturn Keller's theory (Menotti 2001: 321). Robenhausen is one of several examples of these sites built over peat bogs with wood floors rather than platforms on piles supporting the structures (Menotti 2001: 321). Keller's original interpretation of the lake dwelling sites would continue to dominate the literature and discourse for the next 100 years (Leckie 2013). The first challenge to his lake dwelling interpretation came in the 1920s when the Research Institute of Prehistory and the Heritage Office of Tübingen in Germany carried out systematic excavations on the Federsee (Lake Feder)(Menotti 2001: 321). A number of experts in various scientific fields contributed to these excavations, which determined that the settlements were built on the marshy shores of

lakes rather than over the water on platforms (Menotti 2001: 321; Pétrequin and Bailly 2004: 37). From the 1920s on, the lake dwelling hypothesis supported by Keller was questioned first by Reinerth, then by Paret, and was finally completely overturned in the 1950s by Vogt (Menotti 2001: 321). These newer interpretations of the lake dwellings indicated that they were built on the lakeshores, which were prone to occasional flooding (Reinerth), or on marshland near lakes where the ground was less firm (Paret), thus explaining the piles (Menotti 2001: 321-322). The type of settlement also varied by region. During the Neolithic in southwest Germany settlements were solely located on dry lakeshores (Schlichtherle 2004: 30), for example. By the 1980s the argument was laid to rest and modern experts agree that settlements varied from lake-side and over-marsh to some which were in fact built over shallow water (Menotti 2001: 11).

Lake Dwellings as Symbols

The discovery of the lake dwelling cultural complex could not have been better timed. When the sites became more broadly known, beginning in 1854, Switzerland was a relatively new nation that had formed only a few years earlier in 1848. The images of primitive lake dwelling communities created the perfect backstory for a new nation seeking a unifying history and prehistory (Arnold 2013: 877; Pétrequin and Bailly 2004: 37;). The lack of affiliation or continuity with later European ethnic groups made lake dwellers an even more suitable source of national identity for an ethnically and linguistically diverse country such as Switzerland (Arnold 2013: 877). “Pile Dwelling Fever” combined with Swiss nationalism to inspire artistic recreations of the lake dwellers (Schöbel 2004). Newspapers, calendars, textbooks, museum exhibits, and articles, first in the European, then the international press promoted a romanticized image of prehistoric lake dwelling life (Arnold 2013: 877). Interpretations of the lake dwellers were further extended so that they portrayed industrious people who grappled with periodic

violence, based on the frequency with which the sites exhibited evidence of burning (Pétrequin and Bailly 2004: 37). The lake dwellings also provided the first extensive example of archaeological "lifeways" versus sites associated with death, such as graves or battlefields. For the first time, the general public could relate to the past by observing objects from the daily lives of ordinary farmers. In addition, the botanical material that was saved in mass quantities for the first time shed light on daily activities like food and clothing. Finally, lake dwellings revealed the true complexity of central European prehistory providing a past worthy of interest.

Lake Dwelling Excavations and Botanical Studies

Many lake dwelling excavations have taken place and many methods have been applied to this site complex over the past 165 years. The massive quantities of material culture, especially organics, from these sites can be seen as both a boon and a hinderance, requiring a special set of excavation techniques and methods. In Germany, early expeditions on Lake Constance beginning in 1856 focused on artifact collection and salvaging the remnants of piles rather than on uncovering specific sites (Schlichtherle 2004: 22). The first actual excavations of lake dwelling sites required the development of underwater excavation methods. At Lake Geneva, Adolphe von Morlot, a geologist, used a bucket with an inserted glass viewing panel and a pump to supply air, creating a means to breathe underwater so that he could retrieve objects from the lake bottom (Coles and Coles 1989: 20). This method was not required for all lake dwelling sites since many were located near lakes rather than underwater (Coles and Coles 1989: 20). The first excavation of a lake dwelling site in Germany was carried out in 1875 on the Federsee (Schlichtherle 2004: 22). In 1919 the first German excavations by professional archaeologists uncovered five new sites on the Federsee while also uncovering previously

unknown parts of settlements that had been discovered in the 19th century (Schlichtherle 2004: 23).

From 1966-67, excavations at Kleiner Hafner on Lake Zürich were the first systematic underwater field excavations to use a previously developed technique to keep water clear, increasing visibility of the cultural layers that were separated by layers of lake marl (Ruoff 2004: 15). During the same decade in France, excavators utilized scuba diving gear at a Late Bronze Age site on Lake Bourget (Pétrequin and Bailly 2004: 38). In some ways, modern excavations at lake dwelling sites became regionally confined and archaeologists working in different countries were not always aware of the methods and interpretation used by their neighbors (Pétrequin and Bailly 2004: 39). This was partly because excavation methods in the 21st century tended to focus on long-term regional projects that collated data from many sites within a region. These projects often relied on multidisciplinary research methods, highly developed sampling strategies, and long-term data collection in order to make developed assertions about intra- and inter-site relationships (Jacomet and Brombacher 2004). On the other hand, the application process for UNESCO World Heritage Status required the cooperation of six countries for the joint property nomination submitted in order to protect the 111 lake dwelling sites that now make up the multiple property listing "Prehistoric Pile Dwellings around the Alps". This trans-national effort was inspired by cooperative trends in lake dwelling heritage management that began in 2004 when four museums collaborated to produce a joint exhibit in honor of the sesquicentennial of the lake dwelling discovery at Obermeilen (Leuzinger 2004).

There are many sources of information on the plants and food remains from lake dwelling sites, most of which include a discussion of the Robenhausen site. The original analyst of lake dwelling flora was Oswald Heer who wrote a monograph on the plants from these settlements

(1865). The most comprehensive recent study of lake dwelling botanical material provides detailed information on the prevalent domestic staples and wild plants associated with different time periods, sites, and cultures (Jacomet et al. 1991). The Swiss Neolithic settlement of Arbon Bleiche 3 was the subject of a unique, large-scale, interdisciplinary excavation which included sampling strategies tailored toward the recovery of botanicals and other material from individual units across the settlement and in each of more than 20 houses located at the site (Jacomet et al. 2004). The authority on lake dwelling botanical information, Stefanie Jacomet has also published numerous other studies of plant material from lake dwelling sites (2013, 2007, 2006, 2004; Jacomet and Brombacher 2005; Jacomet et al. 1991; Jacomet and Schibler 1985; Jacomet and Schlichtherle 1984).

Chapter III Methods

3.1 Introduction

This chapter begins with a discussion of the importance of lake dwellings to the field of paleoethnobotany. This is followed by a description of the process by which the MPM Robenhausen botanical collection was documented prior to scientific analysis and the archival research that preceded that analysis. The next section provides a list of expected flora based on systematically recovered botanical remains that have been recently analyzed and published (Altorfer 2010), and species identifications in other Robenhausen museum collections. This is followed by descriptions of the archaeological and biological backgrounds of the main botanical categories represented in the collection. The next section describes the process used to identify grain species, seeds, and other organic materials that are part of this botanical assemblage. This section is followed by a discussion of the comparative collection of botanical material assembled for this project. The final portion of the chapter focuses on the development of two separate sets of experimental methods that were used to better understand the formation processes of the crab apple pieces and cereal product fragments in the MPM Robenhausen botanical collection.

3.2 Significance to Paleoethnobotany

Before discussing the methods used to analyze the collection it is important to note that the lake dwellings in general, and Robenhausen in particular were significant and formative in terms of the history and development of paleoethnobotany. The botanical material from Robenhausen represents one of the earliest collections of archaeological plant remains to be saved and analyzed (Renfrew 1973). Prior to these excavations, botanicals from archaeological sites were typically not collected or conserved as a material class and were considered less

significant than other forms of material culture. In the case of Robenhausen specifically, the excavator, Jacob Messikommer, was a farmer who recognized the significance of plant remains, especially with regard to understanding early agricultural practices and the timing of domestication, at lake dwelling sites (Altorfer 2010, 2000; Keller 1866; Munro 1888: 111-112). The Robenhausen excavations were revolutionary both because Messikommer's approach to the material was unprecedented and because of the very large quantity and high quality of organic specimens preserved at the site. In the hands of another antiquarian, all of this information might have been lost.

The botanical material from the site was initially examined by Oswald Heer, a Swiss naturalist and botanist who corresponded with Darwin among other scientists of the day. Heer saw the botanical material as a window into the diet and environment at Robenhausen (Jacomet 2004: 162). In addition to studying the plant remains, Heer's monograph entitled *Die Pflanzen der Pfahlbauten* (1865) identified 82 different species that had been found at lake dwelling sites (Altorfer 2010: 104). This work was included as a chapter in Keller's 1866 publication *The Lake-Dwellings of Switzerland and Other Parts of Europe.* Many of Heer's identifications have been confirmed by more recent archaeobotanical analyses and his designation of *Triticum antiquorum*, a small-grained wheat attributed specifically to the lake dwelling cultural complex, is considered an important documentation of a now extinct domesticated wheat (Jacomet and Schlichtherle 1984).

3.3 Documentation of the Collection

Prior to systematic analysis, some basic characteristics of the MPM's botanical collection had already been noted. One of these characteristics is that some of the objects still have their original labels, which include identifications made by Jacob Messikommer himself (Figure 3.1)

and these labels can date the period when the objects were collected based on the style since Messikommer used different labels over the course of decades of excavation (Altorfer 2000, 2010; Ross 2011). From a museum conservation-based perspective, the MPM's Robenhausen botanical collection has not been maintained to the highest possible standards and does not meet current recommendations for the preservation of waterlogged botanical material (Fritz and Nesbitt 2014; Pearsall 2000). This is primarily due to its excavation in the late 19th century when paleoethnobotanical and archaeological methods were in their infancy. In addition, the history of the material after being removed from the Robenhausen site is unclear and periods of ten to twenty years elapsed between the documented acquisition of some objects from Robenhausen and their formal entry into the MPM's permanent collection. Cases like this one where a collection has been compromised are fairly common in museums containing 19th century excavation materials (Swain 2007).

Figure 3.1: Wood haft from the MPM Robenhausen collection with original Messikommer label.

As discussed in the introduction, one of the goals of this project was to document the initial state of this collection before rehousing some of the material in more secure and less potentially damaging containers. Another goal was to photograph and record the collection so that it can be shared digitally with other institutions. A third goal was the identification,

classification and labeling of all elements of the collection where possible based on visible characteristics. Where identifications could not be determined with complete accuracy, the abbreviation cf., which stands for the Latin *confer* and *conferatur* meaning “compare”, was used in accordance with standard scientific procedure (Peres et al. 2010). In addition, the objects in the collection were given research numbers rather than labels so that additional analyses can be easily carried out and identifications adjusted in the future.

The research for this thesis began with an assessment of the botanical portion of the MPM Robenhausen collection. This documentation process included describing and photographing the initial state of the material including mounting and storage methods. Preliminary research on the three donors who contributed to the collection was conducted at the MPM library and archives. Additional MPM sources consulted during this initial phase included an unfinished study of the botanical material by another Anthropology Masters student and all documentation provided in the accession and catalogue files. Subsequently, a loan request for the botanical material was submitted to the MPM Curator of Anthropology and the MPM Registrar during the spring of 2018, including most of the collection except for apple halves and cereal grains that had been preserved in solid glass or plexi mounts (see photo in Figure 3.2, where two apple halves can be seen in a plexi half globe), which precluded scientific description, analysis, and identification. This material was then analyzed in the Paleoethnobotany Lab in the University of Wisconsin-Milwaukee Archaeological Research Laboratory (UWM-ARL) under the supervision of paleoethnobotanist Jennifer Haas.

Prior to this project, the Robenhausen botanical collection had been divided into the following five categories: cereal grains, bread, apples, hazelnuts, and unidentified items. These

Figure 3.2: MPM Robenhausen drawer as it existed at the start of this project, June 2017.

distinctions were made in the initial phase of cataloging the finds at the museum and do not reflect the actual composition of the collection. For example, there are more *Rubus* seeds in the collection than hazelnuts, but *Rubus* seeds are not mentioned in the catalogue or on object labels (Figure 3.3). The cereal grains in the collection were donated by J.A. Renggly, Adolph Meinecke, and Charles Dörflinger. These grains consist of two large lots and two smaller lots that were labeled “charred wheat” or “charred wheat and barley,” respectively. The large lots include several thousand grains each while the smaller lots contain fewer than one hundred individual pieces each. The apples were donated by the same individuals and include seventy-five specimens labeled “charred wild apples” and “charred cultivated apples”. Fourteen pieces

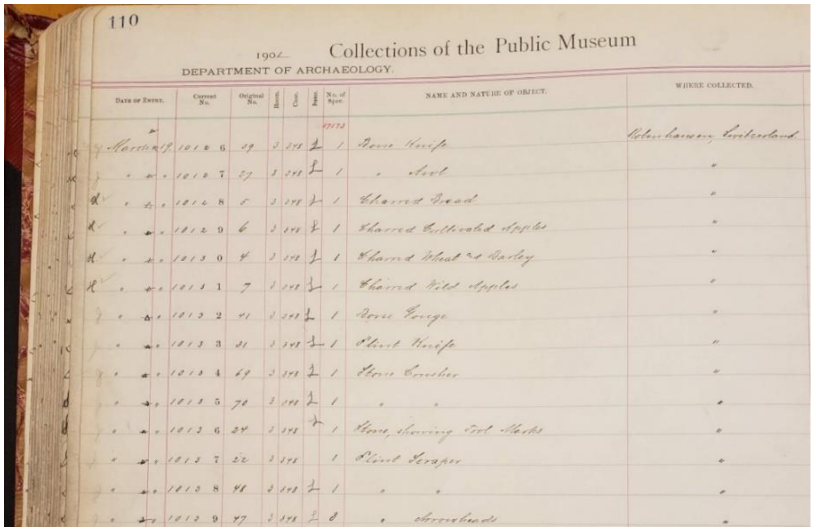

Figure 3.3: MPM catalogue book page listing some of the Robenhausen botanicals included in this project with their descriptions.

of cereal product were donated by Renggly and range in size up to 2.8 cm. in diameter. The collection also includes three uncarbonized whole hazelnuts and one piece of carbonized hazelnut shell, all of which were donated by Dörflinger, who is known to have actually visited Robenhausen based on Messikommer's logbooks (Arnold 2013: 881). Remaining miscellaneous items consist of one conglomerate of charred grains donated by Meinecke and a variety of seeds that were mixed in with three of the lots of grain and are not mentioned in the catalogue descriptions or other MPM documentation (Table 3.1).

In order to complete the scientific documentation of the collection, all materials were measured, weighed, photographed, recorded, and described. Measurements of the length and width of each cereal product fragment and apple piece were taken using the digital microscope's ruler function. The height of each fragment was measured using a metric ruler. Weights were taken in grams to the 0.001 using an Ohaus Precision Standard TS120S digital scale. Each piece of cereal product and apple was described in detail and this information was recorded in an Excel

spreadsheet. For apples, the information included whether the fruit was sliced vertically or horizontally, the presence or absence of seeds, peel, and stem, how much of the original fruit was represented by the remaining piece, and any other significant descriptive information. Photographs of the apples were labelled reverse, meaning peel side, and obverse, referring to the open or cut side of the fruit. Cereal product was described based on the degree to which grains were visible, the presence of crust, and any other significant qualities. Some pieces of cereal product were defined as having flat, structured sides labelled as reverse and unstructured sides labelled as obverse, which would have faced up. Hazelnuts were only represented by four specimens and were recorded using measurements and weights. All materials were photographed at least twice. One set of photographs was taken using the digital microscope camera on the lowest magnification level with a digital scale bar included in each image. Additional photographs were taken using a Dual Pixel 12MP AF Sensor Camera with a scale bar and label in each image. Apples and cereal product were photographed in obverse and reverse with both cameras where possible. Additional images of cereal product at higher levels of magnification were taken in color, black and white, and photo negative to highlight the visibility of individual grains in some pieces and the pores in other pieces. Hazelnuts were also photographed with both cameras from several different perspectives. Cereal grains numbered in the thousands, ruling out the possibility of photographing each specimen. Many grains were measured as part of the identification process (which is described later in this chapter) and all taxonomic groupings were weighed and counted after identification. Where the total number of specimens of a species of grain within a lot exceeded 100, 100 were counted and weighed and the total number was extrapolated using the total weight. Individual representative grains from

each species and catalogue lot were photographed while additional images of groups of grains were taken to provide an overall impression of the condition and appearance of the material.

3.4 Expected Flora

The flora found at lake dwelling sites in the Alpine Foreland during the Neolithic and Bronze Age consisted of a mixture of domesticated and wild plants. For example, during the Pfyn Cultural Period (4500-4000 BC), an analysis of the edible flora found at the AKAD-Seehofstrasse site showed that around 50% of the plants were gathered (Jacomet and Schibler 1985). The domesticated plants found at lake dwelling sites include cereals, flax, and legumes (Jacomet et al. 1990). Major gathered plants included apples, raspberries, blackberries, strawberries, water chestnuts, and hazelnuts (Jacomet et al. 1990)(Figure 3.4). The following table provides a summary of the full table of expected flora in Appendix A and is based on a synthesis of existing lake dwelling literature and museum collections (Table 3.1). This summary table includes the most common plant species in most major museum collections in the U.S. and Europe. The tables in Appendix A include all plant species documented at the Robenhausen site over the past 150 years, the written sources in which they are discussed, most of the major U.S. and European museums in which they are found, and the German names for each species.

Table 3.1: The species most commonly found in Robenhausen museum collections and the major museum where they are found in the United States and Europe.

Museum Key: OH = Ortsmuseum Heiden, MW = Meuseum Wetzikon, HMP = Heimatmuseum am Pfáffikersee, RMK = Rosgarten Museum Konstanz, BHM = Historisches Museum Bern, MKB = Museum der Kulturen Basel, HM SG = Historisches Museum St. Galen, MAW = Münzkabinett und Antikensammlung der Stadt Winterthur, MA SH = Museum zu Allerheiligen Schaffhausen, MAH GE = Musée d’Art et d’Histoire Genéve, MVFB = Museum für Vor- und Frühgeschichte der Staatlichen Museen Berlin, MPM = Milwaukee Public Museum, NMNH = National Museum of Natural History (Smithsonian), CFM = Chicago Field Museum, OAM = Oxford Archaeology Museum, Br.M = British Museum, Be.M = Berlin Museum, PMAE = Peabody Museum of Archaeology and Ethnology.

Scientific Name	English Name	OH	MW	HMP	RMK	BHM	MKB	HM SG	MAW	MA SH	MAH GE	MVFB	MPM	NMNH	CFM	OAM	Br.M	Be.M	PMAE
Abies alba	European silver fir	x							x		x	x		x				x	
Alisma plantago-aquatica	European water plantain				x			x				x		x	x			x	
Carpinus betulus	European hornbeam					X		x	x			x		x					
Chenopodium album	Goosefoot		x	x	x							x	x	x	x			x	
Corylus avellane	Hazelnut	x	x		x	X		x	x		x	x	x	x	x	x	x	x	
Cornus sanguinea	Common dogwood				x			x				x		x				x	
Fagus sylvatica	Red beech	x	x		x	X		x			x	x		x					
Fragaria vesca	Wild strawberry		x	x	x	X	x				x				x				
Galium palustre	Common marsh bedstraw		x		x	X		x	x			x		x				x	
Hordeum vulgare	Barley	x	x	x	x	X	x	x	x		x	x		x	x	x		x	x
Linum usitatissimum	Common flax	x	x	x	x	X	x	x	x	x	x		x	x	x		x	x	
Malus sylvestris	European crab apple	x	x	x	x	X	x	x	x	x	x	x	x	x	x	x	x	x	
Nymphaea alba	European white water lily				x	X					x	x		x					
Papaver somniferum	Opium poppy		x	x	x			x				x		x				x	
Pedicularis palustris	Marsh lousewort				x			x				x		x	x				
Pinus sylvestris	Scots pine				x	X					x	x		x					
Prunus padus	Bird cherry	x			x				x			x		x	x			x	
Prunus spinosa	Sloe	x	x	x	x	X		x		x	x			x				x	
Rubus frticosus	European blackberry		x	x	x	X	x	x			x	x	x	x					
Rubus idaeus	Red raspberry	x		x	x	X	x	x	x		x		x	x			x	x	
Sambucus nigra	Elderberry				x	X					x	x		x	x				
Taxus baccata	Common yew				x	X				x		x		x				x	
Trapa natans	Water chestnut	x	x	x	x	X	x	x	x		x	x		x		x	x	x	
Triticum aest./durum/turg.	Naked wheat	x	x	x	x	X	x	x	x	x	x	x	x		x			x	

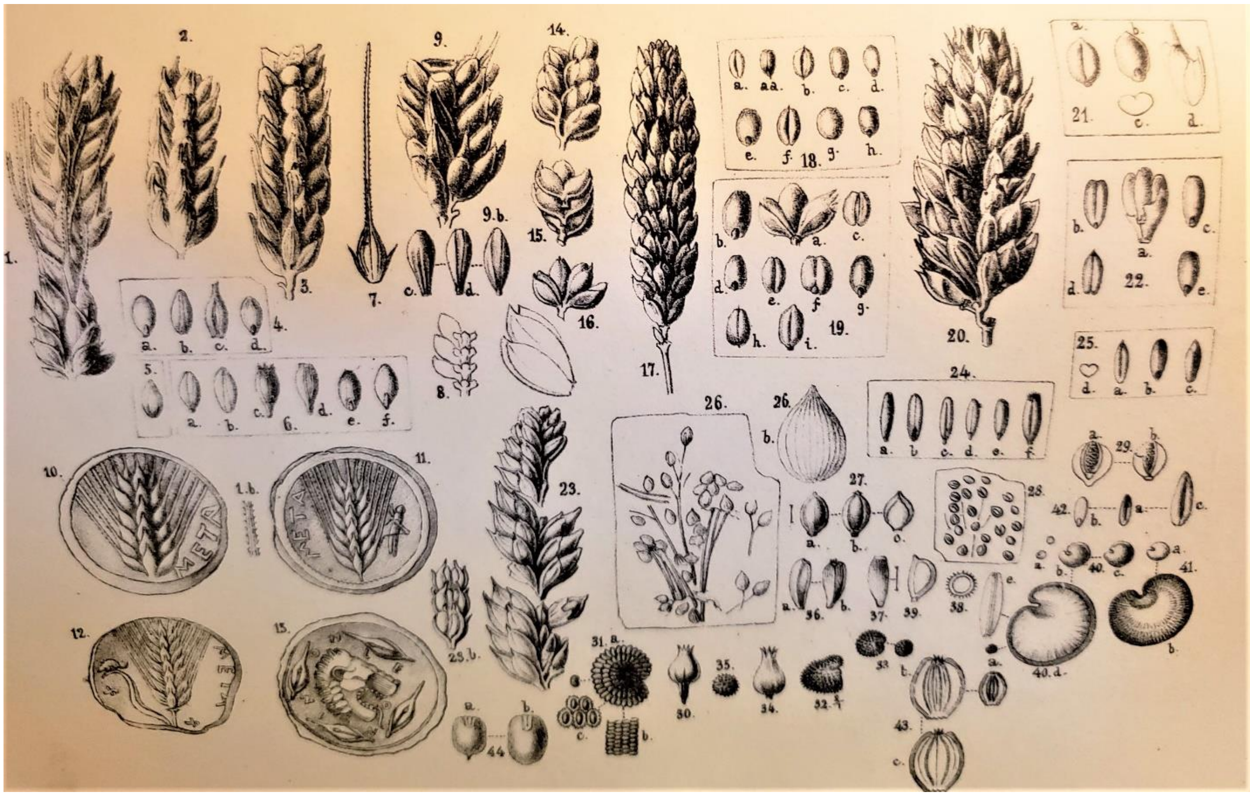

Figure 3.4: Lake dwelling plants and seeds (after Keller 1866 Plate 87).

3.5 Main Species and Food Accounts

The botanical types included in this thesis can be broken down into a few main groups: cereal products, loose cereal grains, crab apples, hazelnuts, and miscellaneous seeds. The second category can be further subdivided into wheat and barley and the last grouping is known to include *Linum usitatissimum, Rubus,* and *Malus* seeds. The following provides a brief overview of each of these major groupings with information about their domestication, relevance, and their significance to human culture.

Apple (*Malus* Species)

The primary wild progenitor of the apple is thought to be *Malus sieversii* (Luby 2003), which grows in the Tian Shan region of Kazakhstan where it was most likely domesticated

(Jordan 2015). This region was part of the Silk Road, which followed older trade routes and promoted an east-west apple dissemination (Gharghani et al. 2010; Juniper and Mabberley 2006: 123; Luby et al. 2000). During this process hybrids of *Malus sieversii* mixed with several species including *Malus prunifolia, baccata, mandshurica,* and *sieboldii*, all of which are native to China (Luby 2003). Recent analyses have demonstrated that there is a high genetic and morphological similarity between apples along this east-west path from Central Asia, extending through Iran, Russia, and Turkey, as compared to other species in the *Malus* genus (Gharghani et al. 2010). While modern apples are closely related to both *M. sylvestris* (European crab apple) and *M. sieversii*, the trees and fruit are more similar to the latter in appearance (Zohary and Hopf 2012). The most conclusive archaeological evidence for the early significance of apples comes from the burial of Queen Pu-abi at Ur, where strings of dried apples were found dating to c.2600 BC (Juniper and Mabberley 2006: 90; Miller 2013).

Malus domestica, or the domestic apple, is a false fruit with five chambers called loculi, with two seeds in each chamber (Zohary and Hopf 2012; Luby 2003). Species of the genus *Malus* are self-incompatible and the offspring that they produce are diverse and do not exhibit the traits of the progenitor (Schlumbaum et al. 2012). They are grown in regions with winters that are cold enough to break the dormancy of the buds, spanning the Old World from Central Asia through Europe (Zohary and Hopf 2012; Luby 2003; Juniper and Mabberley 2006). The origins of the domestic apple are still uncertain, with many sources attributing apple domestication to the ancient Romans around the 3rd century BC (Lechler 1937). This attribution is in part due to the complexity of grafting, which is the traditional method of apple cultivation, and to the numerous literary sources regarding domestic apples in ancient Rome. Carbonized apples are found at sites throughout Europe beginning in the Early Neolithic, coinciding with the

adoption of agriculture, however, in most cases, these apples are thought to be *M. sylvestris*, a wild apple or crab apple (Villaret-von Rochow 1969).

Barley (*Hordeum* Species)

Domestic barley is unique among domesticated grasses because of its similarity to its wild progenitor and its ability to tolerate climatic conditions outside of the range of other staple crops. Barley is also culturally significant because it was the main staple used to brew beer throughout the Old World. The wild ancestor of domestic barley, *Hordeum spontaneum*, grew abundantly in Asia Minor and was also found in the Mediterranean and Central Asia (Harlan and Zohary 1966). Barley is an annual plant, a member of the grass family, *Poaceae*, and of the plant group, *Triticeae* (Ullrich 2014). It is a diploid, self-pollinating, autogamous plant, meaning that pollen is transferred to the stigma within the same flower (Zohary and Hopf 2012). There are hundreds of varieties of domestic barley, while land races number in the thousands (Zohary and Hopf 2012). Barley is high in B vitamins, especially thiamin, niacin, and in the mineral manganese (Ellison 1981). Definitive evidence of wild barley use comes from various sites around Asia Minor. The earliest of these finds from Ohalo II in Israel date to 17,000 BC (Zohary and Hopf 2012). The earliest evidence of barley domestication comes from Tell Aswad, near present day Damascus, at 10,300 BC (Zeder 2011).

There are a variety of traits that separate domestic and wild barley. Like many plants, wild barley has a specialized seed scattering system which depends on the main stem or rachis. In wild barley the rachis is brittle so that the grains disperse easily before the plant has reached maturity (Pourkheirandish and Komatsuda 2007). Domestic barley has a non-brittle rachis that keeps the spikes from shattering upon maturity (Appendix B)(Ullrich 2014). Another important quality is seed dormancy, which makes seeds unable to germinate immediately, even in

favorable conditions, causing it to be more tolerant to droughts and frosts (Ullrich 2014). This dormancy increases the distribution of seeds and allows them to survive longer in unfavorable conditions (Pourkheirandish and Komatsuda 2007). Other changes in barley that indicate domestication include six-rowed spikes and hull-less or naked kernels (Ullrich 2014). Hull-less kernels decrease the amount of insoluble fiber, making the grains more useful for human consumption (Ullrich 2014). When barley diffused from Asia Minor into other areas of the world it developed greater tolerance to cold climates and shorter day length, making it more adaptable in northern latitudes (Ullrich 2014). The most beneficial change in domestic barley was the increased yield of individual plants from two-rowed to six-rowed, tripling the productivity of each plant (Zohary and Hopf 2012).

Wheat (*Triticum* Species)

Like barley, wheat is also an annual plant and a member of the grass family, *Poaceae*, and the plant group, *Triticeae* (Ullrich 2014). Today wheat accounts for over twenty percent of the caloric intake of human groups around the world and is preferred over other cereals due to its high nutritional value (Zohary and Hopf 2012: 19). Unlike barley, wheat has undergone a complex process of domestication, diversifying into many species and subspecies and interbreeding with various wild grasses. Because of this, the origins and classifications of some types of wheat are unknown or accounted differently by experts. Wheat can be divided into three main groups based on number of chromosomes: diploid, tetraploid, and hexaploid wheats (Renfrew 1973:40). It can be further divided based on whether the spikelets lose their glume during the threshing process, as with naked wheat, or retain their form, as with hulled wheat (Renfrew 1973:40).

The domestication of wheat is a complex process because the different species have different wild progenitors. In addition, and as with many plants, taxonomists disagree on the classification and divisions between species, subspecies, and cultivars (Renfrew 1973: 40). Einkorn (*Triticum monococcum*) is a diploid wheat and a relic crop that was domesticated from a hulled, brittle-eared grain, *T. monococcum boeoticum*, with which it still shares many similarities (Zohary and Hopf 2012: 31). Domestic emmer (*Triticum dicoccum)* is a tetraploid hulled wheat species with a brittle rachis (Appendix B)(Stika and Heiss 2013: 360). This type of wheat followed a similar domestication trajectory to einkorn: wild emmer (*T. turgidum disoccoides*) resulted in a hulled domestic crop with brittle ears (Stika and Heiss 2013: 360). However, crossbreeding also gave way to non-brittle eared and free-threshing derived forms such as *T. durum* (also known as *T. dicoccum durum*)(Zohary and Hopf 2012: 31). Crossbreeding of *Aegilops sqarrosa*, a wild grass, with cultivated emmer may have resulted in the hexaploid, non-brittle, hulled *T. spelta* (spelt) and the free-threshing *T. aestivum* (bread wheat), which is the most common type of wheat grown in modern times (Zohary and Hopf 2012: 31). Others contend that there are two versions of spelt, an Asian variation and a European variation; the latter first appeared between 2400 and 2200 BC in the area north of the Alps (Stika and Heiss 2013: 360). This hypothesis is corroborated by the Early Bronze Age distribution of spelt in a small region of central Europe to increased prevalence in a larger geographic region by the Late Bronze Age (Stika and Heiss 2013: 306).

Hazelnut (*Corylus* Species)

Common hazel is found in Europe, the Caucasus, and West Asia, specifically Iran and northern Turkey, where it is a component of the temperate beech and oak forest belt (Zohary and Hopf 2012: 151). The plant is a deciduous shrub or small tree and is one of fifteen species

belonging to the *Corylus* genus (Zohary and Hopf 2012: 151). Hazelnuts measure 10-25 mm in length and have a rounded, ovoid shape. They are attached to the tree by an involucre or bract and covered by a woody pericarp (Renfrew 1973: 159). The domestication process of *Corylus avellana* is not fully understood although its exploitation as a food source can be traced from the Mesolithic to the Medieval Period (Renfrew 1973: 159; Zohary and Hopf 2012: 151). Hazelnuts were gradually selected for larger and higher quality nuts and by Roman times clones were used to plant shrubs (Zohary and Hopf 2012: 151). The modern cultivar, *Corylus maxima*, is a fully-infertile shrub with larger fruits and higher yields than *C. avellana*, but shrubs and hybrids of both plants are still grown (Zohary and Hopf 2012: 151).

Raspberry (*Rubus* Species)

Rubus is a genus of over 500 species of flowering plants that includes many different types of berries, of which the raspberry is the most economically important (Graham and Woodhead 2009: 507). The European red raspberry, *Rubus idaeus*, is a diploid bush composed of single-seeded druplets grouped together on a cone-shaped core (Renfrew 1973: 147). Seeds are 1.8 – 3 mm long, tan-colored, kidney-shaped, and have a distinct reticulated surface (Renfrew 1973: 147). The plant itself is a bush made up of thorny canes which die back in winter and spread quickly in summer (Graham and Woodhead 2009: 509; Renfrew 1973: 147). In Europe, red raspberries have been exploited at least since the Mesolithic and were probably an important component of summer diets (Renfrew 1973: 147).

Flax (*Linum* Species)

Linum ustatissimum is a diploid, annual, self-pollinating, thin-stemmed plant which can be divided into two-varieties based on use (Zohary and Hopf 2012: 101). The shorter, branched

variety of flax is used for its seeds, which can be eaten or pressed as a source of oil, while the taller, less-branched type with smaller seeds is used for fiber, primarily in linen production (Zohary and Hopf 2012: 101). Planting flax in tightly packed groups facilitates this production because clustering prevents the plants from bending and snapping and this produces longer fibers (New England Flax and Linen 2019). Prior to domestication, wild flax was an important source for flax seeds and linseed oil and the fibers were used to make baskets and nets before they were used for textile production (Jacomet 2004: 162-177). Studies indicate that modern domestic flax (*Linum usitatissimum*) derived from the wild type, *Linum bienne*, or pale flax, and that domestication occurred in order to select for plants with higher oil content (Fu et al. 2011: 139-153). Domestic flax is taller than the wild type, has a higher oil content and its seeds don't dehisce or burst when ripe (Allaby et al. 2005: 58-65). The first archaeological evidence of *Linum usitatissimum* comes from Tell Ramad in Syria and dates to 7,000 BC (Allaby et al. 2005: 58-65). Modern flax probably spread from the Near East into Europe, through Anatolia and into Greece between 6500 and 5600 BC, based on domestic seeds found at archaeological sites (Harris 2014). From Greece, domestic flax spread quickly into central Europe, arriving in the Alpine Region between 5400 and 4900 BC (Harris 2014). Seeds from this period have been found in Italy, Northern France, Belgium, the Netherlands, Luxemburg, central Europe, and in the circum-Alpine region (Harris 2014).

Cereal Preparations, Products, and Bread

From a production perspective, breads are cereal products in one of their most time-consuming forms (Heiss 2015: 71). As such they represent what must have originally been a luxury item rather than the staple food that they have become in more recent times (Hayden 2003). Archaeological cereal products found in ancient Egyptian tombs and Viking cremation

burials attest to their value and symbolic significance (Heiss 2015: 71). One of the primary benefits of bread is that it can be stored and rehydrated for use as a component of food recipes or as a starter for beer; this latter use dates to the 3rd millennium in ancient Sumer (Heiss 2015: 71). When bread became a staple is a key question in food studies and one that requires something that might seem obvious: a definition of bread. The definition of modern bread is a mixture of flour (finely ground grain) with milk or water, made with or without yeast, which is formed into a dough and baked in an oven. On the other hand, analyses of prehistoric bread demonstrate that a broader definition for the latter is necessary since many specimens incorporate other plant material in addition to grain (Hansson 1994; Heiss et al. 2017). Another issue is that the differences between archaeological porridge and bread are tenuous since without a discernable outer crust, conflation of carbonized porridge and bread in the archaeological record is likely (Hansson 1994).

The oldest archaeological "breads" predate the Neolithic period and there are many examples of bread from cultures in Asia, Africa, and Europe prior to the first historical breads in ancient Rome. The oldest bread-like substances (which were found in a hearth) come from Shubayqa 1, an Epipaleolithic site in Jordan that dates to 12,300 BC (Arranz-Otaeguí et al. 2018). This bread was made from finely ground wild einkorn (*Triticum boeticum/urartu*) flour that included bits of carbonized tubers and sedges (Arranz-Otaeguí et al. 2018). Other significant breads from the prehistoric Old World include many types found at Çatalhöyük (Arranz-Otaeguí et al. 2018), those from the lake dwelling sites of central Europe, dating to as early as 3900 BC (Heiss 2015: 71) and the aforementioned Scandinavian breads that were part of ritual offerings and cremation burials (Hansson 1994). The oldest cereal products in Europe come from the following Neolithic sites: Doanne in Switzerland, Isére in France, Jersey in Great

Britain, and Izvoare-Neamt in Romania (Popova 2016). Each of these cereal products was made from either barley, a mixture of barley and wheat, or millet (Popova 2016).

Since the early 1990s, the study of bread in archaeological contexts has focused on the differences between historic and prehistoric bread (Hansson 1994). In addition to porridge, other cereal grain products include bulgur, trachanas, galettes, tarts, grain-paste, and toasted grains (Heiss 2015: 72). Unleavened flatbreads are commonly defined as less than 25mm in height while leavened bread are defined as having a height greater than 45mm (Heiss 2015: 72). Recent explorations into cereal products have focused on whether we should define such material using modern parameters, because of the potential to impose modern ideas about food, thereby obscuring the past (Valamoti et al. 2019). Others have criticized the degree to which bread is often left unstudied, and propose that, in studying what appears to be a bread-centered European Neolithic, the focus should be on all grain products found in archaeological contexts (Fuller and Carterro 2018). Grain products can be defined as fused whole grains, but these materials also fall within a broad spectrum, ranging from whole grains in a matrix to loose grains that became fused together and were possibly wet or dry prior to carbonization.

3.6 Identification of the Botanical Collection

The UWM floral lab is equipped with two binocular stereomicroscopes, both of which were used to identify the cereal grains and examine the pieces of charred cereal product in the MPM Robenhausen collection. The lab is also equipped with two digital scales. Recording equipment in the lab includes one digital microscope eyepiece (DinoLite) that can be used in conjunction with a microscope and computer to photograph objects at a high level of magnification. In addition, one standalone digital microscope (DinoLite) can be used with a computer to view and photograph images at lower magnifications. The lab also includes plastic

dishes and different sized glass containers with screw tops which were used to sort the collection during the identification process.

Identification of the grains was primarily carried out with reference to *Identification of Cereal Remains from Archaeological Sites*, 2nd edition (Jacomet 2006)(Figure 3.5 and 3.6). This

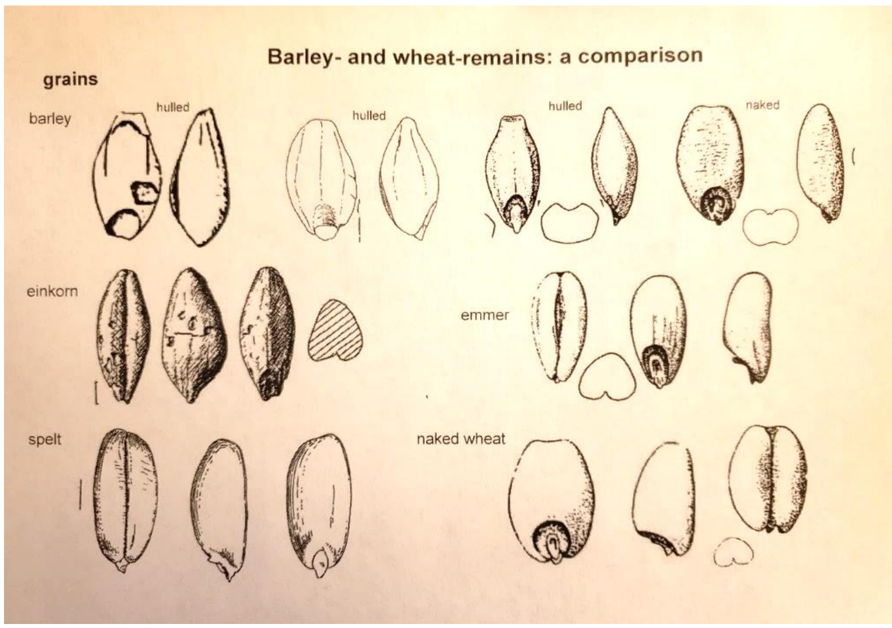

Figure 3.5: Barley and wheat in dorsal, lateral, and ventral perspective (after Jacomet 2006).

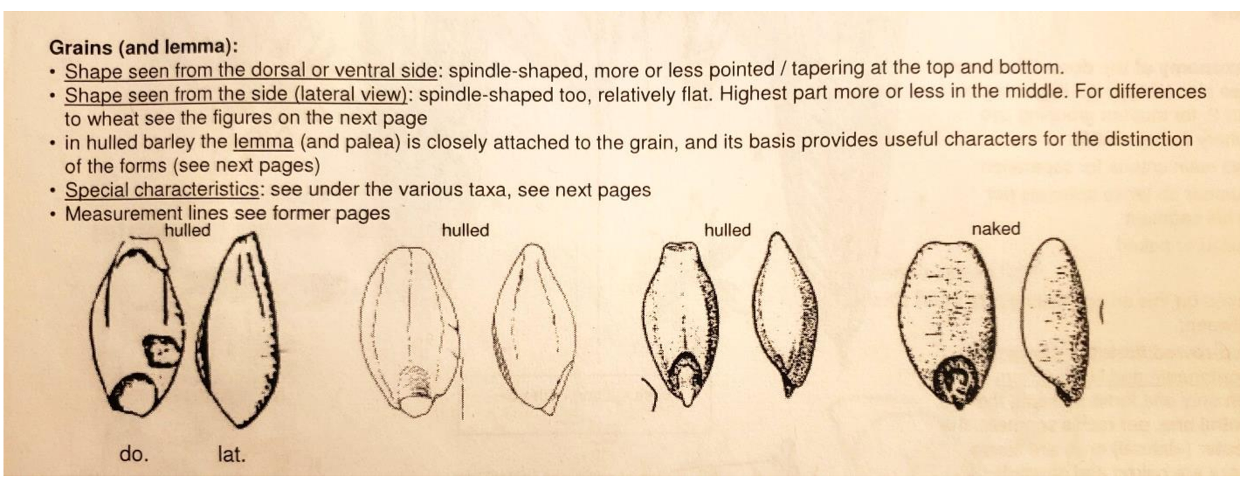

Figure 3.6: Barley in dorsal and lateral perspective (after Jacomet 2006).

guide includes line drawn images and lists of basic parameters for each species of grain. The guide was augmented by recommendations from Ferran Antolín of the University of Basel, an expert on lake dwelling paleoethnobotany and the identification of archaeological cereal grains. *Identification of Archaeological Remains of Wheat: The 1992 London Workshop* (Hillman et al. 1995) was also consulted. In addition, grain identifications were checked against images from the paleoethnobotanical literature (Braadbaart 2007; Hovsepyan and Wilcox 2008; Mashkour et al. 2013; Renfrew 1973; Schlumbaum et al.1998; Tvauri and Vanhanen 2016). The cereal grains were sorted using a process of elimination in which each individual grain was examined using the microscope with an imbedded scale bar to facilitate ease of measurement (Figure 3.7).

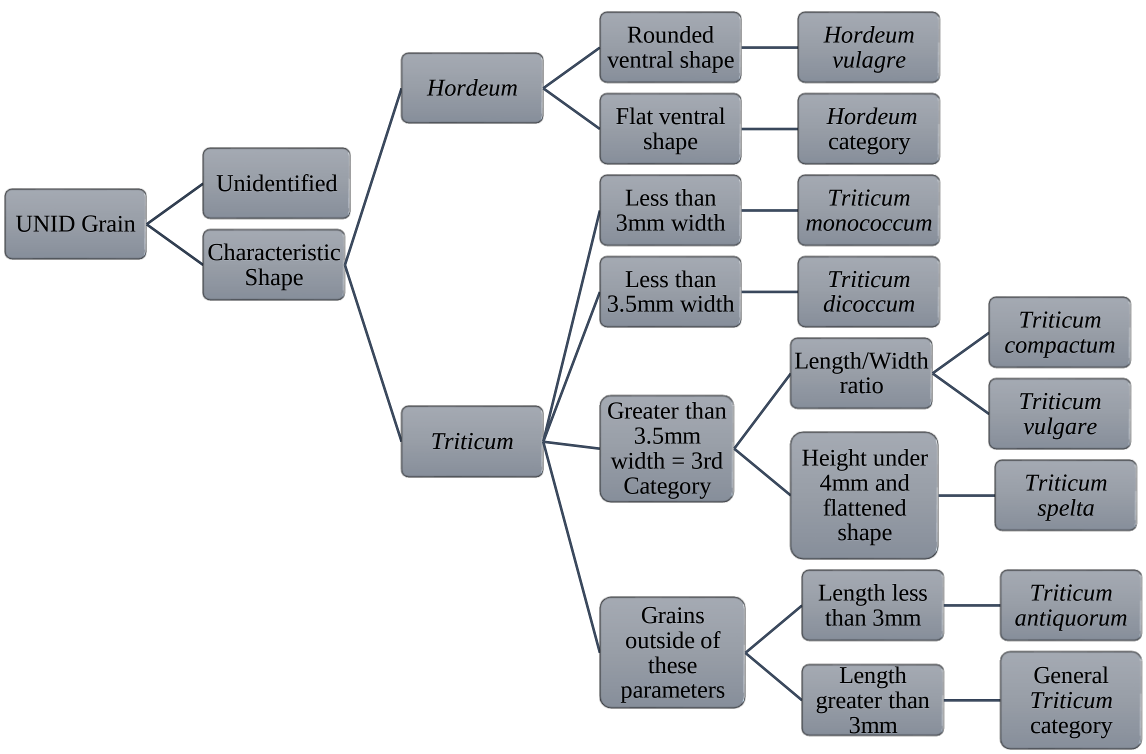

Figure 3.7: Grain identification process flow chart.

Damaged grains that lacked identifying characteristics and those with attached chaff which impeded the visibility of identifying characteristics were placed in an unidentified

category. Grains with identifying characteristics were examined from dorsal, lateral, and ventral perspectives to assess whether they belonged to the genera *Hordeum* or *Triticum* (Figure 3.6). If a grain was identified as *Hordeum*, it was evaluated for characteristics indicative of the six rowed *Hordeum vulgare* or placed in a general *Hordeum* category (Figure 3.7). Grains belonging to the *Triticum* genus were measured in length and width. Grains that were too small (less than 3mm long) to fit the size parameters discussed in the identification guide formed a separate category. Those with a width less than 3mm were examined for *Triticum monococcum* indicators while those with a width less than 3.5mm were examined for *Triticum monococcum* and *dicoccum* indicators; all other grains were separated into a third category. The third category of grains were divided based on the length/width ratio and attributed to either *Triticum compactum* or *Triticum vulgare.* Grains with a height under 4mm and other identifying features were assigned the designation *Triticum spelta*. Grains that did not fit within any of these divisions were placed in a general *Triticum* category.

The non-grain material that had been mixed with the charred wheat and barley included 94 seeds, three larger organics, one nut shell fragment, one insect, and one fish vertebra (Table 3.2). There were also rocks, shell marl, and charcoal. The 94 seeds belong to approximately 19 species and were identified using a variety of methods. Those that were not immediately recognizable were compared to photographs in texts (Berggren 1981; Renfrew 1973) and the list of expected flora for the site (Appendix A). When a species identification could not be made dimensions and comparative images were used to determine the lowest attributable taxon. At the conclusion of this process, an assessment of the collection and accompanying identifying information was provided to the MPM as a guide for future use of the Robenhausen botanical material.

Table 3.2: The non-grain components of MPM Cat. #10130. These elements are grouped by material type.

Material Type	**Description**	**Quantity**
UNID Seed	19 species	49
Rubus Seed	cf. *idaeus*	34
Malus Seed	cf. *sylvestris*	11
Organics	Larger than seeds	3
Nut	Partial, thick-shelled	1
Fish Vertebra	*Cyprinidae*	1
Insect	*Hemiptera*	1
Non-Organics	Plastic and foil	2

3.7 Comparative Collection

Although a comparative collection was developed, it was not the primary source used in the identification of the Robenhausen botanical material. Samples of wheat, barley, hazelnuts, millet, oats, rye, lentils, peas, berries, and beans were obtained from the USDA using the GRIN database. Care was taken to obtain samples from Central Europe where possible although a similar regional source does not necessarily ensure continuity with what would have existed in the Neolithic and Bronze Age. Botanical elements that could not be obtained through this database such as apples and crab apples, were obtained through farmers markets and the University of Wisconsin Arboretum (Figure 3.8).

The comparative collection proved not to be useful for the grain identification process because many of the grain types have changed significantly since the Neolithic and Bronze Age. In addition, carbonization, waterlogging, and other processes deform the grains a great deal. Attempts at replicating the condition of the Robenhausen grains were unsuccessful for a number of reasons. First, the particular waterlogged conditions under which the material had been protected from the elements could not be recreated since the material had been submerged for

such a long period of time. In addition, other factors such as the anaerobic nature of the environment and the alkaline pH level of the peat bog at Robenhausen require a level of experimentation that was beyond the scope of this project. Finally, experimental burning of the grains did not necessarily result in grains that resembled the Robenhausen botanical material. This was due to the limited control possible in the temperature of the carbonization environment, which is especially problematic with cereal grains. In fact, it has been demonstrated with emmer wheat (*Triticum dicoccum*) and spelt (*Triticum spelta*) that grains warp and expand in different ways at different temperatures and under different heating durations (Berihuete-Azorín et al. 2019; Braadbaart 2004).

Figure 3.8: Farmers market apple display of heirloom varieties (left) and a *Malus* “Henry Kohankie” crab apple tree at the University of Wisconsin Arboretum (right).

3.8 Experimental Methods

Experimental archaeology was another method used to better understand aspects of the Robenhausen botanical collection from a foodways perspective. Since there are several different

types of cereal products, the material warranted different approaches. Some of the pieces had visible grains within a matrix while others were made entirely out of whole grains that were fused together. I was interested in understanding how different types of products were formed and in what held the whole grains together. A review of the literature suggested that the apples halves from Robenhausen belong to the species, *Malus sylvestris,* the European crab apple and that they were not domesticated (Altorfer 2000, 2010; Jacomet 2004, 2007, 2013) Although other experiments have illustrated that the apple halves fall within the dimensions associated with this species (Villaret-von Rochow 1969) I was interested in comparing carbonized, dried *Malus sylvestris* to carbonized, dried heirloom apples to see if the latter approached the dimensions of material from lake dwellings. The apple remains found at Mesolithic, Neolithic, Bronze and Iron Age sites in Europe have also been assumed to be dried, but I wanted to verify this assessment within the MPM collection by comparing the appearance of dried, carbonized apples with non-dried or fresh-carbonized apples.

<u>Cereal Product Experiments</u>

The grain materials in this collection examined using these methods include one grain product and ten cereal product fragments. In the case of the fourteen cereal product fragments in the collection, visual inspection had demonstrated that they could be grouped into three categories, defined as “grain visible, ” “few grains,” and “amorphous” the last of which was not the focus of these experiments and would require SEM or another similar method of analysis. The grain-visible pieces consist of whole cereal grains in a matrix. In order to determine what types of grain were used, the level of moisture in the initial pieces, and whether moisture content affected the resulting fragments, a series of different grain product foodstuffs were created. These foods were made with broomcorn millet, barley, ground flaxseed, and farro, which is a

mixture of emmer, einkorn, and spelt grains. For these recipes, *Bob's Red Mill* farro, broomcorn millet, barley and ground flax seed were used.

In the first experiment, barley, millet and farro were separately mixed with water to create a variety of different consistencies ranging from soft whole grains to porridge-like materials. Initial tests followed the instructions on the packages to see what the appearance of the resulting grains would be. From there, different ratios of water to grain were used to create

Figure 3.9: Cereal porridges in aluminum "bowls" prior to carbonization. One part millet, two parts water (left), one part barley, five parts water (center), and one part farro: seven parts water (right).

different degrees of grain swelling and disintegration (Figure 3.9). Some of the farro, barley, and millet that had been cooked with the smallest amount of water (2 parts water 1 part grain) were also made into small round cakes. These recipes utilized ground flaxseed mixed with water as a binding agent to approximate the way in which the whole grains in the MPM collection were held together. This way of preparing ground flax is sometimes called a flax "egg" and is made by mixing 2 ½ tsp. ground flaxseed with 3 Tbsp. water, beating the mixture until the flaxseed is fully incorporated, then chilling the mixture in the refrigerator for 30 minutes or until it has taken

on the characteristic texture of a raw egg (Rinsky and Rinsky 2009: 112). Since chicken eggs were not available until the Early Iron Age and wild bird eggs were not discussed in the lake dwelling literature regarding food, flax was deemed most appropriate as an egg substitute due to the prevalence of flax products such as textiles, rope, and nets at lake dwelling sites. After the millet, barley, and farro mixtures were shaped into small cakes they were baked in a 350 degree Fahrenheit oven for 30 minutes (Figure 3.10). Once they had been baked and cooled, each grain-porridge and cake was individually wrapped in aluminum foil and burnt on a charcoal grill to replicate the carbonized materials found at lake dwelling sites (Figure 3.11). The porridge and cakes were then compared to the grain visible fragments of material from Robenhausen to determine which were most similar in appearance to the material in the collection. A second experiment was used to replicate the cereal conglomerate in the collection. For this experiment dry grains and grains cooked with water (2 parts water, 1 part grain) were carbonized separately in foil packets to determine whether the grain conglomerate in the collection was the result of dry, uncooked or wet, cooked grain being burnt. Like the previous experiment, this experiment was also performed with millet, farro, and barley (Figure 3.12).

Figure 3.10: Cakes made with flax-water mixture. Millet (left), barley (center), farro (right).

Figure 3.11: The same grain cakes after burning. Millet (left), barley (center), farro (right).

Figure 3.12: Experimental cereal grains. Clockwise from top: millet, farro barley, dry (left) and cooked with 1 part grain: 2 parts water (right).

<u>Apple Experiments</u>

Apples found in lake dwelling collections have long been a source of fascination because of the large quantity of specimens recovered from various sites that had been halved and dried in

a similar manner (Antolín et al. 2015; Bieniek and Lityńska-Zając 2000; Bishop 2013; Colledge and Conolly 2014; Keller 1866; Jacomet 2004, 2008; Jacomet and Brombacher 2005; Jacomet et al. 1991; Kubiak-Martens et al. 2015; MacLean 1993; Rottoli and Castiglioni 2008; Schneider 2007; Tolar et al. 2011). Discussions of apple halves in early lake dwelling literature often assumed that since there was such a large quantity that they must be domestic apples rather than crab apples (Villaret-von Rochow 1969: 201). One previous experiment involved cutting and carbonizing fresh crab apple specimens in a laboratory to determine whether the apples from lake dwelling sites were wild crab apples or domestic apples (Villaret-von Rochow 1969: 201). This experiment utilized samples of the European crab apple, *Malus sylvestris*, which were halved and burnt at 220-240 degrees Celsius (Villaret-von Rochow 1969: 201). The crab apples shrunk on average around 25% in width and 28% in length (Villaret-von Rochow 1969: 201) and the resulting carbonized crab apple specimens were similar in size to the largest specimens examined by Heer (1865), measuring between 3.1 x 2.8 cm. The specimens were then compared to examples from four Neolithic and three Bronze Age sites in central Europe (Villaret-von Rochow 1969: 202-205). Based on the results of this analysis, the apples found at the aforementioned sites were demonstrated to be almost entirely within the size range of the experimentally carbonized crab apples (Villaret-von Rochow 1969: 205). The precedent set by this study has been used to assess carbonized apple dimensions at other sites to determine whether they are also crab apples (Bieniek and Lityńska-Zając 2000).

With the recent resurgence of heirloom fruits and vegetables and an increased interest in broadening food diversity as part of modern cuisine, many so-called ancient food varieties have been resurrected in the U.S. over the past thirty years (Graff 2018). This has included an interest in “ancient grains” and explains the ready availability of items like farro and broomcorn millet,

which were used in the previously described grain experiments. This phenomenon extends to apples, which are once again available in a plethora of shapes, sizes, and varieties at farmers markets around the country rather than the four or five varieties available at supermarkets during the middle of the 20th century (Jordan 2015). In addition, recent discussions of lake dwelling food often suggest a comparison between modern dried apple slices and the half apples found at lake dwelling sites (Jetzinger 2019), arguing that the apples found at Robenhausen and other lake dwelling localities may have been dried under the thatched roofs of houses, which were prone to being caught in the accidental fires that periodically wreaked havoc on these communities (Leckie 2013). Because of all of these factors, the previously described experiments were replicated using a wider variety of apple samples and included additional steps to simulate the process of apple drying and carbonization that took place at Robenhausen and other lake dwelling sites.

In order to determine the size of the original apples that make up the pieces in the Robenhausen collection, a variety of different apple specimens were obtained. These ranged from commercial Gala apples to seven different heirloom varieties and two types of crab apples. It was not possible to obtain *Malus sylvestris* crab apples because although several trees were found at regional arboretums, none were producing fruit in the year that this experiment took place (2019). In lieu of these, crab apples of a similar size called *Malus* “Henry Kohankie” and another that was more similar in appearance called *Malus* “Brandywine” were used (Figure 3.13). All of the apples were weighed, measured, and halved before being dried in a Cuisinart five-shelf dehydrator for between 20 and 120 hours on a low heat setting (110 degrees

Figure 3.13: *Malus* “Brandywine” (left) and *Malus* “Henry Kohankie” (right). These are the large and small crab apples used in the apple drying and carbonization experiments.

Fahrenheit). Length of drying times depended on the size of the apple and apples were considered dried when the flesh felt moisture free to the touch (Figure 3.14). The only exception to this was that half of the *Malus* “Henry Kohankie” apples were kept fresh so that they could be carbonized without drying. The resulting apple halves were weighed and measured again, then wrapped in foil and carbonized on a charcoal grill until they were completely blackened. The specimens were measured and weighed a third time, then compared to the apples in the MPM collection.

The crab apples that were not dried prior to carbonization served two purposes. One was to compare the effects of carbonization on fresh and dry apples. The other was to examine the appearance of fresh and pre-dried apple peels after carbonization to see if and to what extent they were visibly different. These experiments further demonstrated the probable size range of the Robenhausen crab apples prior to carbonization and illustrate the many potential variations in size due to the length of the dehydration process used prior to carbonization and the temperature

of the carbonization process itself. The results of the experiments with cereal products and apple halves will be discussed along with the results of the documentation and identification of the different components of the MPM Robenhausen botanical collection in the following chapter.

Figure 3.14: Apples on the dehydrator drying rack after 90 hours. Clockwise from the top left: 4 API Etoile, 1 Gala, 1 API Etoile, 1 Holstein, 1 Golden Pink, 1 Priscilla, 1 Viking.

Chapter IV Analysis

4.1 Introduction

This chapter presents the results of a combination of different methods that were applied to the analysis of the Robenhausen botanical material in the MPM collection. First the new housing and storage solutions developed for the Robenhausen botanical collection are described. This is followed by the documentation and identification of the plant remains by category and their significance for the interpretation of the collection; these categories include cereal grains, miscellaneous seeds, apples, and cereal products. The next section of this chapter presents the results of the experimental methods applied to the crab apples and cereal products. This is followed by a discussion of the implications of the results of the experiments for the MPM Robenhausen material. While this thesis primarily focused on the material housed at the MPM, catalogue descriptions of Robenhausen botanicals in other major museum collections are included in Appendix A and a few general observations about the differences between these assemblages and the MPM collection are discussed. The final section presents the results of the theoretical approach described in the Chapter I and its application to the botanical elements. This discussion suggests some interpretive possibilities regarding the way that food and agriculture took shape at the Robenhausen site.

4.2 Museum Housing and Storage

One of the immediate benefits of the thesis research described here was the rehousing of the Robenhausen botanical material both prior to the loan from the MPM to UWM and during the analytical process that took place in the paleoethnobotany laboratory at UWM. One result of this research project was that the botanical material is now stored in a way that will make it more

useful to the museum and for future researchers as well as ensuring its protection and stability (Figure 4.1). At the beginning of this project the Robenhausen botanical material was stored in mixed media, varying from plastic petri dishes to cellophane bags. There were several different varieties of Riker specimen boxes with plastic window lids and these were held closed by small nails making it difficult to access the cereal grains, apple pieces, and cereal product fragments. Most of these boxes were filled with cotton backing material that had the potential to degrade the botanicals. The three uncarbonized hazelnuts that appeared to have previously been glued to a small circular glass mount, were loose in the drawer. Prior to the loan of the Robenhausen collection from the MPM to UWM, the grains were removed from petri dishes and placed in archivally-stable plastic zipper bags. In addition, Riker specimen boxes with cotton backing were replaced by archivally-stable zipper bags enclosed in museum quality acid-free object storage boxes. The hazelnuts were also placed in the same type of zipper bags and the remaining botanical collection was separated into more of the same type of acid-free object storage boxes based on catalogue numbers, giving the entire collection an organized, uniform, secure housing method.

During the identification process, bits of cotton backing that were stuck to cereal grains and apple halves were removed. All cotton backing material removed at any point during the rehousing process was saved in case additional testing for residue or small seeds is carried out in the future. An inspection of the cotton backing for small organic material using a hand lens (4X magnification) was conducted during the analysis of the collection, but none were found. In addition, material was removed from cellophane packaging that was prone to static cling, causing the grains to stick to the plastic material; the cereals from this packaging were placed in archivally-stable zipper bags. Additional improvements included the separation of botanical

Figure 4.1: The original housing of the MPM Robenhausen collection: the entire collection laid out in the MPM Anthropology Lab (far left), cereal product fragments with cotton backing (center left), apple pieces with cotton backing (center right), some of the collection including grains in Petri dishes, loose hazelnuts on a glass disk, two apple halves with cotton backing, and some of the pieces of wood not included in this study (far right).

Figure 4.2: The rehoused Robenhausen botanical collection at the MPM. The botanical material where it shares a drawer with the textiles from the same site (left) and the collection boxes open to show the elements of the collection separated in individual zipper bags (right).

elements from each catalogue lots into smaller individual zipper bags by genus and species. Each bag was inscribed with a catalogue number and given a research number specific to this project as part of the scientific documentation discussed in the following section.

4.3 Scientific Documentation

One of this project's constructive goals was to report the findings and results of the scientific documentation of the MPM Robenhausen botanical collection. This process involved separating the material within each catalogue number based on taxonomic and categoric identifiers where applicable and necessitated the creation of an additional set of research numbers specific to this project. These research numbers correspond to numbers in the spreadsheet produced for this project that includes all taxonomic and categoric identifications and has been provided to the MPM. Most of this information is included in the following sections, which discuss the identification of each type of botanical material. In addition, images of all specimens are included in Appendix C with the exception of cereal grains, for which representative images of some of the different genera and species identified are included later in this chapter.

The MPM's Robenhausen botanical collection consists of twelve catalogue numbers. These twelve lots include five main material categories: cereal product, cereal grain, crab apple pieces, hazelnuts, and miscellaneous seeds and organics. There are two catalogue lots of cereal product, although one is labelled as bread and another as charred barley. In addition, there are four catalogue lots of mixed wheat and barley grains; although two catalogue descriptions indicate that they exclusively contain wheat, this was found to be incorrect. The remaining six catalogue numbers are divided between four catalogue lots of crab apple pieces and two

catalogue lots of hazelnuts. Seeds and other organics were a component of three catalogue lots of grain, but not reflected in any of the catalogue descriptions.

The documentation of the collection yielded several positive results. First, of the fourteen pieces of cereal product, four pieces were found to connect in two pairs that had originally formed larger fragments (Figure 4.3). Whether breakage occurred in the museum, in

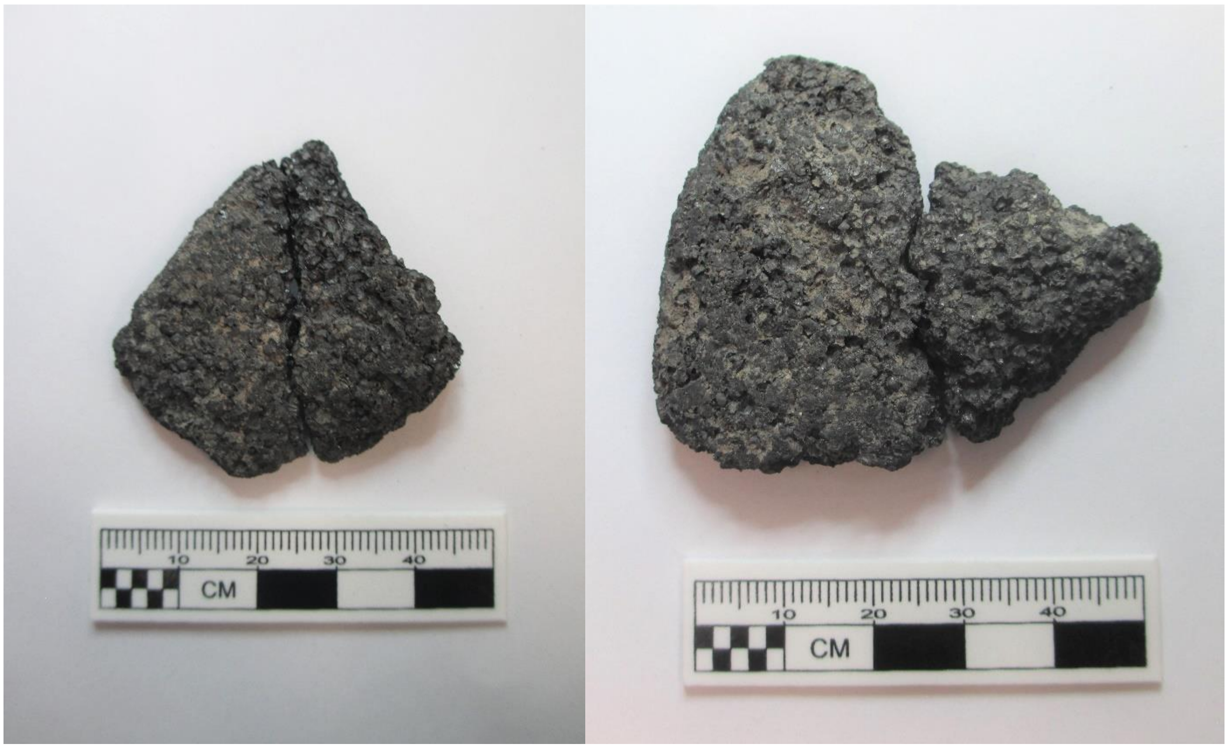

Figure 4.3: The two larger pieces formed by four of the pieces of cereal product.

the possession of a collector, during excavation, in situ prior to excavation, or at some point in prehistory prior to deposition is unknown. Another interesting finding was that the MPM labels and catalogue descriptions were not always accurate. For example, of the 76 objects described and labeled as apples, at least six and possibly as many as eight were not apples; this is discussed in greater detail later in the chapter. Other differences between the catalogue descriptions and

actual material included non-grain material mixed in with the cereal grain lots. These materials consisted of expected organics such as wood charcoal and a variety of small rocks, as well as unexpected organics including an insect, a fish vertebra, a small piece of rope or textile, and a variety of seeds including *Malus, Rubus,* and *Linum.* The identification of these seeds is also further discussed later in the chapter. The key point here is that scientific documentation of organic material is necessary to verify previous museum documentation and cataloguing. This is particularly important when working with an older museum collection that has not undergone periodic reevaluation using recent research and identification protocols.

Cereal Grain Documentation

There are four catalogue lots of grain in the Robenhausen botanical collection at the MPM. Of these four, MPM Cat. #s 10159 (donated by Meinecke) and 15049 (donated by Dörflinger) contain fewer specimens, consisting of 94 grains and 71 grains, respectively. The other two catalogue numbers are much larger, with lot MPM Cat. #10130 (donated by Renggly) consisting of 4654 grains and lot MPM Cat. #15046 (donated by Dörflinger) consisting of 2880 grains. It is unclear why the two lots of grain donated by Dörflinger were separated since they were sold to the museum at the same time; there is the possibility that they come from different parts of the site or were acquired at different points during Dörflinger's visit(s) to Robenhausen. The two smaller lots (Cat. #s 10159 and 15049) were relatively straight forward: there was no additional dirt, shells, or other organic material. The only surprise was the inclusion of 16 *Rubus* seeds in lot MPM Cat. #10159, which were not included in the catalogue description or labelling. MPM Cat. #15046, containing 2880 seeds, was also mostly as described in the catalogue apart from four non-grain botanicals. These include one *Rubus* seed, a small fragment of textile or

rope (Figure 4.4), one small grain which may be a wild type or unripe grain, and one *Linum usitatissimum* (flax) seed.

Table 4.1: The five grain catalogue numbers including donor and catalogue descriptor.

Catalogue Number	Catalogue Date	Accession Type	Donor/Seller	Collected By	Date Collected	Catalogue Description
10130	1901	Gift	Renggly	--	--	Charred Wheat and Barley
10158	1901	Gift	Meinecke	--	--	Charred Barley
10159	1901	Gift	Meinecke	--	--	Charred Wheat
15046	1913	Purchase	Dörflinger	Messikommer	1892	Charred Wheat and Barley
15049	1913	Purchase	Dörflinger	Messikommer	1892	Lot of Charred Grain (*Triticum*)

Figure 4.4: A small piece of rope or textile included in MPM Cat. #15046, which was described as charred wheat and barley (Scale bar = 2mm).

In contrast to the previous three catalogue numbers, lot MPM Cat. #10130 was different in a few ways. First, many of the grains (16.7%) were broken fragments rather than whole pieces of wheat and barley. In addition, the cereal grains in MPM Cat. #10130 were smaller and thinner than those in MPM Cat. #15046 (Figure 4.5). Since large rounded grains are often the product of swelling due to submersion in liquid (Jacomet and Schlichtherle 1984), this suggests

Figure 4.5: A comparison of the catalogue lots of grain. Whole grains from MPM Cat. #15046 (left), whole grains from MPM Cat. #10130 (center) and grain fragments from MPM Cat. #10130 (right).

that the grains in lot MPM Cat. #15046 were wet prior to carbonization, while the grains in lot MPM Cat. #10130 were dry prior to carbonization. There was also a striking difference between the grains in MPM Cat. #15046, which had a silvery, reflective surface, and the grains in MPM Cat. #10130, which were black, with a matte exterior (Figure 4.6). Second, there was a large amount of non-grain debris and other materials including charcoal, rachis segments, one fish vertebra, one insect, a piece of nut shell, three organics, and 94 seeds. Of these seeds, 32 were *Rubus* seeds, 11 were *Malus* seeds, and four were *Linum usitatissimum* seeds. The remaining 47 seeds represent 19 different species.

The largest groupings of identified grains in the collection as a whole can be assigned to the *Triticum* genera (Figure 4.7) and to the naked wheat species designations *Triticum aestivum/turgidum/durum* (Figures 4.8 and 4.9). *Triticum dicoccum* (emmer wheat) was found

Figure 4.6: Charred wheat and barley from MPM Cat. #15046 (left) and #10130 (right). These images show the glossy, silver versus matte, black exteriors of the cereal grains.

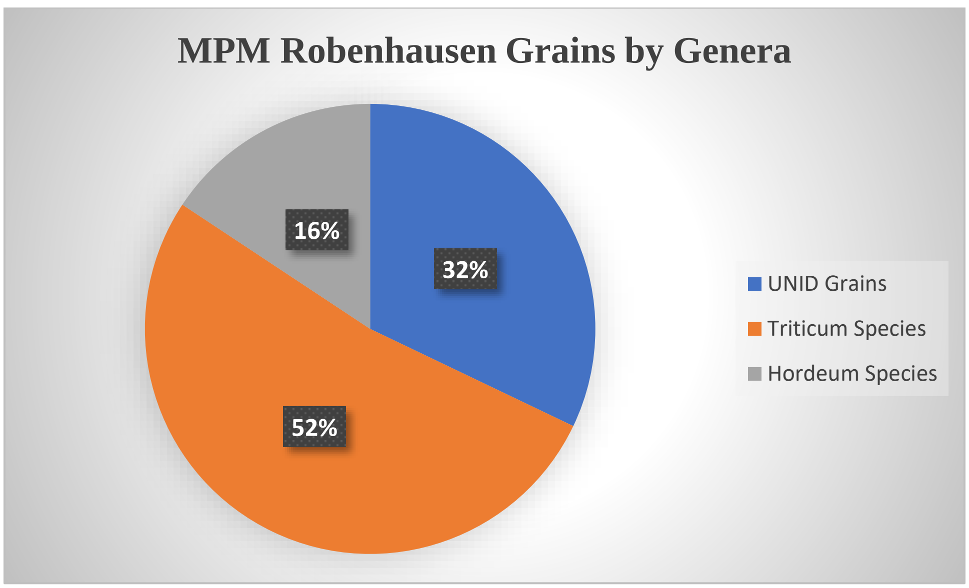

Figure 4.7: MPM Robenhausen grain prevalence by genera.

in small quantities in the two large collections of grain from the site (Figures 4.8 and 4.9). *T. spelta* was identified, but the inherent difficulty in distinguishing spelt from naked wheat indicates that these identifications may have been erroneous. The same is true for the identification of *Triticum monococcum*, which is easily mistaken for the narrower grains of

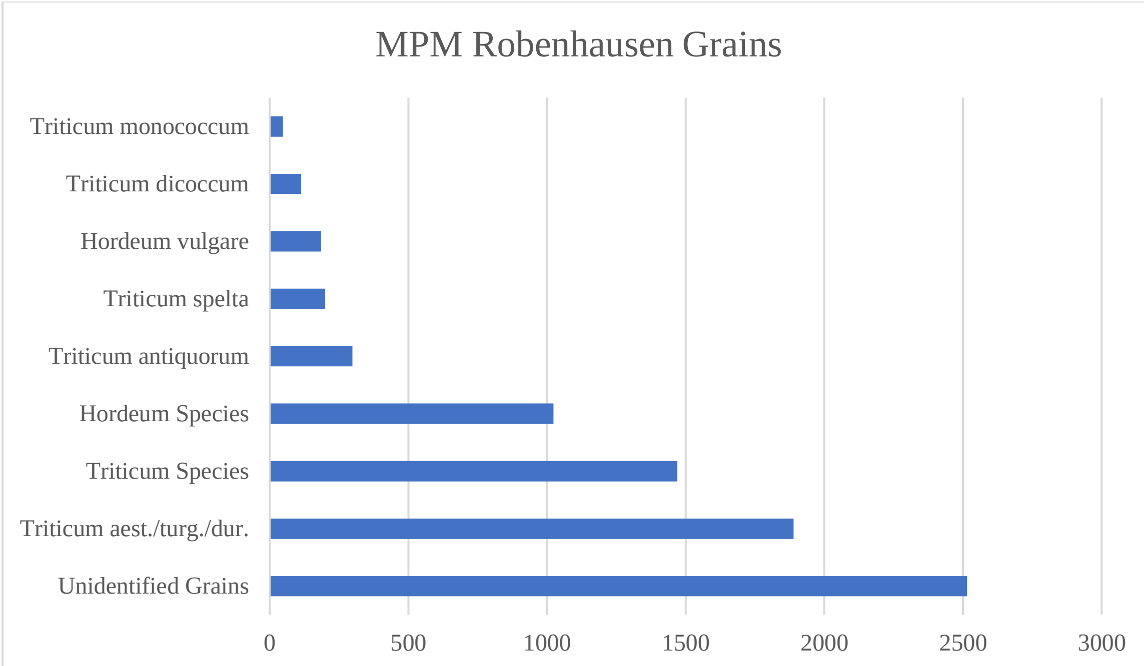

Figure 4.8: MPM Robenhausen grain prevalence by genus and species.

Figure 4.9: *T. dicoccum* (left) and *T. aestivum/turgidum/durum* grains (right) from MPM Cat. #10130 (Scale bars = 2mm).

Hordeum, especially from the lateral viewing perspective. There were significant quantities of *Hordeum vulgare* and *Hordeum,* the latter of which could not be assigned to a specific species (Figures 4.7, 4.8, and 4.10). There was some variability between the two large lots, with MPM Cat. #15046 having a smaller percentage of *Hordeum* and a greater percentage of *Triticum* than

MPM Cat. #10130 (Figures 4.11 and 4.12). However, both lots contained larger quantities of wheat than barley and in both cases, naked wheat was the predominant species. There were significantly more unidentified grains in MPM Cat. #10130 than in MPM Cat. #15046, which was due to the larger number of broken specimens as described above (Figures 4.11 and 4.12).

Figure 4.10: *Hordeum vulgare* (left) and *Hordeum* (right) grains from MPM Cat. #10130 (Scale bars = 2mm).

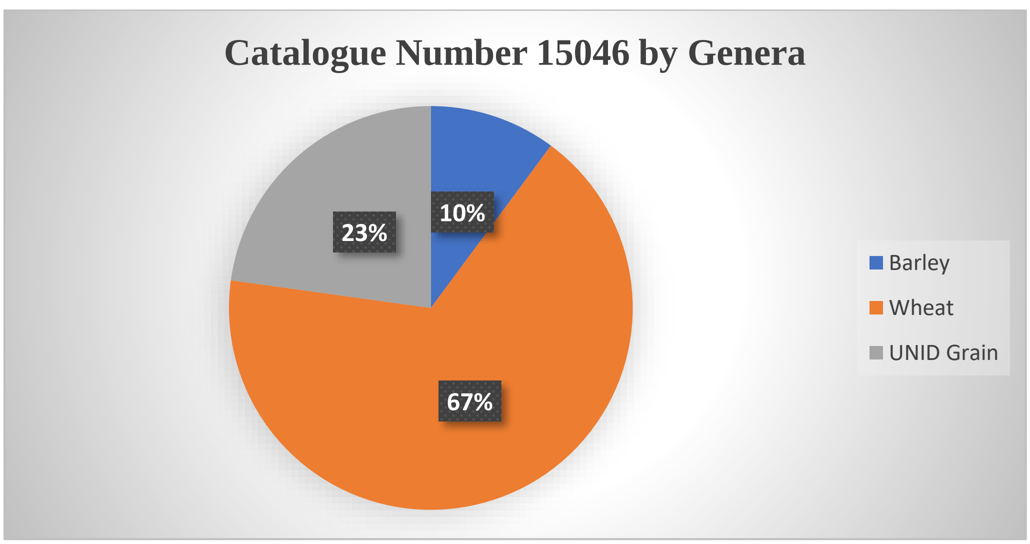

Figure 4.11: Grains from MPM Cat. #15046 by genera.

Paleoethnobotany and archaeobotanical theory provide several methods for interpreting the Robenhausen grain material (Jacomet 2004, 2013). One observation grounded in a large

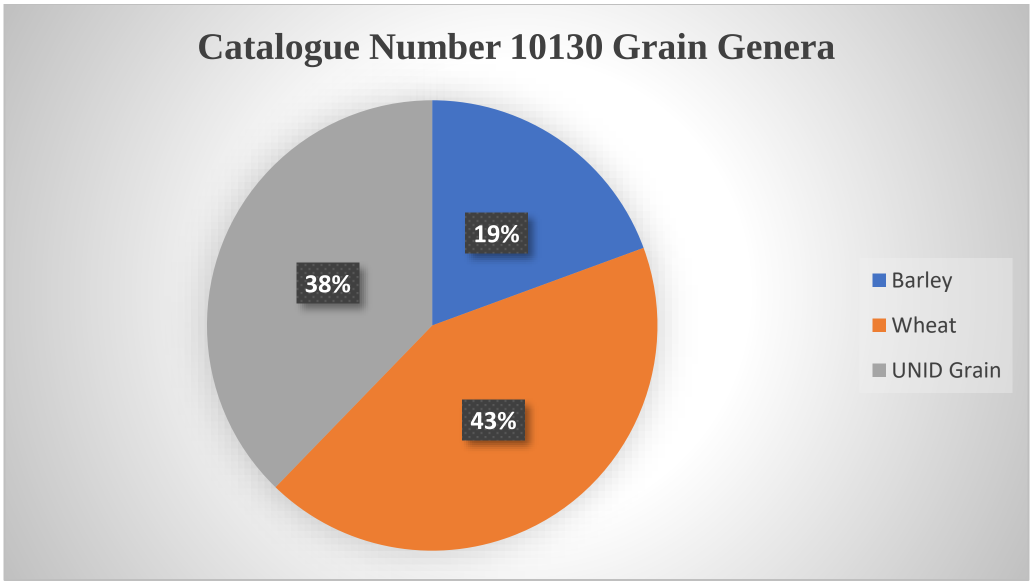

Figure 4.12: Grains from MPM Cat. #10130 by genera.

body of literature is that even with exact provenience and a cohesive assemblage from a given location at the site, there is still a strong possibility that interpretations based on grain percentages would be erroneous. An extensive research project analyzing over 150,000 grains from 30 different cultural levels at 11 lake dwelling sites demonstrated that differential preservation of carbonized and non-carbonized material can skew results a great deal (Jacomet et al. 1991: 273). For example, in an analysis of carbonized cereals from Lake Zürich, *T. monococcum* (einkorn wheat) is indicated to be very rare, while non-carbonized samples show that this species was abundant (Jacomet et al. 1991: 273). On the other hand, *Hordeum vulgare* (barley) appears abundant only in carbonized assemblages and is virtually non-existent in uncarbonized form (Jacomet et al. 1991: 273). This demonstrates that interpretations based on the limited sample of carbonized or uncarbonized grains from a lake dwelling settlement lack the breadth of a mixed sample, which does not exist at certain sites due to preservation related factors. In the case of the MPM Robenhausen cereals, there were no completely uncarbonized

grains, and this combined with limited provenience information suggests that the grains are not the best indicator to establish a timeline for the site.

A few grains deserve special attention for their unique qualities. One group of very small grains that fell outside of the parameters defined by the grain identification guide was initially identified as *Triticum antiquorum*, or small lake dwelling wheat. This was a species recognized by Oswald Heer as a lake dwelling specific domestication phenomenon within the region (Jacomet 1984). If this identification was correct, *T. antiquorum* is a separate species adapted to the environment of the circum-Alpine lake region. Of the over 8000 grains and grain fragments in the MPM sample only one showed evidence for having sprouted and only a dozen evidence for possible malting, indicating that the elements of the assemblage were dried and kept dry and that they were used primarily as a food source rather than for brewing alcoholic beverages such as gruits or grogs (Figure 4.13). Two other grains from Cat. #10130 appear to be rusted, possibly at some point after excavation. There is also the possibility that these grains exhibit a type of fungal disease called *Puccinia graminis* or stem rust, which affects wheat and has been found on carbonized grains from Late Bronze Age Israel (Kislev 1982), but not enough is known about this for a definitive identification.

Figure 4.13: Sprouted barley grain (cf. *Hordeum vulgare*) from MPM Cat. #10130 (Scale bar = 1mm).

Miscellaneous Seed and Organic Documentation

Sorting the cereal grains led to the identification of other organic elements apart from single grains in the collection. These included grain ear fragments, rachis, and non-grain elements such as *Rubus* seeds (Figure 4.14), apple seeds, organics, rocks, shell, an insect, a fish vertebra (Figure 4.24), and a number of other seeds. In addition to the *Rubus* and *Malus* seeds, there were 32 unidentified seeds in lot MPM Cat. #10130. Two of these seeds and a probable third seed were identified as *Linum usitatissimum* or flax (Figure 4.15). The presence of flax seeds is not surprising since many other flax byproducts were found at the site and because large quantities of textile fragments are also part of the Robenhausen collection. In addition, one *Chenopodium album* seed was found in the collection (Figure 4.16). The presence of this grass also makes sense since it is a component of many other Robenhausen collections (Appendix A), and because lake dwelling inhabitants were reliant on gathered plants and food as well as domesticated grains (Altorfer 2000: 173-174; Jacomet 2004; Keller 1866: 336-354).

Figure 4.14: *Rubus idaeus* (red raspberry seeds) from MPM (left, scale bar = 2mm) and Renfrew (1973: Plate 46)(right).

Table 4.2: The seeds, grain, and organic materials found in the MPM grain lots.

Catalogue #	Research #	Scientific Name	Common Name	Count
15046	RSR0111	*Rubus idaeus*	Raspberry	1
15046	RSR0112	*Linum usitatissimum*	Flax	1
15046	RR0113	Textile/rope fragment	N/A	1
10130	RSR0129	Unidentified seed		1
10130	RSR0130	*Achillea millefolium*	Yarrow	1
10130	RSR0131	*cf. Vaccinium myrtillus*	Bilberry	1
10130	RSR0132	*Potentilla/Solanaceae*	N/A	1
10130	RSR0133	*Chenopodium album*	Goosefoot	1
10130	RSR0134	*cf. Spergula arvensis*	Corn Spurry	1
10130	RSR0135	*Linum usitatissimum*	Flax	1
10130	RSR0136	Unidentified seed		1
10130	RSR0137	Unidentified seed		1
10130	RSR0138	*Linum usitatissimum*	Flax	1
10130	RSR0139	Unidentified seed		1
10130	RSR0140	*Brassica campestris*	Wild turnip	1
10130	RSR0141	*Linum usitatissimum*	Flax	1
10130	RSR0142	*cf. Carum carvi*	Carraway	3
10130	RSR0143	Unidentified seed		1
10130	RSR0144	Unidentified seed		1
10130	RSR0145	Unidentified nut		1
10130	RSR0146	*cf. Prunus spinosa*	Sloe	1
10130	RSR0147	Grains with rust?	N/A	2
10130	RSR0148	*Brassica cf. rapa campestris*	Wild Turnip	8
10130	RSR0149	Unidentified seed		1
10130	RSR0150	*Rubus cf. idaeus*	Raspberry	32
10130	RSR0151	*Rubus cf. idaeus in matrix*	Raspberry	2
10130	RSR0152	*cf. Panicoideae*	Grass family	1
10130	RSR0153	Unidentified organic		2
10130	RSR0154	*Malus sylvestris*	Crab apple	11
10130	RSR0155	Sprouted grain	N/A	1
10130	RSR0157	Unidentified seed		4
10130	RSR0158	Insect	N/A	1
10130	RSR0159	*Cyprinidae vertebra*	N/A	1
10159	RSR0169	*Rubus cf. idaeus*	Raspberry	16

Figure 4.15: *Linum usitatissimum* or flax from MPM (Cat. #10130)(left, scale bar = 1mm) and Renfrew (1973: Plate 46)(right).

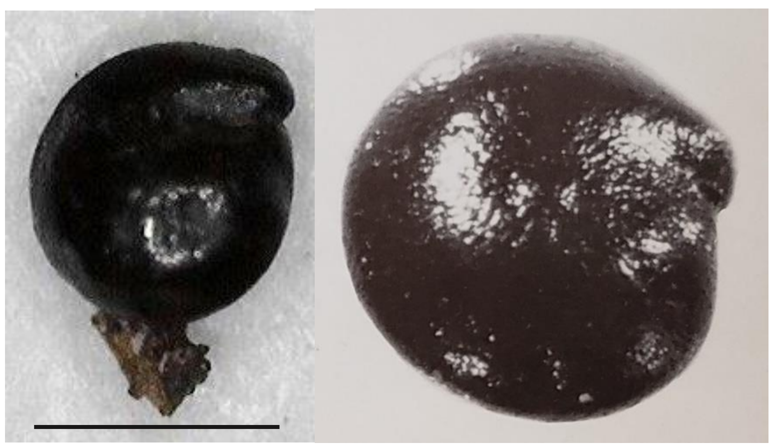

Figure 4.16: *Chenopodium album* or goosefoot from lot MPM (Cat. #10130)(left, scale bar = 1mm) and Renfrew (1973: Plate 46)(right).

Other probable seed identifications include *Achillea millefolium* or common yarrow (Figure 4.17), *Carum carvi* or carraway seeds (Figure 4.18), members of the *Brassica* genus, possibly *Brassica rapa campestris* (wild turnip) or *Brassica nigra* (black mustard)(Figures 4.19

and 4.20), *Spergula arvensis* or corn spurry (Figure 4.21), and *Vaccinium myrtillus* or bilberry (Figure 4.22). One additional seed was identified as belonging to either *Potentilla* or *Solanaceae*

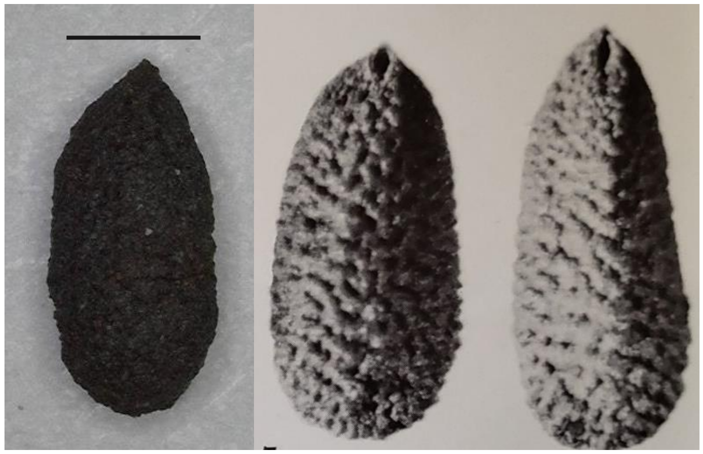

Figure 4.17: *Achillea millefolium* or common yarrow from MPM (Cat. #10130)(left, scale bar = 1mm) and Renfrew (1973: Plate 46)(right).

Figure 4.18: C.F. *Carum carvi* or carraway from MPM (Cat. #10130)(left, scale bar = 1mm) and Abdalaziz et al. (2017: Fig. 1)(right).

(Figure 4.23). If the identification of carraway seeds is correct, these are the first representatives of this species identified in one of the Robenhausen museum collections listed in Appendix A. *Carum carvi* seeds were identified by Heer at the Robenhausen site and are discussed as a possible flavoring agent in lake dwelling cuisine in his 1865 monograph (Keller 1866: 342).

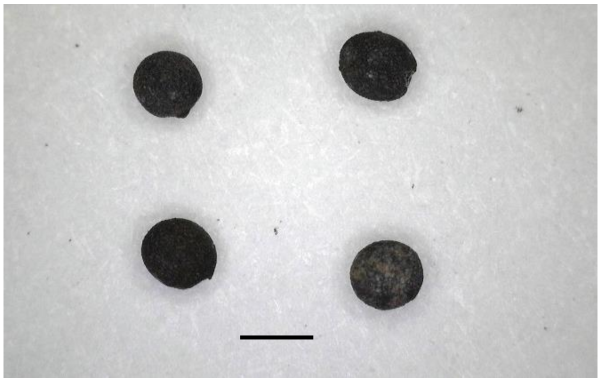

Figure 4.19: *Brassica* species from MPM Cat. #10130. These appear most similar to *Brassica rapa campestris* (wild turnip)(Figure 4.20) but may also be *Brassica nigra* (black mustard), which is documented at Robenhausen.

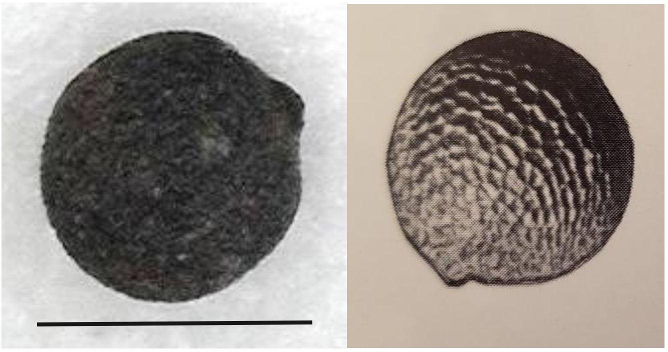

Figure 4.20: *Brassica rapa campestris* or wild turnip from MPM (Cat #10130)(left, scale bar = 1mm) and Berggren (1981: Plate 70)(right).

Figure 4.21: *Spergula arvensis* or corn spurry from MPM (Cat. #10130)(left, scale bar = 1mm) and Renfrew (1973: Plate 47)(right).

Figure 4.22: *Vaccinium myrtillus* or bilberry from MPM in dorsal and ventral perspectives (Cat. #10130, scale bar = 1mm).

Figure 4.23: *Potentilla* or *Solanaceae* (left) and cf. *Prunus spinosa* or sloe fruit (right) from MPM (Cat. #10130)(Scale bars = 1mm).

The fish vertebra found in MPM Cat. #10130 was identified as belonging to the *Cyprinidae* family and barring cleaning of the specimen, a lower level of taxonomic identification was not possible (Wim Van Neer, pers. comm., 2019*)*(Figure 4.24). *Cyprinidae* is the most widespread freshwater fish family and also the second largest family of fish in the world (Durand et al. 2002). However, in Europe *Cyprinidae* are less diverse and families that

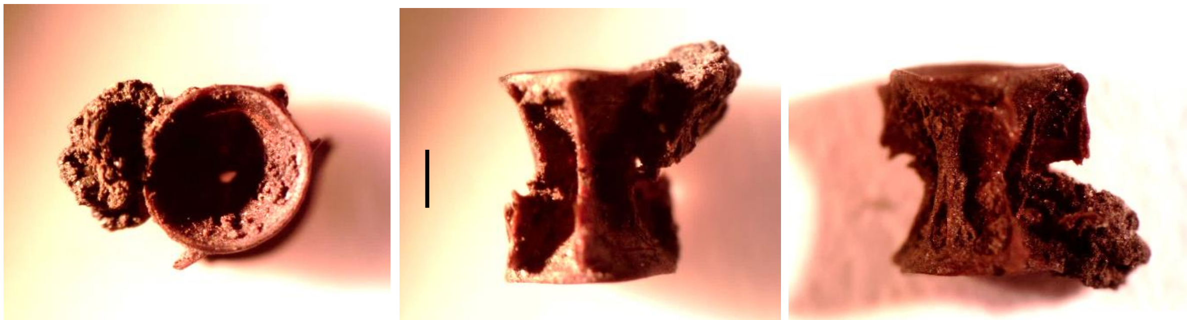

Figure 4.24: *Cyprinidae* vertebra from MPM (Cat. #10130)(scale bar = 0.5mm).

have many genera in Asia are represented by a single species in Europe (Bănărescu and Coad 1991: 134). This family of fish proliferated in central Europe in the Eocene and there are currently forty extant species in this region (Bănărescu and Coad 1991: 140). Fish belonging to this group were a common food source for Mesolithic and Neolithic communities in the Danube River region (Dimitrijević et al. 2016; Živaljević et al. 2017). Modern consumption focuses primarily on carp, but other varieties including minnows are also part of European cuisine (Bănărescu and Coad 1991: 147). In addition to use as a food source, cyprinid teeth, which attach to the lower pharyngeal bone or branchial arches rather than the jaw, were used as adornment (Živaljević et al. 2017). *Cyprinidae* are a component of lake dwelling museum collections at the Harvard Peabody Museum of Archaeology and Ethnology and the Chicago Field Museum (Ross 2011: 63-64). These fish are commonly found at lake dwelling sites when fine-screening and sieving are used as excavation techniques, however, this has been infrequent in the past and a representative picture of fishing has yet to be developed (Schibler et al. 1997: 565). Due to this sampling bias, larger taxa such as pike, and medium-sized fish such as lake trout, salmon, and char tend to dominate (Schibler et al. 1997: 565). At the site of Zürich-Mozartstrasse, where fine screening and sieving took place, *Cyprinidae* such as carp were found

in the shallow waters where most fishing activities occurred (Schibler et al. 1997: 565). During the Cortaillod Culture, small fish were a more important resource, giving way to the exploitation of larger fish during the Pfyn Culture, suggesting that fine-net fishing was replaced by more deliberate practices at this site sometime between 3800-3700 BC (Schibler 1997: 566).

Apple Documentation

The Robenhausen botanical collection included 76 objects that were identified as carbonized apples in the MPM documentation (excluding three encased in a plexiglass paper weight that were not included in this thesis). Of the 76 objects identified as apple fragments, at least six were not apples (Figure 4.25). Of those six, one looked similar to the "amorphous" cereal products in the collection. An additional three objects were actually pieces of wood, and the final two organic fragments are most likely pieces of unidentified nuts. Two other objects may be nuts or some other type of organic material but are degraded and were difficult to identify. Of the remaining 68 apple pieces, seven were sliced horizontally rather than vertically, while one whole apple was present in the assemblage, 26 comprised half of an apple and the remaining 41 represented a smaller fraction. Most of the apples were labelled as wild crab apples while ten that were slightly larger on average were labelled as cultivated. There is no documentary information regarding how this designation was created or who assessed the collection. One key difference between the crab apples labelled cultivated and those labelled wild is that many of the cultivated specimens do not appear entirely carbonized (Figure 4.26). This may have created a small size discrepancy between the two different categories in the collection and could be the reason that they were described differently.

Figure 4.25: Some of the objects labeled as apples (MPM Cat. #10131). The top row are pieces of wood while the bottom center and right are pieces of nuts, and the bottom left is probably cereal product.

Figure 4.26: Crab apple halves from MPM Cat. #s 10131 (left and center) and 10129 (right), the latter of which is described as a charred, cultivated apple and is not fully carbonized.

A basic assessment of the size of the different apple groupings indicates that the apples likely belong to the species *Malus sylvestris*, the European crab apple. The metric attributes of

the 26 apple halves have an average diameter or width of 1.9 cm, a value that falls within the average size range for the crab apple species (1.0 to 4.0 mm). It is noted that the Robenhausen apple are comparatively small, a fact not too surprising as the apples were likely dried and carbonized, two processes known to result in a decreased specimen size. Since the results of the

Table 4.3: Documentation of the MPM's Robenhausen apple halves, including average length, width (diameter) and weight of each apple half for comparison with experimental results.

Cat. #	**Res. #**	**Weight**	**Length**	**Width**	**Height**	**Slice Type**	**Seed(s)**	**Apple Portion**
10131	RSR0015	0.333	2.1	2.0	0.9	Vertical	No	Half
10131	RSR0018	0.317	2.3	2.3	0.8	Vertical	No	Half
10131	RSR0019	0.198	2.1	1.6	0.8	Vertical	No	Half
10131	RSR0020	0.293	1.7	1.9	1.0	Vertical	Yes	Half
10131	RSR0022	0.253	1.8	2.0	1.1	Vertical	Yes	Half
10131	RSR0023	0.265	1.4	1.5	0.8	Vertical	No	Half
10131	RSR0025	0.332	1.9	1.9	0.9	Vertical	No	Half
10131	RSR0029	0.234	1.9	1.9	0.9	Vertical	No	Half
10131	RSR0034	0.189	1.8	1.9	1.1	Vertical	No	Half
10131	RSR0035	0.257	1.9	1.9	1.0	Vertical	No	Half
10131	RSR0039	0.263	1.6	1.9	1.0	Vertical	No	Half
10131	RSR0043	0.544	1.4	1.9	1.6	Vertical	Yes	Half
10131	RSR0050	0.322	1.8	1.8	1.2	Vertical	No	Half
10131	RSR0051	0.291	1.8	1.8	1.2	Vertical	Yes	Half
10131	RSR0057	0.245	1.9	1.9	1.2	Vertical	No	Half
10131	RSR0062	0.352	1.8	1.8	1.0	Vertical	Yes	Half
10131	RSR0064	0.519	2.1	1.3	1.6	Horizontal	Yes	Half
10131	RSR0065	0.226	1.7	1.6	1.0	Vertical	No	Half
10131	RSR0067	0.263	1.6	1.5	0.9	Vertical	No	Half
10131	RSR0070	0.482	2.0	1.9	1.3	Vertical	No	Half
10131	RSR0073	0.295	2.0	1.7	1.0	Vertical	Yes	Half
10129	RSR0077	0.375	2.4	2.2	0.9	Vertical	No	Half
10129	RSR0078	0.756	2.3	2.7	1.3	Vertical	No	Half
15047	RSR0087	0.716	1.8	2.2	0.8	Vertical	Yes	Half
15047	RSR0088	0.272	1.8	2.0	1.0	Vertical	No	Half
10161	RSR0089	0.544	2.0	2.2	0.8	Vertical	No	Half
Average		0.351	1.880	1.896	1.042			

experiments discussed later in the chapter indicate that the MPM Robenhausen crab apples were dried, this suggests that their size would have been reduced significantly prior to burning. The carbonization process would have reduced the size even more while the effects of such long-term waterlogging on these specimens are difficult to ascertain.

Cereal Product Documentation

The cereal products in the MPM Robenhausen collection include 15 specimens, 14 of which are part of MPM Cat. #10128 and were described as bread in the catalogue, while MPM Cat. #10158 was described as charred barley and is categorized as a cereal conglomerate. The 14 objects in MPM Cat. #10218 were further subdivided into three categories based on visual analysis using a binocular stereomicroscope and a hand lens. These three types were termed "grain-distinct," "few grains," and "amorphous" based on the visibility of their constituent elements (Table 4.4, Figures 4.27 and 4.28). The four grain-distinct pieces of cereal product are primarily composed of millet with the hulls still attached. Interestingly, all four grain-distinct pieces connected to another piece, forming two larger pieces of cereal product in total. It was unclear whether these two larger pieces might have formed part of the same loaf or cake and the fragility of the specimens precluded further attempts to fit them together. The four grain-distinct pieces of cereal product displayed a curvature suggesting that they were baked on a convex surface (Figure 4.29).

Of the two remaining types of cereal product, those with "few grains" were primarily amorphous, but the visibility of several whole grains of wheat or barley in each piece placed them in a separate category from the "amorphous" type. There were no visual markers distinct enough to identify the constituent grains to a specific taxon, but their general shape and the nature of the grain assemblage from Robenhausen make wheat and barley the most likely

candidates. The “amorphous” cereal products could also be called homogenous based on the absence of visibly separate structures within the matrix. This latter type probably bears the greatest resemblance to modern bread while the “few grain” pieces are hypothesized to be a hardened porridge, trachana, or other concoction which solidified in a fire or burning event, possibly within the confines of a ceramic container. There is also the possibility that the “few grains visible” pieces were part of a cereal product where some whole grains were incorporated into a dough made of flour which was produced using finely ground cereals. Alternatively, the “few grains visible” and “amorphous” pieces may simply be different parts of the same type of substance where finely ground material was mixed with whole grains as described above.

Table 4.4: Objects labeled as bread from the MPM Robenhausen collection divided by type: GD = Grain Distinct, A = Amorphous, FG = Few Grains Visible. These types were defined by the researcher for this thesis based on Heiss et al. (2019) and Valamoti et al. (2019).

Catalogue #	**Research #**	**Weight**	**Length**	**Width**	**Height**	**Type**
10128	RSR0001	1.504g	4.1cm	2.2cm	0.8cm	GD
10128	RSR0002	2.030g	2.7cm	2.1cm	1.8cm	A
10128	RSR0003	2.100g	2.85cm	2.85cm	1.2cm	GD
10128	RSR0004	4.945g	4.7cm	3.1cm	1.35cm	GD
10128	RSR0005	1.863g	2.5cm	2.2cm	1.7cm	A
10128	RSR0006	1.502g	3.6cm	2.3cm	1.1cm	GD
10128	RSR0007	3.837g	4.2cm	3.0cm	1.4cm	FG
10128	RSR0008	1.019g	2.1cm	1.9cm	1.9cm	A
10128	RSR0009	1.473g	2.9cm	2.1cm	0.9cm	FG
10128	RSR0010	1.074g	3.0cm	1.6cm	1.1cm	FG
10128	RSR0011	0.850g	2.4cm	1.8cm	1.0cm	A
10128	RSR0012	0.332g	2.1cm	1.3cm	0.7cm	FG
10128	RSR0013	0.265g	1.8cm	1.7cm	0.7cm	FG
10128	RSR0014	NA	NA	NA	NA	FG

Figure 4.27: Amorphous (left) and few grain (right) cereal products from MPM (Cat. #10128)

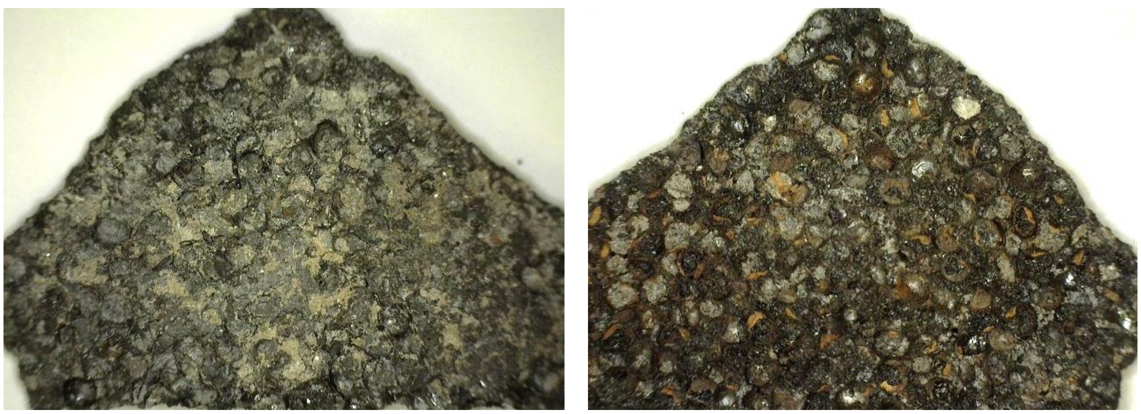

Figure 4.28: Grain-visible cereal products from MPM (Cat. #10128). Upward facing side (left) and downward facing side (right). These were determined to be primarily composed of millet.

Figure 4.29: Grain distinct cereal product piece showing curvature suggesting that it was baked on a convex surface.

4.4 Experimental Archaeology Results

Apple Experiments

While large quantities of carbonized crab apples halves have been found at many prehistoric sites in Europe dating to the Mesolithic (Bishop 2013: 48; MacLean 1993), Neolithic (Antolín et al. 2015; Bieniek and Lityńska-Zając 2000; Colledge and Conolly 2014; Jacomet 2004, 2008; Jacomet and Brombacher 2004; Jacomet et al. 1991; Keller 1866; Kubiak-Martens et al. 2015; Rottoli and Castiglioni 2008; Schneider 2007; Tolar et al. 2011; Villaret-von Rochow 1969), and Bronze Age (Villaret-von Rochow 1969), few experiments have been conducted to better understand this material. The primary study focused on a comparison between modern carbonized *Malus sylvestris* samples and five apple collections from Neolithic and Bronze Age sites (Villaret-von Rochow 1969).

Two of the key questions concerning Robenhausen apples in the MPM collection involve processing sequences. The first is the degree to which apples reduced in size when they were dried then carbonized versus fresh prior to carbonization. The second involves the possibility of distinguishing between fresh apples and dried apples that were carbonized based on the appearance of the peel. To answer these questions, I carbonized fresh crab apples and crab apples that had been dehydrated and compared the two groups. A third question was whether there was any possibility that the MPM Robenhausen apples could have been a domestic fruit or an intermediary stage between wild and domesticated. In order to investigate this, I dehydrated and carbonated heirloom and store bought apples alongside two types of wild crab apples to compare the size of the dried, carbonized domestic apples to the two modern types of crab apples and the MPM Robenhausen material. Because *Malus sylvestris* specimens were difficult to acquire, the experiments with crab apples used *Malus* "Brandywine" which is similar in

appearance, but larger, and *Malus* "Henry Kohankie", a comparably sized crab apple with an elongated shape (Figures 4.30 and 4.31). The drying process, which utilized a standard kitchen dehydrator, reduced the apple size of the store bought, heirloom, and both crab apple types significantly.

Figure 4.30: *Malus* "Brandywine" crab apples, clockwise from upper left: whole, cut, dried, and carbonized.

The results of the two experiments provide additional information about apple drying processes in prehistoric Europe. The first experiment examined the effects of drying and carbonization on the size differences of crab apples. One possible shortcoming of the previous experiments with crab apple carbonization as a comparison to lake dwelling apples and those found at other sites in Neolithic Europe was that they were fresh prior to carbonization (Bieniek and Lityńska-Zając 2000; Villaret-von Rochow 1969). For this experiment half of the apples

were dried prior to carbonization while the other half were kept fresh and sliced then immediately carbonized. The results of this experiment demonstrated that while the crab apples that were dried and then burnt shrank in diameter by 32%, those that were fresh prior to carbonization only shrank in diameter by 15%. This indicates that the effects of pre-carbonization processes on apples are significant enough that they could potentially skew an identification made based on post-carbonization diameter. Another interesting result of the experiment comparing the effects of carbonization of pre-dried and fresh apples is that the pre-dried apples retained their aspect ratio while the fresh apples shrank more in length than in diameter, altering their appearance substantially (Figure 4.32). The second experiment showed that there was some variation in the way that the apples reduced in size, such as a greater reduction in height than width in some types, for example. However, overall the results showed

Figure 4.31: *Malus* “Henry Kohankie” crab apples, clockwise from upper left: cut, dried, pre-dried carbonized, and fresh carbonized. Note that the fresh carbonized apple reduced in length while maintaining a similar diameter when carbonized.

Figure 4.32: MPM and experimental crab apple comparison, MPM Cat. #10129 (left), pre-dried, carbonized experimental (center), and fresh, carbonized experimental (right).

that apples reduced in size through drying and carbonization in proportion to their original size and that the resulting sizes of the domestic, heirloom, and large crab apples was outside of the size range for the MPM collection, the smaller crab apples from this experiment, and both the modern and prehistoric crab apples from the Villaret-von Rochow experiment (1969).

Cereal Product Experiments

Experiments were also conducted using several different types of grain to make a variety of cereal preparations to better understand the food processing activities represented by the cereal products in the MPM Robenhausen collection. Some of the questions that these experiments were intended to answer included: how the whole grains in the cereal products were held together, what the consistency of the cereal preparations might have been prior to carbonization, and whether the single specimen defined as cereal conglomerate could have been created by uncooked grains fusing together during carbonization. To answer these questions, three techniques were used to mimic two of the three categories of cereal product in MPM Cat.

#10128 (grain-distinct and few grains) and a third type defined as a cereal conglomerate (MPM Cat. #15018).

The first technique used one part grain and two parts water, which was combined with a flax "egg" to bind the whole grains together. These cereal grain cakes were baked in a 350 degree (F) oven for 30 minutes. The second technique involved, one part grain combined with three parts water, five parts water, and seven parts water to create porridges with different levels of grain definition. Figure 4.33 compares a millet cake with a millet porridge, showing the difference in texture and the visibility of the individual grains. The third technique used uncooked grains and grains mixed with two part water. Each cereal grain product was made

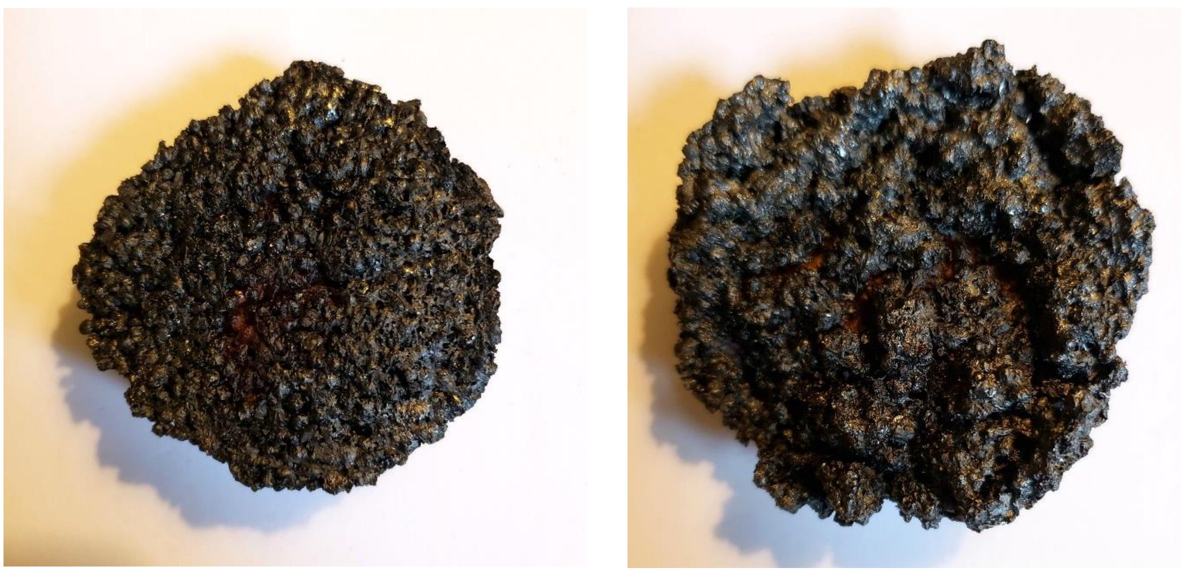

Figure 4.33: Experimental millet cake (left) and porridge (right) after carbonization.

with one type of grain and all three techniques were applied to millet, farro, and barley. This resulted in a total of 18 cereal products with six different consistencies made from three types of grain. The six consistencies included uncooked loose grain, grain cooked with 2, 3, 5, and 7 parts water, and grain cakes held together using flax "eggs". All of the cooked and baked

materials were allowed to cool at room temperature, then everything was individually wrapped in aluminum foil and placed on a charcoal grill until carbonized.

4.5 Discussion

Comparison of the Robenhausen Collection to the Experimental Results

The apple experiments conducted here corroborated the findings of Villaret-von Rochow (1969) and indicate that the MPM Robenhausen apples are cf. *Malus sylvestris*, the European crab apple. While some of the smaller heirloom apples, primarily the Golden Pink and Priscilla, did shrink a great deal and came close to the size of the largest crab apples in the Robenhausen collection, they were outside of the size range established for both the MPM apples and for those found in prehistoric European contexts (Heer 1865; Villaret-von Rochow 1969). Of the two crab apple varieties used for this experiment, the Brandywine apples bore greater physical similarities to *Malus sylvestris*, despite being larger. This larger size was maintained throughout the drying and carbonizing processes and is reflected in the final diameter measurements which were larger than the average for both MPM Robenhausen apple halves and those documented by Villaret-von Rochow (1969)(Table 4.5).

The most common theory regarding the many carbonized apples recovered from lake dwelling sites is that they were dried in the space beneath the thatched roofs of houses and rehydrated for use throughout winter, providing a source of vitamin C during the coldest months of the year. An ethnographic analog for the storing of apples in thatch from pre-industrial Slovakia notes that crab apples were preserved in hay (Stoličná 2016: 247). Although not the same as drying in the roof of a house, this method provides some possible insight into the thought process that led to crab apple drying in the thatched house roofs at lake dwelling sites.

Since the apples were dry prior to burning, these processes have the potential to affect the results of carbonization experiments. Table 4.6 shows the results of experiments with Henry Kohankie apples, which are different in shape but similar in size to *Malus sylvestris*; the average weight and diameter are the most similar to the MPM Robenhausen apples.

Table 4.5: Experimental results of drying and carbonizing large crab apples, heirloom apples, and grocery store apples.

Apple Type	**ID**	**Fresh Weight**	**Fresh Diameter**	**Dry Weight**	**Dry Diameter**	**Carbonized Weight**	**Carbonized Diameter**
Brandywine	S1	15.1	4.1	3.7	2.3	0.7	2.2
Brandywine	S2	15.7	4	3.3	2.7	0.7	2.5
Brandywine	S3	17.2	4	4	2.8	2.4	2.7
Brandywine	S4	14.5	3.8	3.6	2.8	1.4	2.6
Brandywine	S5	14.8	4.1	3.7	2.6	2	3
Brandywine	S6	15.7	4.3	3.3	2.9	0.7	2.6
Brandywine	NS2	17.3	4	4.1	2.9	1.8	3.1
Brandywine	NS3	15.8	4	3	2.7	1.1	2.6
Brandywine	NS4	11.8	3.8	2.3	2.5	0.9	2.4
Brandywine	NS5	10.7	4.1	2.2	2.5	1.5	2.7
Average		14.86	4.02	3.32	2.67	1.32	2.64
Gala	---	82	6.5	27.6	5.4	8.8	5.4
API Etoile	1	49.4	5.7	13.6	4.1	5.8	4.5
API Etoile	2	41.9	5.1	9.4	3.6	2.3	4
API Etoile	3	41.5	5.4	8	3.8	2	3.8
Viking	---	38.4	5.1	7.6	3.7	2.4	3.9
Holstein	---	31.1	5.1	9.3	3.6	4.5	3.9
Golden Pink	---	27.5	5.4	4.5	3.5	1.7	3.5
Priscilla	---	32.7	5	5.7	3.4	1.2	3.6

One final question addressed by the experiments with apples was to what extent the peels of the fresh and pre-dried carbonized apples would differ when carbonized. According to Helbæ̈k (1952), contracted margins and wrinkled peels indicate that an apple was dried before

carbonization (Bieniek and Lityńska-Zając 2000). Based on a comparison between the pre-dried and fresh carbonized crab apples in the experiment to an example from the Robenhausen material, the apples from the site in the MPM collection were dried prior to carbonization (Figure 4.32). In addition, some of the pre-dried experimental crab apples were dried to different degrees, and the wrinkled peel of the Robenhausen apple most closely matches crab apples dehydrated for 75 hours, then dried in a heated room for an additional two-week period (although this second phase of drying was unintentional).

Comparing the different types of cereal preparations to the "grain visible" Robenhausen material likewise shows that the millet hulls were not removed at Robenhausen as described in an early lake dwelling exhibit at the MPM (Dawn Scher Thomae, pers. comm., 2018)(Figure 4.34). In addition, the flax "egg" used to bind the experimental millet cake added more matrix than was present in the Robenhausen material, indicating that the Robenhausen material was minimally hydrated during the cake-forming process and that the grains were also relatively unprocessed. The experiments were also used to assess the conglomerate of charred barley in the Robenhausen collection. The appearance of the experimental one part grain and five parts water

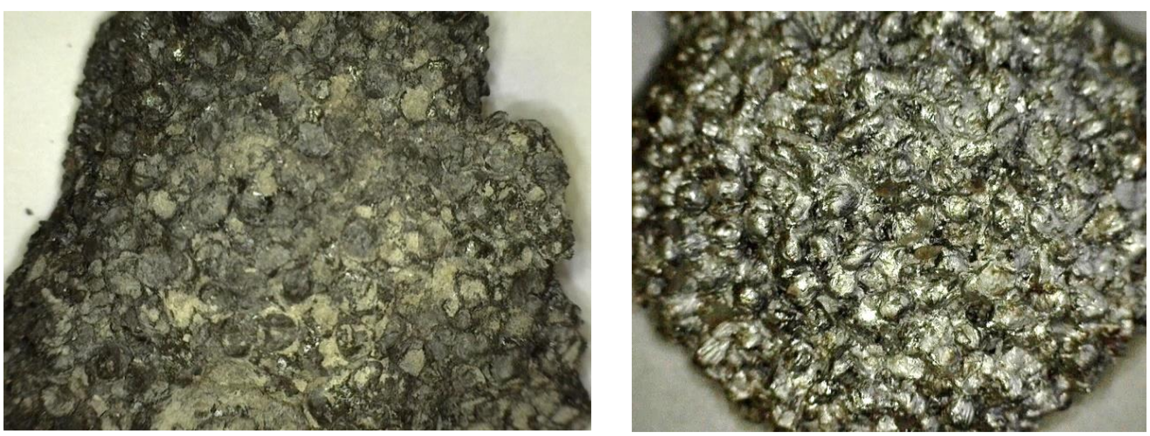

Figure 4.34 : MPM and experimental millet grain products. Grain distinct cereal product (Cat. #10128)(left) and experimental millet cake (right).

Table 4.6: Experimental results with small crab apples.

Crab Apples	Fresh Weight	Fresh Diameter	Dried Weight	Dried Diameter	Carbonized Weight	Carbonized Diameter
1	6.7	2.8	0.7	1.4	0.6	1.0
2	6.7	2.8	2.0	1.8	0.35	1.8
3	5.4	2.2	1.5	2.0	0.8	2,0
4	5.4	2.2	2.3	1.9	1.2	1.9
5	7.1	2.7	1.3	1.9	0.6	1.8
6	7.1	2.7	2.7	2.1	0.2	1.7
7	6.4	2.5	2.9	1.8	1.1	1.9
8	6.4	2.5	1.6	1.9	1.3	0.9
9	4.3	2.4	2.7	1.6	0.9	1.7
10	4.3	2.4	2.1	2.0	0.3	1.9
11	3.8	2.8	1.0	2.0	1.2	1.4
12	3.8	2.8	0.8	1.9	0.2	1.3
Average	5.6	2.6	1.8	1.9	0.7	1.6
13	7.2	2.5	N/A	N/A	0.8	2.0
14	7.2	2.5	N/A	N/A	0.4	2.0
15	3.3	2.2	N/A	N/A	1.7	2.5
16	3.3	2.2	N/A	N/A	1.2	2.3
17	5.3	2.3	N/A	N/A	0.7	2.0
18	5.3	2.3	N/A	N/A	0.2	2.0
19	6.9	2.7	N/A	N/A	1.3	2.3
20	6.9	2.7	N/A	N/A	1.5	2.5
21	5.0	2.8	N/A	N/A	0.7	2.3
22	5.0	2.8	N/A	N/A	0.6	2.0
23	6.4	2.8	N/A	N/A	2.0	2.5
24	6.4	2.8	N/A	N/A	0.4	1.9
Average	5.7	2.6			1.0	2.2

ratio used to form a porridge is most similar to the material from the museum collection (Figure 4.35), suggesting that MPM Cat. #10158, described in the catalogue simply as charred barley, is actually a grain preparation similar to porridge.

Comparison of the MPM Collection to Other Robenhausen Botanical Collections

A variety of factors distinguish the various Robenhausen museum collections from one another. First, the size of these collections is variable, and some contain a broad spectrum of material while others are minimal and restricted to a few categories. Second, the extent to which these collections have been analyzed is different, since some have been studied in detail, while others have not been analyzed since they were recovered during excavation, and original catalogue descriptors are the extent of the available information. Additionally, while some

Figure 4.35: MPM and experimental wheat and barley grain products. Experimental one part grain, five parts water (upper left), experiemental one part grain, one part water (upper right), MPM Cat. #10158 grain product (lower left) and experimental dry grain (lower right).

collections retain their original documentation, labeling, and housing, in other cases these accompanying items have been removed or lost and the record of the removal of the material from the Robenhausen site no longer exists. Third, since the botanicals in most Robenhausen museum collections listed in Appendix A were removed from the site between 130 and 155 years ago (Altorfer 2010), taxonomic nomenclature and common identifying markers for certain species have changed over time. This is not unique to botanical analysis; the same occurrence was also noted in an examination of faunal material from lake dwelling sites at the Harvard Peabody Museum of Archaeology and Ethnology and the Chicago Field Museum (Ross 2011). The information found in 19th century floral and faunal labels is historically interesting since it allows the changes in taxonomic nomenclature to be traced and studied.

In addition to these differences, the various Robenhausen botanicals in museum collections also have some features in common. One is the presence of the following nine plant categories (Table 3.2): *Corylus avellana* (hazelnut), *Hordeum vulgare* (barley), *Linum usitatissimum* (flax), *Malus sylvestris* (European crab apple), *Rubus idaeus* (red raspberry), and *Triticum aestivum/turgidum/durum* (naked wheat). Since collecting in the 19th century focused on acquiring representative elements of lake dwelling daily life (Kauz 2004), it makes sense that museums sought representative elements for display. However, since sorting of cereal grains and identification of naked wheat was probably not a regular occurrence, the presence of this species in all of the collections indicates how common it was at the Robenhausen site. Another similarity based on closer examination of catalogue information is that many museums have either two or three representatives of each major category. For example, the MPM collection includes three uncarbonized hazelnuts. In addition, the material donated by each of the three MPM donors includes a grouping of either two or three crab apples. This is not unique to the

MPM collection; it also applies to the material at the Smithsonian National Museum of Natural History and the Field Museum in Chicago. This also probably applies to other museums; however, botanical counts were not obtained for every collection mentioned in this thesis.

4.6 Theoretical Interpretation of the Collection

The theoretical discussion of foodways in Chapter I presents a number of approaches to botanical material, one of which relates specifically to the development of Neolithic cuisine, making it particularly well-suited to the interpretation of food remains from the Robenhausen site. The concept of regional *Neolithicities* suggests that culinary practices that developed in different parts of the world after the introduction of agriculture were based on preexisting technologies, which influenced processing techniques, consumption patterns, and the character of food (Fuller and Carretero 2018). One example of this is the preexistence of pottery technology and specifically, the bowl in East Africa, where porridge became a staple food, while in the Near East, where cereal domestication preceded pottery technology, bread predominated (Haaland 2007). In order to interpret the MPM Robenhausen botanicals it is important to consider the other material in the collection alongside these plant remains, which did not exist in isolation, but rather, were part of a material assemblage that included pottery, bone and antler tools, wooden implements, lithics, and textiles.

As previously discussed in this thesis, Robenhausen and other lake dwelling sites are especially well known for intricately woven linens that far exceed the skill level once attributed to people in Neolithic central Europe (Altorfer 2000: 141-145, 172; Jacomet 2004). The fibers used to weave these linen textiles were made from flax, which is processed through retting or soaking the stalks in water until they have rotted to the correct degree to make them pliable for weaving without breaking. In fact, ease of access to flax processing locations may have been a

practical reason for living near the lakes in central Europe during the Neolithic, prior to the widespread use of wool (Leuzinger 2004: 246-247). During this period, the inhabitants of Robenhausen grew enough flax to supply multiple households with material for weaving, and each house at the site contained the remains of a warp weighted loom (Altorfer 2010: 141-143; Keller 1866: 40). Excavations at the site also indicate that flax strings, cords, and nets were common at (Keller 1866: 40) and some of these items are included in the MPM Robenhausen collection (Lillis 2005). Flax fields must have surrounded the site and were probably in close proximity to it, based on an experimental project carried out from 1990-1995 in which flax fields near houses that were enclosed by wattle fences were the most successful (Leuzinger 2004: 246-247). All of this information together indicates that this was a regional or local *Neolithicity* in which flax, fiber processing, and string, net, and linen production were a dominant focus of daily activities.

The Robenhausen site was also a location where abundant cereals of different types were grown (Altorfer 2000: 172) in agricultural fields where the grain probably mingled with flax (Figure 4.36). The presence of plots that grew from small patches to agricultural fields through the course of the Neolithic is indicated by changes in weed assemblages (Bogaard 2005; Jacomet 2004: 172). At other lake dwelling sites such as Arbon-Bleiche 3 and Pfyn-Breitenloo, cereal and flax fields were located close to the settlement based on the presence of *Silene cretica*, a characteristic grass weed (Leuzinger and Rast-Eicher 2011: 535-542). All agricultural fields were tended using a variety of tools and tasks such as plowing were probably accomplished with help from domestic animals. Cereals were harvested and then processed through an intricate series of steps depending on the final product, which seems to have varied. Harvesting activity is indicated by large quantities of grains stored in vessels up to two feet in diameter (Altorfer 2000:

172). Evidence for variation in the final products is suggested by the remains of cereal preparations that range on a continuum from fused whole grains to porridge-like material to a more refined bread-like consumable. The fact that cereals were ground and made into bread-like product is further indicated by large quantities of grinding stones and by the presence of circular stones which were heated and used for baking (Keller 1866: 40).

Figure 4.36: Artist's recreation of a lake dwelling settlement area. This image shows the surrounding land and agricultural fields (after Jacomet et al. 1989: Fig. 60).

Fruit and nut trees were also a component of the Robenhausen *Neolithicity*, although they were most likely wild or cultivated rather than domesticated. Specifically, crab apples and hazelnuts, but also other tree-fruit such as acorns, cherries, and pears were harvested and stored. The way that these fruit trees grow suggests that they would have thrived and proliferated as increasingly larger areas of land were cleared for agriculture (Bishop 2013). Food storage is

indicated by the large quantities of apples that were sliced in half and dried in lake dwelling homes under the thatched roof (Figure 4.37), while consumption is shown by middens of cherry pits found in the spaces between the houses (Coles and Coles 1989). Based on this evidence, the people of Robenhausen lived in a settlement that was actually quite large when the agricultural fields around the houses are included in site-size estimations. These fields were planted with flax, barley, and different wheat species, and some weeds and wild grasses might have been harvested alongside domesticated grasses. In addition, fruit and nut trees were scattered across the landscape in gradually increasing quantities in correspondence with cleared fields and the fruits of these trees were processed, stored, and eaten.

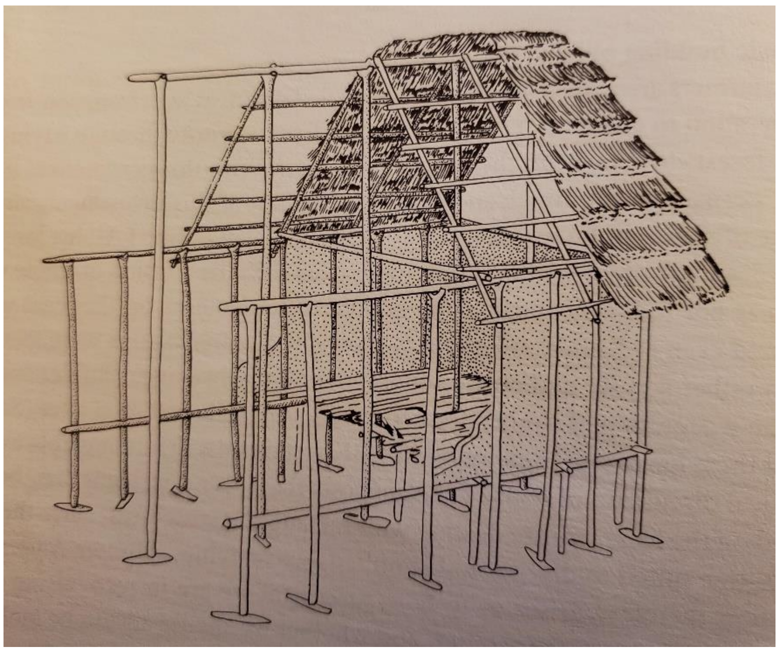

Figure 4.37: A reconstruction of a Pfyn culture lake dwelling house. This image shows the area under the thatched roof where crab apple halves could have been dried (from Billamboz and Schlichtherle 1985, after Whittle 1988: Fig 3.1).

The question of how this particular *Neolithicity* developed relates to the idea that preexisting technology, tools, and raw materials influence the form that food and cuisine take in

a particular region. The movement of domesticated plants into central Europe took place around 4500 BC when the Neolithic founder crops from Asia Minor took root (Whittle 1994: 136-137). Since domestic flax and domestic cereals moved into Europe at around the same time, the existence of one did not necessarily precede the other at circum-Alpine lake dwelling sites. However, plant fiber technology was not new to the region and its inhabitants had been using tree bast to make nets, ropes, and textiles prior to the introduction of domestic flax (Leuzinger and Rast-Eicher 2011). In addition, the Mesolithic inhabitants of the Alpine region had relied on gathered crab apples, other fruit trees, and nuts, although not to the same extent as in later periods (Jacomet 2007). At Robenhausen and other lake dwellings in the region, at the point when cereals and flax were introduced, life was characterized by proximity to the lakes (representing a processing location), plant fiber technology to make ropes, nets, and textiles, and some degree of reliance on crab apple and other fruit and nut trees as components of subsistence. These first two preexisting condition are especially important since they paved the way for skillful flax processing and linen manufacture. In terms of the MPM collection of botanical and food remains, this leads to the question: how did these preexisting and coexisting technologies and domesticates come together to influence the way that cereal grains, crab apples, and other botanicals were grown, harvested, processed, cooked, and consumed?

One possible interpretation suggested here is that flax seeds were incorporated into the cuisine as a binder and that flax products were used as a processing tool and a way to store Neolithic foodstuffs. In terms of modern cuisine, ground flax seed mixed with water is commonly used as an egg substitute in vegan recipes for baked and fried food (Rinsky and Rinsky 2009: 112). In other words, flax seed as a binder in foods may represent a Neolithic technological innovation since ground flax mixed with water could have been used as a

component in the matrix that held together cereal grains. Such innovations are not generally associated with Neolithic cuisine, possibly because the organic material from archaeological sites is typically not preserved. However, in the case of the lake dwellers, some varieties of the cereal product that were preserved could have been made using this food production technique.

As fabric made from flax relates to food processing, certainly complex weaves would have been characteristic of costume, home decoration, or trade. At the same time, loosely woven materials made from flax may have served other cultural purposes, such as nets for fishing and sieves for processing grain. In this context, strings and bags made from flax fiber may have been used to suspend crab apple halves from the ceiling beams of lake dwelling houses to dry. There are several archaeological examples of dried apples halves hung on strings during this period (Bishop 2013; Miller 2013) and two apple caches were found, probably suspended in bags from thatched rooves dating to the Bronze Age occupation at Sovjan in Albania (Allen 2005). One final suggestion based on a flax inspired regional *Neolithicity* is that loosely woven flax textiles might have been stretched beneath the thatched roof of lake dwellings and used as a surface for drying the large quantities of apple halves that were later carbonized and eventually became part of the archaeological food remains found at these sites. While this and some of the other ideas suggested here may well be imaginative suppositions, their utility lies in the basis that they provided for thinking about the potential complexity of foodways in prehistory, something which is made possible by the exceptional preservation of organic material at Robenhausen and other lake dwelling sites.

Chapter V Conclusion

5.1 Introduction

This thesis project has utilized a combination of different methods combined with the theoretical perspective of foodways research to analyze a museum collection of plants and food excavated in the 19th century. The MPM Robenhausen botanical material is significant to many areas of research and has a great deal of potential beyond what has been explored here. This chapter begins with a discussion of agriculture at Robenhausen based on this collection, focusing on the combination of domestic and wild plants used at the site, the way the products of these subsistence strategies complimented one another, forming a local and regional cuisine, and the way that location and agriculture related choices were made at lake dwelling sites. The next section suggests a series of general implications for the approach of similar collections of lake dwelling botanical material in museums. This is followed by possible directions for future research, building on the different approaches explored in the last four chapters with applications to Robenhausen and lake dwelling botanical studies. The final portion of this chapter provides conclusions based on the links between prehistory and history which are interwoven within the background of archaeology at Robenhausen, Switzerland.

5.2 The Nature of Food at Robenhausen

In order to assess the significance of the MPM Robenhausen botanical collection, a theoretical framework focused on foodways describes the way in which societies interact with food and can be applied directly to the archaeological past. The people at Robenhausen and other circum-Alpine lake dwelling sites relied on a mixed subsistence strategy utilizing the products of agriculture and animal domestication alongside hunting and gathering. While these

vacillating foodways are sometimes viewed from a standpoint of practicality and even reversion when crops, for example, were unsuccessful, they might also be viewed as choices. Speaking broadly, the idea of cultural tradition and considerations of practicality are concepts that allow the circum-Alpine lake dwelling phenomenon as a whole to be better elucidated. In this model, rather than suggesting that prehistoric farmers made choices that were entirely based on values, customs, and heritage or that they were subject to the ecological sphere in which they lived and governed by practical considerations, a mosaic of the two strategies is indicated. By applying this concept to the lake dwellings, a combination of cultural choices and adaptive response to the environment helps archaeologists to envision a cohesive culture and to understand the individuals within that culture. Applying this concept further elucidates a world in which food procurement and processing activities dominated daily activities, shaped identities, and acted as symbolic constructs (Hastorf 2017: 92-93).

Food processing is a component of foodways research, which explores both the practical and cultural components of cuisine and applies directly to the Robenhausen botanical collection. In order to understand food processing, it is important to acknowledge the fact that some foods may not be consumable in a raw state (Hastorf 2017: 91). In the case of the Robenhausen material, this applies to the grains and the crab apples, which would both have been difficult to consume without some form of processing. The cereal products in the Robenhausen collection display the greatest level of processing since they require a large number of steps, including threshing, winnowing, drying, storing, grinding, mixing, kneading, and baking (Hastorf 2017: 93). These processes also involve a range of objects or tools with associated use-life histories, spaces where processing activities can be carried out, skilled individuals with experiential

knowledge, and a specific order of stages for processing. This general discussion leads to more specific discussions of the different components of the Robenhausen botanical material.

One of the most interesting qualities of the "grain visible" cereal product fragments is the curved shape and the presence of a distinct bottom and top on all four pieces. Based on these characteristics, the fragments, when whole, were cooked on a convex surface. Different ways of cooking bread have been the focus of ethnographic and ethnoarchaeological studies and many different methods are used throughout the world. Examples include the *tandir* oven in which the dough adheres to the inside vertical wall of the oven when baking (Parker 2011) and the *saj*, a curved metal pan which is placed over a fire with the brim resting on three stones while bread is cooked on the curved surface (Mulder-Heymans 2002). Another type of cooking device, *bedja* bowls were used in Egypt during the Old Kingdom to cook bread by pouring dough into preheated, tempered pots to cook (Chazan and Lehner 1990). While the exact surface used to bake the Robenhausen grain visible cereal products is unknown, it is interesting to consider the possible systems used by the inhabitants of Robenhausen. Were these cakes made on a curved griddle, baked on the outer surface of a clay pot, or simply cooked on round heated stones?

Given the nature of the MPM cereal grains, most standard paleoethnobotanical quantitative techniques cannot be applied, however, broad interpretations based on the spectrum of grains in the Robenhausen collection are possible. For example, in the loose grain collection, the dearth of either *Panicum miliaceum* or *Setaria italica* (millet) confirms the fact that these components of the collection predate the Late Bronze Age, when these two grains became abundant in lake dwelling contexts (Jacomet et al. 1991: 270). At the same time, some of the cereal product fragments are made entirely from *Panicum miliaceum* dating them to the Bronze Age occupation levels. In addition, the small quantities of *T. dicoccum* (emmer wheat) found in

the MPM's Robenhausen material suggest that the bulk of the assemblage belongs to the Pfyn culture, when naked wheat and barley were the dominant crops, rather than to the later Horgen and Corded-Ware cultures, when emmer wheat became more important (Jacomet et al. 1991: 267-268). Another explanation for the prevalence of naked wheat is that the Pfyn cultural material dominates the Robenhausen collection in quantity since the Pfyn strata represent the longest occupational periods at the site (Altorfer 2010). The absence of loose millet grains combined with evidence for cereal products made entirely from millet also raises a number of questions. Does millet represent a product of local farming or was it an imported material? Was it processed outside the settlement, which could explain the absence of loose grains? Was there a period when millet was grown but not stored in the same way that wheat and barley were? In general, what do cereal product constituents imply when they are not present as loose grains or do the different samples simply illustrate the chronological sequence of grains at Robenhausen?

The interpretation of the MPM Robenhausen botanical collection presented here draws on many theoretical viewpoints, but rests most strongly on foodways research. In this respect, the question is not whether the objects labeled as bread are really porridge, but rather, what types of cereal products were manufactured from processed grain during the Late Neolithic in Switzerland. In addition, the idea that preexisting technologies and materials like textiles and flax could have shaped other aspects of life at this site is important since food culture does not exist separately from other aspects of life. This exact concept was the inspiration for the experimental approach using millet cakes to interpret the products represented in the MPM collection. Using a common raw material, in this case flaxseed, combined with a modern cooking technique, a flax "egg," suggests that cooking innovations took place in the Neolithic just as they do today. Although this may seem like an overextension since only four flax seeds

were found in the MPM Robenhausen botanical material, the presence of large quantities of flax at Robenhausen is well documented (Altorfer 2010, 2000; Keller 1866; Lillis 2005). In addition, flax byproducts are part of the MPM collection, but were grouped with linen textiles and were the focus of a separate research project (Lillis 2005). By providing an integrated perspective, foodways theory opens up the possibility of accessing food innovation in prehistory and suggests that people in the Neolithic understood technical and nutritional aspects of cuisine. For example, the technique of using ground flax as an egg-like material is something that could have been discovered and passed down as part of a cultural lexicon of food knowledge. At the same time, flax, which is considered a "superfood" from our modern perspective, might have also been recognized as a high quality source of protein during the Neolithic.

Gathered materials were important to the foodways at Robenhausen, where they would have added to the variety of tastes and flavors while also contributing to the nutritional content of subsistence resources and providing important vitamins at different points throughout the year. The value of stores of wild plants is demonstrated most visibly by the large quantities of crab apples and the way in which they were prepared is interesting to examine. The apples were systematically halved, probably to expedite the drying process, but, limited experimentation showed that removal of the core from a dried apple half was a cumbersome process and only produced a small amount of flesh for consumption. If eating the plain apples in this dried form was the primary goal, then dried apple rings like the modern pieces found in food coops and grocery stores would have certainly been more convenient. This suggests that dried crab apples could have served other purposes. Some potential uses include adding to dishes as a flavoring agent, or the production of beverages. For example, in pre-industrial Slovakia crab apples were delicacies consumed primarily in winter (Stoličná 2016: 247) when vitamin C was at a premium.

Culinary processes included fermenting dried crab apples, which were boiled, sweetened with sugar, and consumed in this state, but this liquid was also thickened with flour and eaten with potato cakes (Stoličná 2016: 247). Another process using fresh crab apples utilized fermentation to create vinegar which was combined with other ingredients to make sour sauces and soups (Stoličná 2016: 247).

Other important gathered foods represented in the MPM Robenhausen collection included raspberries, bilberries, caraway seeds, goosefoot, hazelnuts, sloe, and wild turnip. The raspberries, which can be harvested beginning in late spring, would have added flavor, taste and texture to the diet, and been a source of antioxidants, vitamins C, A, and calcium (Graham and Woodhead 2009: 509-510; Stoličná 2016: 246). Bilberries would have also contributed vitamins C, A, and calcium to the diet while adding flavor and color to the food spectrum (Stoličná 2016: 246). Caraway seeds are gathered in fall and might have been incorporated into cereal products or used as a condiment to add flavor to soups, stews, and meats (Keller 1866: 342; Stoličná 2016: 244). Goosefoot seeds can be gathered beginning in the spring and are a source of calcium, magnesium, vitamin C, and iron (Stoličná 2016: 243). Hazelnuts ripen toward the end of summer and are harvested in September and October; they can be eaten raw, but they can also be ground into flour and incorporated into bread, a practice which was common in 18th century Scotland (Bishop 2013: 56-58). Sloes, also known as blackthorn fruits, have been dried and consumed by women while spinning flax to help produce enough saliva to moisten the threads (Stoličná 2016: 246); they may have been important in this regard at lake dwellings like Robenhausen. *Brassica* seeds found at Robenhausen may indicate consumption or processing activity since they are often considered a weed when associated with plant cultivation (Bishop 2013: 162). Taken together, these various food resources added many dimensions to

Robenhausen foodways and indicate that a developed culinary experience filled with nutritious options was part of life at this settlement.

Foodways research applied lake dwelling studies is useful because of its ability to address depositional processes, preservation factors, food security, catastrophic events, plant diversity, and occupation length (Peres 2017; Twiss 2012). For example, since the anerobic environment at Robenhausen preserved carbonized material which otherwise might have been lost, there is a greater quantity of burnt material from the site than usually seen in archaeological contexts. This has the potential to skew interpretation since this situation might be explained as resulting from more destructive site-wide fires than actually occurred. While the preservation of carbonized remains skews the material record, there were in fact at least two fires at the Robenhausen site. That these fires interrupted daily life is indicated by the presence of burnt edible foods rather than food by-products. Although the fires may be interpreted as the result of violence or warfare, fires would have been commonplace due to the thatch and wood construction at the site and their use for cooking, warmth, and craftsmanship. The fact that a lake dwelling village recreation in an open air museum caught fire shortly after opening supports the frequency of this type of occurrence (Leckie 2013). In terms of food security, the existence of large stores of food at Robenhausen combined with skillfully worked wood and textile artifacts suggests that the site's inhabitants had achieved a level of surplus that allowed them to focus on arts and crafts. The assemblage presented here and those found at other lake dwelling sites are suggestive of low levels of plant subsistence diversity and great reliance on a few main food groups, namely cereal grains, cereal grain products, crab apples, hazel and other nuts, and small quantities of berries and other gathered foods. However, studies of foodways suggest that a low level of plant diversity is indicative of shorter occupational periods and does not necessarily reflect a limited

diet. Since most lake dwelling sites were occupied for shorter periods and serial occupations over a several thousand year span were common, a greater food diversity at Robenhausen than that represented by the MPM and other museum collections is probable.

This thesis demonstrates some of the ways that an older museum collection can contribute valuable insights through careful study and analysis. These insights are not dependent upon detailed provenience evidence because interrogating the value of individual pieces of cereal product suggests possible interpretations of culinary strategies and cuisine at Robenhausen even in the absence of such data. With regard to the apples, the idea that they might have been used as both a flavoring agent and a vitamin supplement throughout the winter combines practicality and cultural preference. Too often, an assumption is made that food was plain and unpleasant in prehistory and that people consumed the same thing every day (Küster 2000: 1228). In many ways, this attitude toward lake dwelling food is ironic since prior to the discovery of these sites, the complexity of organic materials in Neolithic Europe was underestimated. The original assumption that low-diversity botanical assemblages reflect shorter occupations is challenged by the subsistence situation at Robenhausen and other lake dwelling settlements, which was both more diverse and variable than the material record indicates. Archaeological interpretations are impacted by food studies because they question food typologies and definitions (Valamoti et al. 2019) as well as the potential of food taste and texture preferences in prehistory, an arena that requires additional exploration. For example, assumptions about bland food in prehistory fail to consider the way that modern diets influence tastes and flavors when, in the absence of the vast array of spices and ingredients available now, the nuances of various more subtle additives such as caraway seeds might have been appreciated by the Neolithic palate.

Finally, recent interest in the motivations and identities of individuals in prehistory compels us to ask whether cereal product, apples, hazelnuts, and other prevalent foods from Robenhausen were the basis of a regional cuisine or culinary tradition. Stemming from this is the possibility that food, food processing, and the construction of diet were a constituent element of the identities of the people who lived at the site. Here the concept of regional *Neolithicities* suggests that varying regional food products and traditions developed based on the presence of technologies and raw materials (Haaland 2007; Fuller and Carrtero 2018). In other words, food does not exist in a vacuum, it is shaped by the material culture used to produce, prepare and consume it and the way that people interact with everything around them. Taken together, the foods, tools, and food associated craft products at Robenhausen were an expression of life and also effected the lives of the individuals and the larger community that occupied this settlement.

5.3 Implications for 19th Century Botanical Collections

Several aspects of this project are important in the study of 19th century museum botanical collections. First, some of the protocols for handling botanical material that are recommended by paleoethnobotanists are difficult to apply to these collections. These include methods for preserving waterlogged materials that suggest maintaining a high moisture level to limit changes in chemical composition, embedding, sectioning, and grinding specimens as analytical methods, and the use of quantitative statistical models (Pearsall 2000: 117-119, 170-174, 192-224). At the same time, some of these protocols can be usefully applied based on this analysis of the MPM Robenhausen botanical material. One of these is the use of research numbers for species identification within each catalogue number. This is helpful because identifications are likely to be revisited, allowing information to be updated without altering the housing of the material. In the case of a project where large numbers of digital photographs are

taken, these can also be labelled with the research numbers. Another important aspect of the methods used here was to record the state of the collection in detail before beginning any research. One additional suggestion to emerge from this project is that, although taxonomic identifiers may be dated, information from records and previous analysts frequently has merit and provides a history of changing scientific perspectives.

Another lesson gained during the course of this project is the importance of accurate and systematic documentation of the botanical material in each lake dwelling museum collection. In this instance, six "apple pieces" (MPM Cat. #10131) were found to be wood, nuts, and cereal products. In addition, a chunk of charred barley (MPM Cat. #10158) may actually be a porridge or cereal conglomerate. In the case of MPM Cat. #10130, nearly one hundred seeds and a fish vertebra were discovered in a collection thought to consist entirely of charred grains. Other unexpected findings included the cereal product fragments (MPM Cat. #10128) which fit together to form larger pieces, and a small rope or textile fragment mixed in with another lot of charred grain (MPM Cat. #15046). In other words, it is best not to solely rely on the written record and to study all material in great detail. This practice must be applied to all Robenhausen and lake dwelling botanical material housed in museums in order to know exactly which species and materials are present in each collection. These findings might also broaden the collective plant spectrum represented for the Robenhausen site.

5.4 Future Research

This thesis has revealed a plethora of additional lines of exploration. Some are based on the MPM's Robenhausen collection, others are based on Robenhausen material in general, and additional lines of inquiry focus on broader questions related to the lake dwelling cultural complex and the study of prehistoric foodways. In terms of the MPM Robenhausen cereal

products, SEM imaging of the fragments could reveal their constituent elements since this form of analysis has been used recently in several comparable cases and each time it has broadened our understanding of these food products (Hansson 1994; Heiss et al. 2017, 2019; Valamoti et al. 2019). In addition, radiocarbon dating of sample fragments of the various types of grain products, crab apples, and individual cereal grains donated by Renggly would have the potential to more definitively resolve the question of fraudulent attribution described in the introduction.

The experiments with grain products were designed to investigate this specific collection in lieu of other methods such as SEM and carbon dating, but they may have applications for cereal product studies in general, whether or not more scientific forms of analysis are available. Various experimental options are possible based on the preliminary results presented here. One option is grinding grains using stone querns to make flours with different consistencies in order to potentially replicate products made with both coarse and fine-grained material. Other options include the addition of different vegetable elements to explore the complexity of prehistoric cuisine. For example, a recent analysis of two clumps of charred cereal product from the Parkhaus Opera site on Lake Zürich found celery pericarp to be a constituent element (Heiss et al. 2017). Making a cereal product that included celery might have implications for understanding the complexity of food and taste in prehistory. The experiments conducted here would also have been aided by the availability of more rustic raw ingredients such as barley, millet, and wheat grains that retained their hulls; experiments using such materials may prove enlightening in the future.

In terms of crab apples, while the Robenhausen material has been demonstrated to fit within the size parameters of *Malus sylvestris* the question of domestication remains unresolved. Currently, the domestic apple is associated with Roman civilization, but this process might have

begun during the Neolithic or Bronze Age and there may be intermediary specimens from European archaeological sites. Recent research using the DNA of waterlogged *Malus* remains to understand the process of domestication in Europe illustrates that ribosomal DNA may help to identify genetic changes in apple specimens over time (Schlumbaum et al. 2011). Regarding the experimental component of this thesis, there are a number of ways to improve the methods in order to better understand apple processing at lake dwellings and other Mesolithic, Neolithic, and Bronze Age sites. First, a more uniform drying technique would be useful since the dehydrator is a modern devise. Using ethnoarchaeology as a guide in developing experimental methods suggests that drying the crab apples near a fire or in a shed might better simulate the drying activity that took place at Robenhausen. Second, a method for testing the level of hydration in the apples as they dried could help to refine the experiments. Third, one observation was that different varieties of apples shrank in different ways, possibly based on inherent qualities of the apples; one hypothesis is that the sugar content of the apple may have impacted changes in shape. A final improvement would be a muffle oven and crucibles to carbonize the apples and provide a means to gauge heating temperatures, carbonize apples uniformly, and provide more definitive results. Other suggested experiments include, replication of what was done in this project in terms of pre-dried and fresh apples and the effects of these processes on the peel, and experiments with waterlogging to understand its effect on the material. These could both have implications for carbonized *Malus* specimens from other archaeological sites found throughout Europe during the Mesolithic, Neolithic, and Bronze Age.

5.5 Cultural Continuity at Robenhausen

This thesis has presented the argument that regional *Neolithicities* were based on tools, technologies, raw materials, and other preexisting factors within the prehistoric world of the

circum-Alpine lake dwellers, with a focus on the potential use of flax seed in food at the site of Robenhausen, on Lake Pfäffikon, near Zürich. Based on this concept, flax and the many different materials produced using both its fiber and its seeds, may have had a role in shaping the structure of food at Robenhausen and other lake dwelling sites during the Neolithic and Bronze Age. The idea described here is that textile technology at Robenhausen may have been ingrained in other activities such as food processing and procurement, food storage, and even cooking. In the previous chapter it was suggested that nets, string, rope, cloth, and bags made of plant fibers might have been used in a variety of capacities to store and process food at Robenhausen. It was also suggested that, based on the importance of flax in the lives of the individuals who lived at the site, these seeds could have become incorporated into the local or regional cuisine, making flax a distinguishing element of the food culture.

With this in mind, it is interesting to note that textiles are not just a part of the prehistory of the Robenhausen site, they are also significant to its history and its modern economy. For example, the waters of Lake Pfäffikon were maintained at a high level for many years until the development of the textile industry in the region led to artificial water regulation on waterways powering spinning mills (Altorfer 2010: 19). This also led to dredging and straightening of the Aa River to accommodate an increased flow of water so that during the dry months of the year, the water level dropped revealing the remnants of pile dwellings in the winter of 1856-1857 and leading to the discovery of the site (Altorfer 2010: 19). In other words, without the 19th century textile industry in the region, Robenhausen, an important Neolithic textile production site itself might never have been discovered. In addition, the same textile factory located on the Aa River that prompted the discovery of the prehistoric site (Figure 5.1) still exists today and textile production remains an important part of the Swiss economy. In other words, textile manufacture

has been linked to this region since the Neolithic, was the impetus for the discovery of a site belonging to a prehistoric culture that helped unite a nascent country and has been a contributing factor in shaping other aspects of life in Switzerland. What makes this concept especially significant in the context of archaeology, is that, without the exceptional preservation of organic material at lake dwelling sites like Robenhausen, none of this would be apparent and that fact has broad implications for material culture-based interpretations of prehistory.

Figure 5.1: Sign from a factory in modern Wetzikon, Switzerland. Located on the Aa River, this factory is near the Robenhausen site. (photo credit: Bettina Arnold, 2004).

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APPENDIX A: Expected Flora

Expected flora are species likely to occur at the Robenhausen site based on identification by early excavators and later analysis.

(Table adapted from Altorfer [2010] with additional information from Karg et al. [2019]).

Museum Key: OH = Ortsmuseum Heiden, MW = Museum Wetzikon, HMP = Heimatmuseum am Pfäffikersee, RMK = Rosgarten Museum Konstanz, BHM = Historisches Museum Bern, MKB = Museum der Kulturen Basel, HM SG = Historisches Museum St. Gallen, MAW = Münzkabinett und Antikensammlung der Stadt Winterthur, MA SH = Museum zu Allerheiligen Schaffhausen, MAH GE = Musée d'Art et d'Histoire Genéve, MVFB = Museum für Vor- und Frühgeschichte der Staatlichen Museen Berlin, MPM = Milwaukee Public Museum, NMNH = National Museum of Natural History (Smithsonian), CFM = Chicago Field Museum, OAM = Oxford Ashmolean Museum, Br.M = British Museum, Be.M = Berlin Museum, PMAE = Peabody Museum of Archaeology and Ethnology.

Symbol Key: x = present in a museum collection, o = possibly present (after Altorfer 2010).

		OH	**MW**	**HMP**	**RMK**	**BHM**	**MKB**	**HM SG**	**MAW**	**MA SH**	**MAH GE**	**MVFB**	**MPM**	**NMNH**	**CFM**	**OAM**	**Br.M**	**Be.M**	**PMAE**
Scientific Name	**English Name**																		
Abies alba	**European silver fir**	**x**							**x**		**x**	**x**		**x**				**x**	
***Acer* sp.**	**Maple**																		
Achillea millefolium	**Common yarrow**												**o**						
Agrimonia eupatoria	**Common agrimony**																		
Agrostemma githago	**Common corn-cockle**																		
Ajuga reptans	**Common bugle**																		
Alisma plantago-aquatica	**European water plantain**				**x**			**x**				**x**		**x**	**x**			**x**	
Alnus glustinosa	**Common alder**																		

Angelica sylvestris	**Wild angelica**																		
Anomodon viticulosus	**Rambling tail-moss**					**x**													
Arctium lappa	**Greater burdock**											**x**		**x**					
Arctium minus	**Lesser burdock**																		
Arenaria serpyllifolia	**Thyme-leaved sandwort**														**x**				
***Betula* sp.**	**Birch**							**x**						**x**				**x**	
Betula pendula	**Silver birch**											**x**		**x**					
Bidens cernua	**Nodding bur-marigold**					**x**													
***Brassica* sp.**	**Cruciferous vegetables**												**x**		**x**				
Brassica nigra	**Black mustard**														**x**				
Brassica rapa campestris	**Wild turnip**		**x**	**x**															
***Carex* sp.**	**Sedge**											**x**						**x**	
Carex diandra	**Lesser panicled sedge**														**x**				
Carex flava	**Yellow sedge**														**x**				
Carex laevivaginata	**Smooth-sheathed sedge**														**x**				
Carex lepidocarpa	**Lepoina sedge**														**x**				
Carex strigosa	**Thin-spiked wood sedge**														**x**				
Carex vesicaria	**Bladder-sedge**														**x**				
Carpinus betulus	**European hornbeam**					**x**		**x**	**x**			**x**		**x**					
Carum carvi	**Caraway**												**x**						
Ceratophyllum demersum	**Hornwort**				**x**							**x**						**x**	

Cenococcum geophilum	**ECM Fungus**																		
Centaurea cyanus	**Cornflower**																		
***Characeae* sp.**	**Stonewort**																		
Chara vulgaris	**Common stonewort**										**x**		**x**						
Chenopodium album	**Goosefoot**		**x**	**x**	**x**						**x**	**x**	**x**	**x**			**x**		
Chenopodium polyspermum	**Manyseed goosefoot**										**x**		**x**	**x**					
Chenopodium rubrum	**Red goosefoot**																		
Cicuta virosa	**Cowbane**																		
***Cirsium* sp.**	**Plume thistle**																		
Cornus sanguinea	**Common dogwood**				**x**			**x**				**x**		**x**				**x**	
Corylus avellana	**Hazelnut**	**x**	**x**		**x**	**x**		**x**	**x**		**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	
***Crataegus* sp.**	**Hawthorn**																		
Crepis capillaris	**Smooth hawksbeard**														**x**				
Daedalea quercina	**Oak mazegill**																		
Daucus carota	**Wild carrot**																		
Echinochloa crus-galli	**Barnyard grass**														**x**				
Equisetum arvense	**Common horsetail**																		
Eupatorium cannabinum	**Hemp-agrimony**																		
Fagus silvatica	**Red beech**	**x**	**x**		**x**	**x**		**x**			**x**	**x**		**x**					
Fallopia convolvulus	**Wild buckwheat**																		
Fragaria vesca	**Wild strawberry**		**x**	**x**	**x**	**x**	**x**				**x**				**x**				

Frangula alnus	**Alder buckthorn**																		
Fraxinus excelsior	**European ash**																		
Galeopsis tetrahit	**Common hemp-nettle**																		
Galium mollugo	**Hedge bedstraw**					**x**													
Galium palustre	**Common marsh bedstraw**		**x**		**x**	**x**		**x**	**x**			**x**		**x**				**x**	
Galium spurium	**Stickwilly**																		
Gentiana campestris	**Yellow gentian**														**x**				
Gentiana germanica	**Chiltern gentian**														**x**				
Heracleum austriacum	**Austrian hogweed**																		
Hieracium diaphanoides	**Translucent hawkweed**														**x**				
Hordeum vulgare	**Barley**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**		**x**	**x**	**x**		**x**	
Hydrocotyle vulgaris	**Common pennywort**											**x**							
Hylocomium brevirostre	**Short-beaked wood-moss**																		
Hyoscyamus niger	**Henbane**																		
Ilex aquifolium	**Common holly**																		
Iris pseudacorus	**Yellow iris**				**x**							**x**							
***Juglans* sp.**	**Walnuts**														**x**				
Juglans regia	**English walnut**																	**x**	
Juniperus communis	**Common juniper**																		
Lens culinaris	**Lentil**								**x**										

Ligustrum vulgare	**Wild privet**										**x**								
Linum austriacum	**Asian flax**																		
Linum usitatissimum	**Common flax**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**	**x**		**x**	**x**	
Lolium temulentum	**Darnel**				**x**							**x**							
Lychnis flos-cuculi	**Ragged-robin**																		
Lycopus europaeus	**Gypsywort**														**x**				
Malus sylvestris	**European crab apple**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**
Medicago minima	**Bur medick**																		
Mentha aquatica	**Water mint**																		
Mentha arvensis	**Wild mint**																		
Menyanthes trifoliata	**Bog bean**				**x**							**x**		**x**				**x**	
Moehringia trinervia	**Apetalous sandwort**																		
Myosotis arvensis	**Field forget-me-not**														**x**				
Myrica gale	**Bog myrtle**														**x**				
Najas intermedia	**Spiny water nymph**																		
Najas marina	**Spiny water nymph**																		
Neckera complanata	**Flat feather moss**																		
Neckera crispa	**Crisped neckera**																		
Nuphar lutea	**Yellow water lily**				**x**							**x**		**x**					

Nuphar pumila	**Dwarf water lily**											**x**							
Nymphaea alba	**European white water lily**				**x**	**x**					**x**	**x**		**x**					
Origanum vulgare	**Oregano**														**x**				
Papaver somniferum	**Opium poppy**		**x**	**x**	**x**			**x**				**x**		**x**				**x**	
***Panicum* sp.**	**Millet**																		
Panicum miliaceum	**Broomcorn millet**																		
Pastinaca sativa	**Parsnip**											**x**		**x**					
Pedicularis palustris	**Marsh lousewort**				**x**			**x**				**x**		**x**	**x**				
Peucedanum palustre	**Milk parsley**				**x**			**x**				**x**		**x**					
Phragmites australis	**Common reed**																		
Physalis alkekengi	**Chinese lantern**		**x**	**x**		**x**		**x**											
Picea abies	**Norway spruce**				**x**	**x**								**x**				**x**	
***Pinaceae* sp.**	**Pine**													**x**			**x**		
Pinus mugo	**Creeping pine**											**x**							
Pinus sylvestris	**Scots pine**				**x**	**x**					**x**	**x**		**x**					
Pisum sativum	**Pea**										**x**								
***Poaceae* sp.**	**Grasses**																		
***Polygonum* sp.**	**Knotweed**																		
Polygonum hydropiper	**Water-pepper**											**x**		**x**				**x**	
Polygonum persicaria	**Lady's thumb**																		
Polyporus fomentarius	**Tinder fungus**		**o**						**o**		**o**								

Polyporus igniarius	**Fire sponge**				**o**							**x**		**x**					
Potamogeton compressus	**Grass-wrack pondweed**		**x**									**x**		**x**					
Potamogeton nodosus	**Longleaf pondweed**											**x**							
Potamogeton natans	**Broad-leaved pondweed**																		
Potamogeton perfoliatus	**Claspingleaf pondweed**							**x**				**x**							
***Potentilla* sp.**	**Cinquefoils**																		
Potentilla norvegica	**Rough cinquefoil**														**x**				
***Prunus* sp.**	**Stone fruits**																		**x**
Prunus avium	**Wild cherry**										**x**								
Prunus domestica	**European plum**																		
Prunus mahaleb	**Mahaleb cherry**																		
Prunus padus	**Bird cherry**	**x**			**x**				**x**			**x**		**x**	**x**			**x**	
Prunus spinosa	**Sloe**	**x**	**x**	**x**	**x**	**x**		**x**		**x**	**x**			**x**				**x**	
Pyrus pyraster	**European wild pear**																		
Quercus robur	**European oak**											**x**			**x**		**x**		
Ranunculus aquatilis	**Common water-crowfoot**											**x**		**x**				**x**	
Ranunculus flammula	**Lesser spearwort**																		
Ranunculus hederaceus	**Ivy-leaved water-crowfoot**																		
Ranunculus lingua	**Greater spearwort**																		
Reseda luteola	**Dyer's weed**																		

Rorippa islandica	**Northern yellowcress**																		
Rosa canina	**Dog rose**		**x**			**x**						**x**		**x**					
***Rubus* sp.**													**x**		**x**				
Rubus frticosus	**European blackberry**		**x**	**x**	**x**	**x**	**x**	**x**			**x**	**x**		**x**					
Rubus idaeus	**Red raspberry**	**x**		**x**	**x**	**x**	**x**	**x**	**x**		**x**		**x**	**x**			**x**	**x**	
Rumex aquatilis	**Whitewater crowfoot**														**x**				
Rumex obstusiofolius	**Bitter dock**														**x**				
Sambucus ebulus	**Danewort**				**x**									**x**					
Sambucus nigra	**Elderberry**				**x**	**x**					**x**	**x**		**x**	**x**				
Scheuchzeria palustris	**Pod grass**				**x**							**x**							
Schoenoplectus lacustris	**Lakeshore bullrush**				**x**				**o**		**x**	**x**		**x**					
Schoenoplectus tabernaemontus	**Softstem bullrush**																		
Scleria lacustris	**Wright's nutrush**																		
Scutellaria galericulata	**Common skullcap**																		
Setaria italica	**Foxtail millet**		**x**			**x**													
***Silene* sp.**	**Catchfly**										**x**								
Silene alba	**White campion**											**x**							
Silene cretica	**Cretan catchfly**					**x**						**x**		**x**					
Slinene latifolia	**White campion**																		
Solanum dulcamara	**Bitter nightshade**							**o**											
Sorbus aucuparia	**Rowan**																		
Sorbus aria	**Common whitebeam**																		

Sparganium erectum	**Simplestem bur-reed**																		
Spergula arvensis	**Corn spurry**												**o**						
Spergula pentandra	**Wingstem spurry**																		
Stellaria graminea	**Common starwort**																		
Stellaria media	**Chickweed**																	**x**	
Taxus baccata	**Common yew**				**x**	**x**				**x**		**x**		**x**				**x**	
Teucrium montanum	**Mountain germander**														**x**				
***Tilia* sp.**	**Linden**													**x**					
Tilia cordata	**Littleleaf linden**											**x**							
Tilia platyphyllos	**Largeleaf linden**				**x**				**x**	**o**	**x**								
Trapa natans	**Water caltrop**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**	**x**		**x**		**x**	**x**	**x**	
***Triticum* sp.**	**Wheat**												**x**		**x**	**x**			**x**
Triticum aestivum /turgidum/durum/	**Naked wheat**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**	**x**		**x**			**x**	
Triticum dicoccon	**Emmer**			**x**		**x**		**x**					**x**						
Triticum spelta	**Spelt**												**o**						
Urtica dioica	**Common nettle**														**x**				
Vaccinium myrtillus	**Bilberry**												**o**						
***Verbascum* sp.**	**Mullein**																		
Viburnum lantana	**Wayfarer**				**x**	**x**		**o**											
Vicia	**Vetch**																		
Vicia sativa	**Common vetch**							**x**						**x**					

Symbol Key: x = present according to botanical literature, o = possibly present, [blue box] = Huber and Schoch (1999)(after Altorfer 2010).

		Heer 1865	**Neuweiler 1905**	**Christ 1862**	**Göpfert**	**Schoch 1993**	**Lang**	**Ulrich**
Scientific Name	**German Name**							
Abies alba	**Weisstanne**	**x**	**x**	**x**				
***Acer* sp.**	**Ahorn**	**x**	**x**					
Achillia millefolium	**Gemeine Schafgarbe**							
Agrimonia eupatoria	**Gewöhnlicher Odermennig**		**x**					
Agrostemma githago	**Kornrade**	**x**	**x**					
Ajuga reptans	**Kriechender Günsel**		**x**					
Alisma plantago-aquatica	**Gemeiner Froschlöffel**	**x**	**x**					
Alnus glustinosa	**Schwarzerle**	**x**	**x**					
Angelica sylvestris	**Wilde Brustwurz**		**x**					
Anomodon viticulosus	**Trugzahnmoos**						**x**	
Arctium lappa	**Grosse Klette**	**x**						
Arctium minus	**Kleine Klette**		**x**					
Arenaria serpyllifolia	**Thymianblättriges Sandkraut**							
***Betula* sp.**	**Birke**		**x**					
Betula pendula	**Warzen-birke**	**x**						
Bidens cernua	**Nickender Zweizahn**						**x**	
***Brassica* sp.**	**Kohl**							
Brassica nigra	**Schwarze Senf**							

Brassica rapa campestris	**Rübe**					**x**		
***Carex* sp.**	**Segge**	**x**	**x**					
Carex diandra	**Drahtsegge**							
Carex flava	**Echte Gelbsegge**							
Carex laevivaginata	**(Gelbsegge)**							
Carex lepidocarpa	**Schuppenfrüchtige Gelbsegge**							
Carex strigosa	**Dünnährigge Segge**							
Carex vesicaria	**Hainbuche**							
Carpinus betulus	**Hainbuche**	**x**	**x**	**x**			**x**	
Carum carvi	**Wiesenkümmel**	**x**		**x**				
Ceratophyllum demersum	**Gemeines Hornblatt**	**x**	**x**					
Cenococcum geophilum	**Schlauchpilz**		**x**					
Centaurea cyanus	**Kornblume**	**x**	**x**					
***Characeae* sp.**	**Algenart**		**x**					
Chara vulgaris	**Armleuchteralge**	**x**	**x**					
Chenopodium album	**Weisser Gänsefuss**	**x**	**x**			**x**		
Chenopodium polyspermum	**Vielsamiger Gänsefuss**	**x**	**x**					
Chenopodium rubrum	**Roter Gänsefuss**	**x**						
Cicuta virosa	**Wasserschierling**		**x**					
***Cirsium* sp.**	**Kratzdistelart**		**x**					
Cornus sanguinea	**Roter Hartriegel**	**x**	**x**	**x**				**x**
Corylus avellana	**Haselstrauch**	**x**	**x**	**x**			**x**	**x**
***Crataegus* sp.**	**Weissdorn**							**x**
Crepis capillaris	**Kleinköpfige Pippau**							
Daedalea quercina	**Eichenwirrling**	**x**	**x**		**x**			
Daucus carota	**Möhre**	**x**	**o**					

Echinochloa crus-galli	**Hühnerhirse**							
Equisetum arvense	**Acker-Schachtelhalm**			x				
Eupatorium cannabinum	**Wasserdost**		x					
Fagus silvatica	**Rotbuche**	x	x	x			x	x
Fallopia convolvulus	**Windenknöterich**		x					
Fragaria vesca	**Walderdbeere**	x	x	x		x	x	
Frangula alnus	**Gemeiner Faulbau**		x					
Fraxinus excelsior	**Gewöhnlicher Esche**	x	x					
Galeopsis tetrahit	**Gemeiner Hohlzahn**		x					
Galium mollugo	**Gemeines Labkraut**						x	
Galium palustre	**Sumpf Labkraut**	x	x				x	x
Galium spurium	**Falsches Klettenlabkraut**		x					
Gentiana campestris	**Feldkranzenzian**							
Gentiana germanica	**Deutsche Fransenenzian**							
Heracleum austriacum	**Wiesen Bärenklau**			x				
Hieracium diaphanoides								
Hordeum vulgare	**Mehrzeilige Spelzgerste**	x				x	x	x
Hydrocotyle vulgaris	**Wassernabel**	x	x					
Hylocomium brevirostre	**Etagenmoos**	x	x					
Hyoscyamus niger	**Bilsenkraut**		o					
Ilex aquifolium	**Stechpalme**	x	x					
Iris pseudacorus	**Gelbe Schwertlilie**		x					x
Juglans **sp.**	**Walnuss**							
Juglans regia	**Echte Walnuss**							
Juniperus communis	**Heide Wachholderbeere**	x	x					

Lens culinaris	**Linse**							
Ligustrum vulgare	**Liguster**							
Linum austriacum	**Österreichischer Lein**		**x**	**x**				
Linum usitatissimum	**Lein Flachs**	**x**				**x**	**x**	**x**
Lolium temulentum	**Taumelloch**	**x**						
Lychnis flos-cuculi	**Kuckuckslichtnelke**		**x**					
Lycopus europaeus	**Gemeiner Wolfstrapp**		**x**					
Malus sylvestris	**Apfel**	**x**	**x**	**x**		**x**	**x**	**x**
Medicago minima	**Zwerg Schneckenklee**	**x**	**x**					
Mentha aquatica	**Bachminze**		**x**					
Mentha arvensis	**Ackerminze**		**x**					
Menyanthes trifoliata	**Bitterklee**	**x**	**x**					**x**
Moehringia trinervia	**Dreinervige Nabelmiere**		**x**					
Myosotis arvensis	**Acker-Vergissmeinnicht**							
Myrica gale	**Gagelstrauch**							
Najas intermedia	**Mittelgrosses Nixkraut**		**x**					
Najas marina	**Meer Nixkraut**		**x**					
Neckera complanata	**Neckermoos**	**x**						
Neckera crispa	**(Neckermoos)**							
Nuphar lutea	**Grosse Teichrose**	**x**	**x**	**x**				
Nuphar pumila	**Kleine Teichrose**	**o**	**o**	**x**			**x**	
Nymphaea alba	**Weisse Teichrose**	**x**	**x**	**x**			**x**	**x**
Origanum vulgare	**Oregano**							
Papaver somniferum	**Schlafmohn**	**x**	**x**			**x**		**x**
***Panicum* sp.**	**Hirse**							
Panicum miliaceum	**Rispenhirse**		**x**					
Pastinaca sativa	**Pastinak**		**o**					
Pedicularis palustris	**Sumpf Läusekraut**	**x**	**x**					
Peucedanum palustre	**Sumpfhaarstrang**	**x**	**x**					
Phragmites australis	**Schilfrohr**		**x**					

Physalis alkekengi	**Judenkirsche**					**x**	**x**	
Picea abies	**Rottanne/Fichte**	**x**	**x**	**x**			**x**	
Pinaceae	**Kieferngewächse**							
Pinus mugo	**Bergföhre**	**x**	**o**	**x**				
Pinus sylvestris	**Waldkiefer**	**x**	**x**	**x**			**x**	
Pisum sativum	**Erbse**		**x**					
***Poaceae* sp.**	**Gräser**		**x**					
***Polygonum* sp.**	**Knötriche**							
Polygonum hydropiper	**Wasserpfeffer Knöterich**	**x**	**x**					
Polygonum persicaria	**Pfirsisch Knöterich**		**x**					
Polyporus fomentarius	**Zunderschwamm**	**x**	**o**		**x**			
Polyporus igniarius	**Feuerschwamm**	**x**	**x**		**x**			
Potamogeton compressus	**Flachstengliges Laichkraut**	**x**						
Potamogeton nodosus	**Flutendes Laichkraut**	**x**	**x**					
Potamogeton natans	**Schwimmendes Laichkraut**	**x**	**x**					
Potampgeton perfoliatus	**Durchwachsenes Laichkraut**	**x**	**x**					
***Potentilla* sp.**	**Fingerkraut**		**x**					
Potentilla norvegica	**Norwegisches Fingerkraut**							
***Prunus* sp.**	**(Steinfrucht)**							
Prunus avium	**Süsskirche**	**x**	**x**	**x**				**X**
Prunus domestica	**Pflaume**	**x**	**x**					**o**
Prunus mahaleb	**Echte Weichselkirsche**	**x**	**o**					
Prunus padus	**Traubenkirsche**	**x**	**x**					**x**
Prunus spinosa	**Schlehe / Schwarzdorn**	**x**	**x**	**x**		**x**	**x**	
Pyrus pyraster	**Birne**	**x**	**x**	**o**				
Quercus robur	**Stiel- oder Sommereiche**	**x**	**x**					

Ranunculus aquatilis	**Gemeiner Wasserhahnenfuss**	**x**	**x**					
Ranunculus flammula	**Kleiner Sumpfhahnenfuss**	**x**	**x**					
Ranunculus hederaceus	**Efeuwasserhahnenfuss**	**x**						
Ranunculus lingua	**Grosser Sumpfhahnenfuss**		**x**					
Reseda luteola	**Färberreseda**	**x**	**x**					
Rorippa islandica	**Echte Sumpfkresse**		**x**					
Rosa canina	**Hundsrose**	**x**	**x**				**x**	
***Rubus* sp.**	**Rosenart**							
Rubus frticosus	**Brombeere**	**x**	**x**	**x**		**x**	**x**	**x**
Rubus idaeus	**Himbeere**	**x**	**x**	**x**		**x**	**x**	
Rumex aquatilis	**Sauerampfer**							
Rumex obstusiofolius	**Stumpfblättrigeampfer**							
Sambucus ebulus	**Attich**	**x**	**x**					
Sambucus nigra	**Holunder**	**x**	**x**				**x**	**x**
Scheuchzeria palustris	**Blumenbinse**	**x**	**x**					
Schoenoplectus lacustris	**Sumpfbinse**	**x**	**x**					**x**
Schoenoplectus tabernaemontus	**Tabernaemontusbinse**		**o**					
Scleria lacustris								
Scutellaria galericulata	**Sumpfhelmkraut**		**x**					
Setaria italica	**Kolbenhirse**		**x**				**x**	
***Silene* sp.**	**Leimkraut**		**x**					
Silene alba	**Weisse Lichtnelke**	**x**	**x**					
Silene cretica	**Flachsnelke**	**x**	**x**				**x**	
Silene latifolia	**Nachtnelke**							
Solanum dulcamara	**Bittersüss**		**x**					
Sorbus aucuparia	**Eberesche**	**x**	**x**					

Sorbus aria	**Mehlbeere**	**x**	**x**					
Sparganium erectum	**Astiger Igelkolben**		**x**					
Spergula arvensis	**Ackerspark**							
Spergula pentandra	**Fünfmänniger Spark**	**x**						
Stellaria graminea	**Grasblättrige Sternmiere**	**x**	**x**					
Stellaria media	**Vogel Sternmiere**	**x**	**x**					
Taxus baccata	**Elbe**	**x**	**x**	**x**			**x**	**X**
Teucrium montanum	**Berggamander**							
***Tilia* sp.**	**Linde**			**o**				
Tilia cordata	**Winterlinde**	**x**	**x**					
Tilia platyphyllos	**Sommerlinde**		**x**					
Trapa natans	**Wassernuss**	**x**	**x**	**x**		**x**	**x**	**X**
***Triticum* sp.**	**Weizen**							
Triticum aest./durum/turg.	**Saatweizen**	**x**	**x**	**x**		**x**	**x**	**X**
Triticum dicoccon	**Emmer**					**x**	**x**	
Triticum spelta	**Dinkel**							
Urtica dioica	**Große Brennnessel**							
Vaccinium myrtillus	**Heidelbeere**	**x**	**x**	**x**				
***Verbascum* sp.**	**Königskerze**		**x**					
Viburnum lantana	**Wolliger Schneeball**	**x**	**x**				**x**	
***Vicia* sp.**	**Wicken**							
Vicia sativa	**Futterwicke**							

APPENDIX B

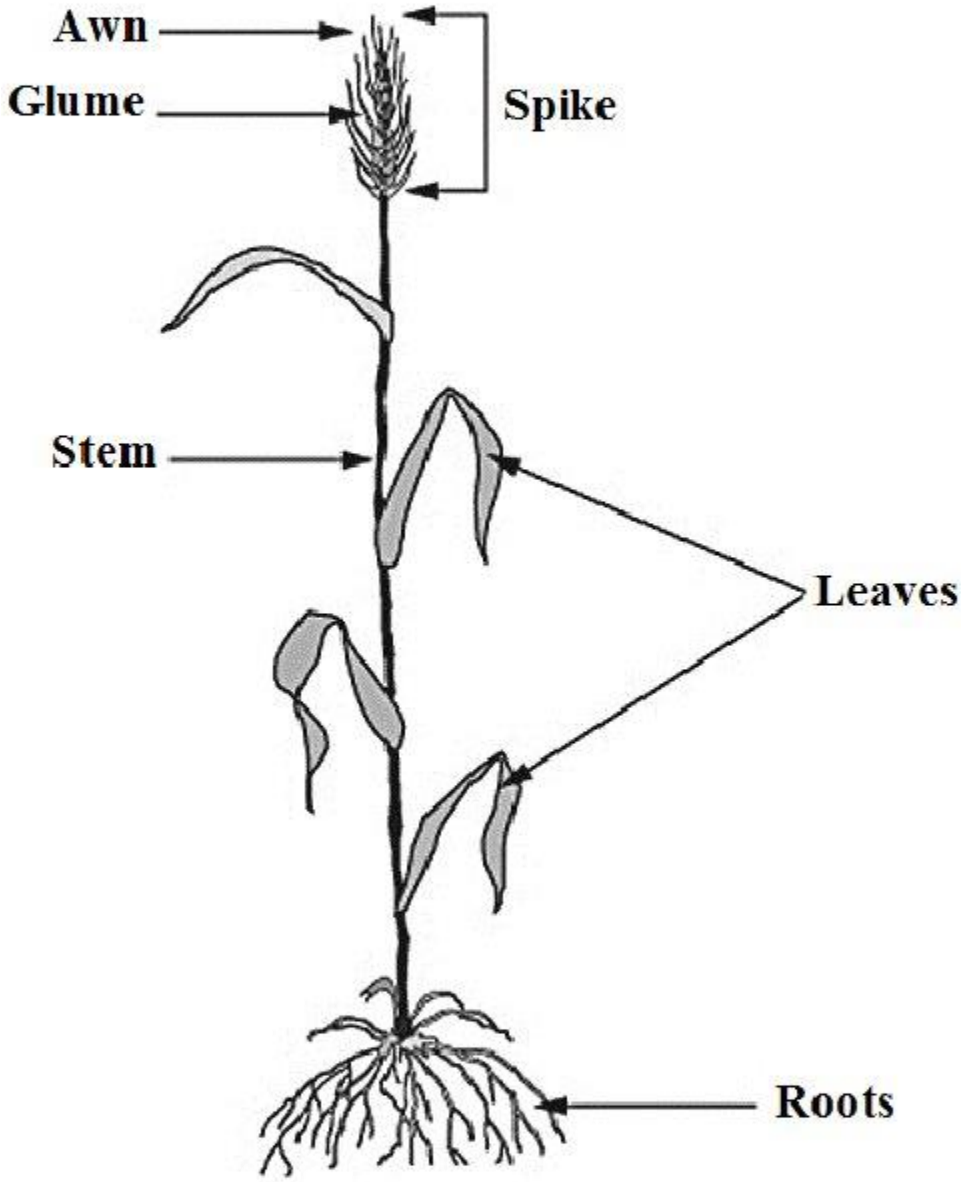


Diagram of a Wheat Plant

Khan and Mubeen 2012

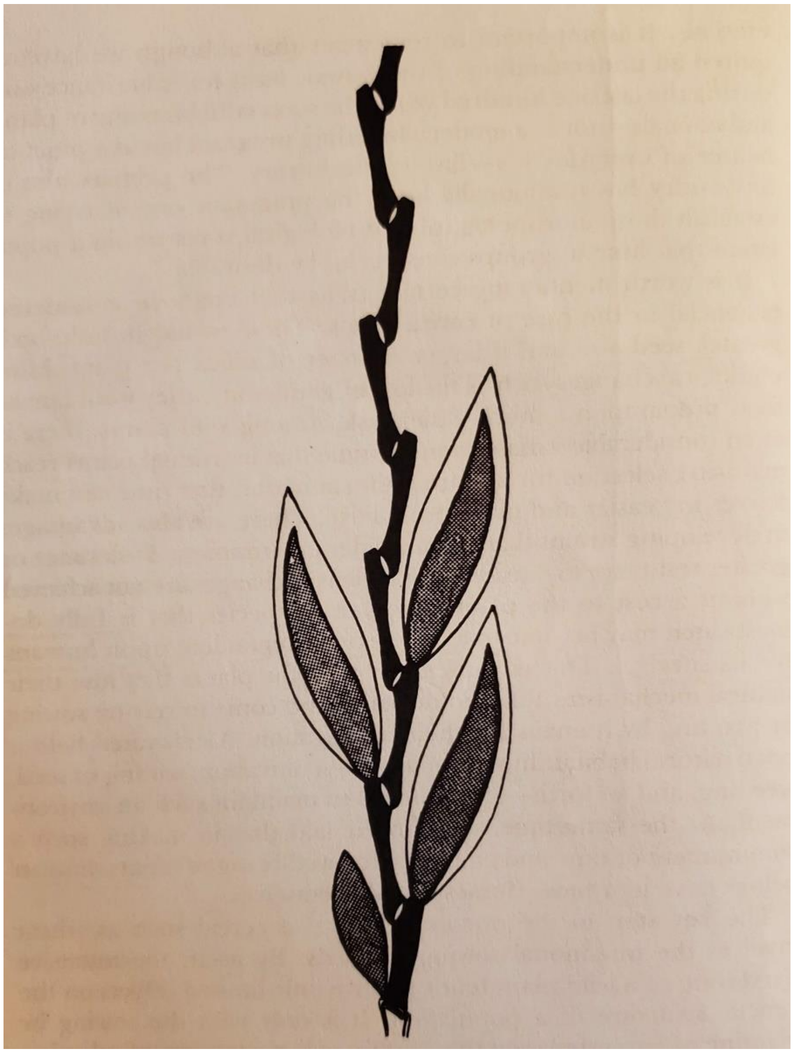
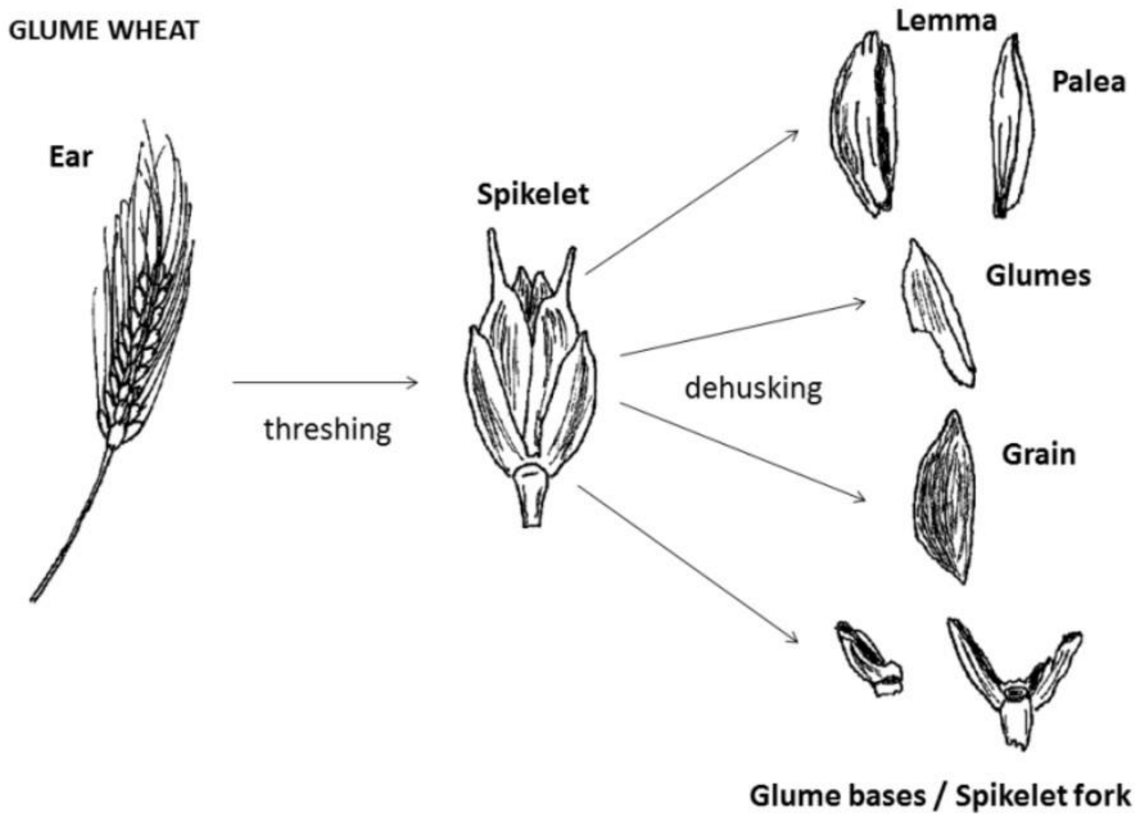


Diagram of a Cereal Spike

The central column is the rachis and the white lines are interstices which separate the rachis into segments called internodes. The rachis of a domestic cereal is solid, while that of a wild cereal is more brittle and prone to shattering in order to scatter spikelets and their seeds for propagation.

Renfrew 1973: Fig #2.2, from Helbaek 1969, Fig #138).



Dissection of a Wheat Glume

Legume Laboratory, wordpress.com

APPENDIX C: Collection Images

Cereal Product, MPM Cat. #10128

Cereal Product, MPM Cat. #10128

Cereal Product, MPM Cat. #10128

Cereal Product, MPM Cat. #10128

Hazelnuts (*Corylus Avellana*), MPM Cat. #15048

Charred Grain, MPM Cat. #10158

Hazelnuts (*Corylus Avellana*), MPM Cat. #10672B

Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

Crab Apples (*Malus sylvestris)*, MPM Cat. #10131



Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

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Crab Apples (*Malus sylvestris*), MPM Cat. #10131

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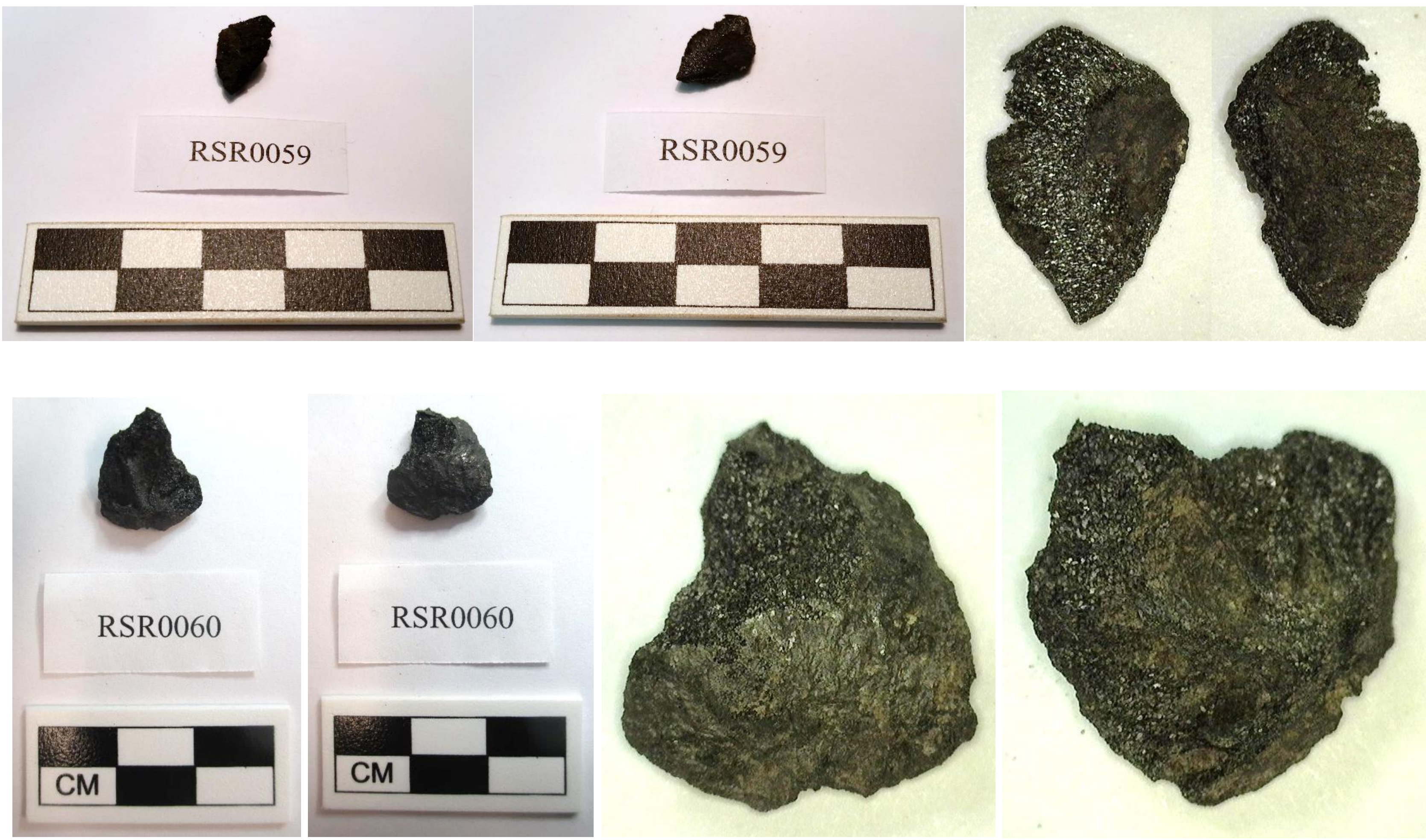
Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

Crab Apples (*Malus sylvestris*), MPM Cat. #10131



Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

Crab Apples (*Malus sylvestris)*, MPM Cat. #10131



Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

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Crab Apples (*Malus sylvestris)*, MPM Cat. #10131

Crab Apples (*Malus sylvestris)*, MPM Cat. #10129

Crab Apples (*Malus sylvestris)*, MPM Cat. #10129

Crab Apples (*Malus sylvestris)*, MPM Cat. #10129




RSR0086
CM


RSR0086
CM

Crab Apples (*Malus sylvestris)*, MPM Cat. #15047

Crab Apples (*Malus sylvestris)*, MPM Cat. #10161

Crab Apples (*Malus sylvestris)*, MPM Cat. #10161