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3. Literature review

3.1. The theoretical framework: The early research and the Pfahlbauproblem

The history of lake dwelling studies was initiated by Ferdinand Keller (1866), in the middle 19th century, with the research at the Swiss lakes and the comparative studies at the south of the Alpine region, predominantly in Italy, where he traced the descendants of the Alpine lake dwellers. The provenance of the lake dwellers was a key issue for this early research, together with the discussion on the structure and location of the lake dwellings in relation to the lakeshore. The first finds, from the lakes of Zurich and Bienne, were published at the Bulletin of the Antiquarian Society of Switzerland (Keller, 1854). This material was, as reported by Keller, attributed to a well-developed culture, most likely the Celtic, a hypothesis based on the rich Bronze Age objects. He argued that the houses were built on platforms in the water, if the water-level during the Neolithic was like the present. Few years after Keller’s publication, Troyon (1860) publishes an extensive study on the lake settlements worldwide, from the Stone Age to modern times, where he supported Keller’s hypothesis in relation to the position of the lake dwellings. These first publications became very popular and the general public was intrigued by the romantic view of their descendants (Ruoff, 2004), triggering in this way a number of lake sites discoveries around Europe (Menotti, 2004a). Keller’s hypothesis on the existence of raised platforms in the lake water was at that time beyond any criticism and this view would be only reconsidered in the 1940’s by the German archaeologist Hans Reinerth. Based on the finds of Sipplingen and Unteruhldingen on Lake Constance, Reinerth (1936), questioned Keller’s theory on the structure of the lake dwellings. He was the first to ground his argument on scientific criteria (Wallace, 1999), as the excavation was further supported by environmental and geological data (Magny, 2004). He therefore argued that the location of the houses was entirely depended on environmental factors and he described the lake dwellings as structures built on low piles raised on dry ground, subjected to periodical flooding due to frequent water level fluctuations. It was then that the Pfahlbauproblem would be initiated, a term, which describes the debate on the type and location of the lake dwellings in relation to the lakeshore.

Vogt (1955) assessed Reinerth’s hypothesis and argued for the existence of ground constructions, using as proof pieces of wood found between clay structures and lake sediments, which he interpreted as insulation. To confirm this theory, he explored the existence of pedogenetic processes occurring at the time of the first human settlements. Further evidence came from the Late Bronze Age lacustrine site of Zug-Sumpf on Lake
Zug (Switzerland), where Paret (1958) excavated houses built directly on the dry ground; he therefore claimed that Keller’s hypothesis of raised houses was only a romantic visualization of the past (Bailloud, 1958).

In the early 80’s, new evidence on the Pfahlbauproblem came from the lake Neuchâtel in France. The improved technology gave the opportunity to the Swiss academic Christian Strahm to conduct underwater research and to prove that the raised platforms did occasionally exist (Suess and Strahm, 1970). Today, the use of more rigorous excavation techniques and the presence of interdisciplinary studies have confirmed that the types of lake dwellings vary between different sites, and that all aforementioned theories (Keller’s, Reinerth’s, Vogt’s and Paret’s) could hold true in different occasions (Wallace, 1999) with the existence of houses built on the ground, houses with slightly raised floors, or houses on piles (true lake-dwellings). It is further generally accepted that in a great extent ground constructions are found in small lakes, where water level fluctuations are slight, while in bigger lakes raised dwellings were built in the littoral zones and ground level structures are found in the supra-littoral zones. In many cases, all the above types have been proved to exist simultaneously at the same site (Magny, 2004).

The different types and locations of lake dwellings and the consensus that both raised and ground structures coexist in certain sites has been therefore interpreted in the literature as an adaptation to topographic constraints (van de Noort and O’Sullivan 2006). Yet, the above patterns could mirror conscious distinctions in the organizational structuring of the settlements and in this way, reflect the choices and the selection strategies of the different social groups through time. Furthermore, anthropological research on the modern stilt villages in Cambodia (Keskinena, 2006), has demonstrated that topographic zoning in the lake settlements, which includes dry and wet regions and different dwelling types, is associated with a number of socioeconomic factors. As such, wealthier villagers, who own arable land for cultivation, occupy dry locations, while poorer fishermen occupy stilt houses built on wetter regions.

3.1.1. Man and the lacustrine setting
After having solved the “Pfahlbauproblem”, academic research, being equipped with more rigorous methodological tools, turned its focus to the study of the relationship of man with the lacustrine regime and on the impact of the lake level alterations to the adaptive strategies of the lake dwellers. This change was a result of the integration in wetland studies of environmental sciences and the application of interdisciplinary
methodologies. The question posed was to what extent the fluctuations of the water level would influence the decision making of the lake dwellers and whether this was the only factor that would determine choices of site occupation, abandonment and reoccupation. In Keller’s times it was assumed that climate and lake water level were similar to the present (Magny, 2004). In the beginning of the 20th century, however, the first palynological studies conducted in Switzerland, proved that during the Holocene the mid-European lake levels underwent multiple oscillations. During the last decades many lake level reconstructions associated with lakeside villages (Brochier, 1982, Magny and Richard, 1988, Magny, 1993, 2004, 2007, Ostendorp, 1996, 2006) have tested the prevailing assumption that the lake dwelling phenomenon was a result of favorable environmental conditions (Marzatico, 2004).

3.1.1.1. The deterministic approach
The fact that the lake dwelling sites are strongly associated with natural resources has activated the use of climatic data as an exclusive means of interpreting cultural change (van de Noort and O’ Sullivan 2006). As such, the direct correlation between water level fluctuations and human adaptive strategies reflects the theoretical framework of the ecological deterministic approach (Trigger, 2005), which interprets cultural changes as consequences of environmental trigger.

In the framework of environmental determinism, sedimentological tools have been used to prove that the lake villages were built at a time of climatic amelioration; site abandonment was attributed to conditions of climatic deterioration (van de Noort and O’ Sullivan 2006). A characteristic example of this approach is the study of Magny (1992, 1993, 2007, Magny et al., 2006) on the sedimentary sequences in the Jura lakes, Chalain and Clairvaux, where, using sedimentology and detailed chronology, he suggested that the climatic variations can be closely related to the occupation phases of the sites. In addition, he used residual atmospheric curves, as an indirect indicator of climatic change, in order to confirm that the Neolithic sites were occupied during periods of climatic amelioration (Magny, 1993).

Menotti (2009), on the other hand, has studied the influence of climate deterioration on the human selection strategies by examining individual lake sites as different case studies. Considering the climatically driven water level fluctuations (Magny, 1992, 1993, 2001, Yu and Harrison, 1995, Magny, 2004), it is argued that changes in precipitation and humidity influence lake villages, but the degree of this influence is very much dependent on the
type of the lake and the location of the lake houses. Other factors, such as tectonic activity, erosion and human activity, can cause different changes in the hydrology of a lake and have a different impact on anthropogenic practices (Gornitz, 1995). Thus, it is possible that, during the same climatic variations, one lake records lesser or weaker fluctuations than another lake situated nearby. For example, Lake Constance has seasonal fluctuations that could measure up to 3 meters, while at the same time smaller lakes can have minor changes. Menotti (2009) concludes that, while climatically driven fluctuations could be the driving force of formation or abandonment of a site, it is suggested that even during major climatic shifts only a small number of settlements were directly influenced.

This predicted relationship between climatic changes and human choices is furthermore obscured by site scale case studies. Pétrequin and Bailly (2004) argue that there were in fact periods when climatic conditions in the lacustrine environment were favorable, but the lakeshores were not settled. For instance, short-term deteriorations in the climate in the first half of the 37th and 36th centuries BC had little impact on lake shore occupation. The one that occurred in the 34th century BC, on the other hand, was more distinct, although some lakes (especially in the western part of Switzerland) continued to be occupied. A similar situation, but in a much larger scale, is found between 24th and 18th centuries BC, when, apart from very sporadic examples, the lake shores were not occupied at all. In the same framework Zhilin, (2007), based on the evidence of Mesolithic-late Neolithic sites of central Russia states that the complex economy of forest hunters, fishers and gatherers was perfectly adapted to the forest environment being flexible to survive without any substantial changes regardless of climatic perturbations. Consequently, the question of habitat on wetland sites would appear to go well beyond a direct correlation using the hypothesis of climatic conditions.

Parallel to the environmental deterministic approach stands the demographic deterministic approach, which sees the gradual demographic increase as a dominant independent variable, which can trigger cultural change (Trigger, 2005). This theory has been used by Anne-Marie and Pierre Pétrequin (1988) in order to interpret the advent of the lake dwelling phenomenon. According to this view, the lake shores were first occupied, when demographic pressure urged populations living on dry lands to migrate into marginal lacustrine settings and adapt to the given environmental circumstances, developing in this way a unique cultural system.
3.1.1.2. The evolutionary theory

As the deterministic approaches did not offer convincing answers to questions concerning the relation of man with the surrounding environmental setting, some scholars have attempted to apply models borrowed from the evolutionary approach of the anthropological paradigm to the interpretation of the advent and evolution of the lake dwelling phenomenon. One aspect of the evolutionary theory is the view of the different cultures under a linear, evolutionary prism and therefore differentiate them in terms of cultural hierarchy (Trigger, 2005).

Shennan (2000), following this approach, suggests a two-dimensional approach for the interpretation of differences in the advent, abandonment and reoccupation of lacustrine sites. He describes two types of lake settlements, the core and the epicenter ones. The first are those that are well developed and, by expanding, they create new sites both in neighboring and in distant regions. The second are those, which are receiving the migratory populations and are therefore subjected to a process of acculturation. Such cases are the lake villages in Lake Constance, regarded as core sites, where episodes of reoccupation are attributed to the same cultural group, as this is reflected in the homogeneity in the architecture and artefacts. Chalain and Clairvaux, on the other hand, are considered epicentric sites of Lake Constance, being reoccupied periodically by two different groups (in 3200BC and 3050BC respectively), both originating from the region of Lake Constance.

An alternative model of the linear evolutionary theory is the multilinear, ecological evolutionary theory of adaptation, which is greatly influenced by aspects of cultural ecology and was initiated by Steward (1955). According to this theory the environment poses some constraints to human adaptation skills, however, it does not determine the way people react to the environmental changes. These skills are very much influenced by other factors such as the historical and ideological aspects of the cultural systems. By applying different comparative studies, this theory aims to construct patterns of the way in which the different cultural systems have been evolved, implying that they follow parallel cultural routes in similar natural circumstances (Trigger, 2005). These similarities constitute the cultural core, which includes economic, political and religious aspects and are thought to demonstrate high degree of adaptability to natural perturbations.

This model has been followed by Menotti (2009) in a study on the abandonment of the lake dwelling sites. According to this theory, climatic deterioration could have both direct
and indirect impact on the occupation of a site. In this sense, some villages would be evacuated immediately, while others could have a later response, because of the economic crisis, which would be triggered by the environmental change. This phenomenon can be followed by a population displacement on dry land adjacent to formerly densely settled lake areas. Menotti (2009) confirms that there was a consistent and relatively widespread pattern of population displacement in the Alpine region, in which settlement shifted to new locations, because of critical changes in the previously favorable settings, forcing a degree of economic and cultural change, as well as an adaptation to the new social patterns. During flooding periods, the lake dwellers were forced to shift their villages inland, where they interacted with agricultural groups. They were forced to a process of acculturation, having at the same time maintained their contact with the lacustrine environ and returning to it, when the conditions were more favorable. However, Pétrequin and Bailly (2004) argue that at the time of the abandonment of Clairvaux and Chalain lake villages in France and the decline in the number of sites for the rest of Jura region and western Switzerland, there was no inland site, which could support the theory of population shifting to dry lands.

A similar approach is followed by Argobast et al. (2006), who argue that climatic changes did have indirect influence on lake villages. As the equilibrium of the lake ecosystem changed, there was a subsequent insufficiency in staple food, which led to the seeking of alternative food sources (Schibler et al., 1997, Ebersbach, 2004). These changes together with the over-exploitation of woodlands led to the exhaustion of the natural sources and might have forced the lake-dwellers to move to other areas.

The above studies question the one-dimensional theories of environmental determinism and interpret change and continuity, hiatus and occupation in wetland villages by adopting multifaceted interpretations. They are however based on explanatory theories that view patterns of expected behavior on assumed equally developed cultures and understand differences in adaptive strategies, merely as exceptions to the predictable pattern.

3.1.1.3. The anthropological paradigm and the behavioral interpretations
The emphasis on cultural regularities of the evolutionary theory gave plausible generalized explanations on extended phenomena along the lake dwelling history, but failed to see and interpret variations in the cultural, economic and ideological aspects of each cultural system, which would result to different adaptive strategies. These
differentiations become visible, as more detailed case studies are published and as experimental models based on anthropological research are applied on the interpretation of the archaeological record. In this framework, Pétrequin (1984) in his book *Gens de l'eau, gens de la terre* describes different cases of lake dwelling sites, which follow individual life cycles and occupation phases and reflect wide-ranging levels of adaptation to environmental constraints.

It is therefore argued that different communities can exhibit diverse responses to the same perturbation and develop different strategies of accommodation to potential triggers (Minnegal and Dwyer, 2007). This statement has been the result of a recent anthropological study in Melanesia, where two social groups (Kubo and Budamuni) were studied in terms of their response to periods of drought. The groups, while occupying similar environments and technological capacities, felt the results of drought in varied intensities and these variations are attributed to the interaction of people with the local geographic circumstances (altitude, topography, drainage) and the ways in which they had accommodated modes of subsistence to those circumstances. These differences per se were again influenced by choices that people had made within the context of existing constraints.

Van de Noort and O’Sullivan (2006) suggest that social and political reasons could be the forcing mechanisms of abrupt changes in the lifespan of a site, such as abandonment. By using Brück’s (1999) theoretical approach in the life cycles of houses, they describe communities as entities, whose history is closely related to biography of the inhabitants. In doing so, they argue that the wetland houses could have been abandoned for several reasons, which are difficult to trace archaeologically through regional, landscape targeted approaches. Death, malady or the presence of bad spiritual forces could lead to the abandonment of a site or dwelling, as this has been proved through ethnographic observations. Therefore, the authors claim that the understanding of the abandonment of wetland sites should not been viewed differently from that of dry land site abandonment, giving the example of the intentional destruction, burning and abandonment of houses of the Neolithic villages of South Eastern Europe (Chapman, 1999, Stevanovic, 2002, Tringham, 1990). In this sense, abandonment is seen as an end of a continuum (David and Kramer 2001) and as such it comprises of a number of processes that function in different scales.

The same approach is followed by Schlanger and Wilshunser (1993) in their research in
Mesa Verde Anasazi. In this study, it is suggested that the analytical scale of investigation is very important in understanding the processes of occupation, destruction and abandonment of a site and that synthesized landscape reconstructions of population growth and decline can result in ambiguous correlations of climatic deterioration to site changes. Accordingly, they propose a high-resolution chronology of construction and abandonment of individual structures, through which they identified several episodes of the occupational history of the site. This finest-scale analysis - the analysis of individual structures - appears to contradict the climatic deterioration / abandonment theory. They therefore conclude that the villages studied were not abandoned as clusters in abrupt events, but rather individually and gradually throughout one occupation period. It has also been possible to show that, while some houses have been abandoned, others were constructed, so that occupation zones within a village shifted, tacked and changed across time.

3.2. Methodological framework
3.2.1. The lake dwellings sites
3.2.1.1. Activity areas and the use of space
The identification of activity areas and the interpretation of the use of space has been a matter of primary concern in the studies of lacustrine villages. The reconstruction of pile posts position has been a standard method to study the plan and structural organization of the site. Piles have been among the few features that have remained intact and frequently in situ. This method gives the opportunity to trace the evolution of the occupational history of the site regarding the structure, plan, orientation and use of raw material (Schfferdecker et al., 1974). The piles are studied in terms of size, preservation, erosion, and shape and in this way, several inferences are made in relation to the type of the structure (superimposed – terrestrial), by combining data from several features, the evolution of the spatial organization through time is examined (Hourmouziadi and Giagoulis, 2002). This method, while essential as a first step towards understanding the organizational structure of lacustrine sites, provides only a static, descriptive presentation of the architectural features, without including any information on the natural and human processes and activities that influenced the creation of the occupational history of the lake villages.

Another type of analysis, which has been developed in the basis of spatial studies, is the artifact distribution method. This technique represents the trend for objective, positivist interpretations as stated in the theoretical framework of the processual archaeological
theory (Trigger, 2005). In the lake dwelling studies, this method has been applied by Tardieu (2002) at the site of Charavines, who has employed spatial analysis, constrained clustering and other statistical methods (factorial analysis of classification, automatic classification), in order to isolate activity areas across site space. This study aims at reconstructing the socioeconomic history of the site and has identified changes in the use of space between occupational phases. Furthermore, the limits of occupational and free spaces between structures have been distinguished and spatial classifications, as interior/exterior, artist activity areas/domestic spaces etc., have been made. This method, while effective in the first classification of artifact clustering, fails to integrate the analysis of the depositional processes, under which the artifact distributions have been formed and in the case of wetland sites this lacuna can lead to serious misinterpretations in terms of activity areas recognition.

By applying a complementary method of analysis emphasizing again the distribution of activities and use of space in a horizontal stratigraphy, Brochier (1982) has used the distribution of sedimentological units and artifact distribution analysis, as a means of identifying activity areas.

A higher resolution method of analysis, which has been used to trace human activities within activity areas, is soil micromorphology. Soil micromorphology concerns the description, interpretation and to an increasing extent, the measurement of components, features and fabrics in soils, at a scale which cannot readily be seen with the naked eye (Bullock et al., 1985: 9). Wallace (1999, 2000, 2003) has used soil micromorphology for the identification of activity areas in wetland sites, in the northern rim of the European Alps: Hornstaad (Lake Constance, Germany), Risch-Oberrisch (Lake Zug, Switzerland) and Station 19 (Lac de Chalain, France), in order to “detail human use of the landscape through the distinction of archaeological features”. The main purpose of the study is the recognition of human activities through the analysis of materials used to construct floors, walls and hearths. Some of the activities considered: trampling on floors, packing of daub or firing of hearth material. Moreover, a theoretical framework was developed, in which data that would otherwise be difficult to interpret could be examined. Much of the data was described as resulting from passive accumulation. This can be contrasted with active accumulation, when features were intentionally constructed, leaving a primary surface which today can be identified. Furthermore, Wallace approaches the question of pile dwelling location using different lines of evidence, on the premise that settlements could
not have been built at ground level, if there was a substantial amount of wave activity or water movement during occupation.

3.2.1.2. The site formation processes
In fluctuating lake margins, natural processes can extensively modify archaeological contexts (Wallace 1999, Karkanas et al., 2011), therefore the question regarding the fragmentary archaeological record is significant, since even one large storm could potentially remove an entire occupational horizon (Wallace, 1999). The question therefore is related to the extent that the archaeological record has been modified or removed. For this reason, several studies have explored the lacustrine formation processes by applying diverse methodological tools.

Morton (2004) discusses depositional lacustrine environments of Paleolithic sites through multiple empirical, theoretical, and experimental aspects. While in a different cultural context as the studies described thus far, this analysis is considered representative, as it constitutes a unique case of experimental work on the depositional and post depositional processes of lacustrine archaeological artefacts. Morton examines lithic assemblage scatters and associated material, such as vertebrate fauna in a lacustrine depositional context, for “establishing not only the contextual integrity of the information, but also making accurate inferences regarding early human behavior and ecological adaptive strategies”. An important contribution of this study is the application of an array of diverse experimental methods (wave tank experiments in energy fluctuations, lacustrine regressions and transgressions, artefact dispersal, transport, clustering, orientation, scatter and sedimentation experiments) that can be utilized to replicate lacustrine site-formation processes. Such integrative and multi-perspective methods are an indispensable approach for arriving at accurate inferences regarding lake-margin contexts.

Another method of analysis related to site formation processes is the integration of geomorphological and environmental tools applied by Crook (2007) for the pile dwellings of hunter gatherers, in the Savannah River region. In this paper, ecological and sedimentology data, oyster shells, gastropods analysis and archaeological information are combined, in order to interpret the complexity of the organizational structure of the site within a dynamic lacustrine setting. This study explores the dynamic cultural context through the recovery and analysis of archaeological and paleo-ecological data and investigates the adaptive strategies and the human induced shaping of the landscape in a geomorphological context. A similar approach has been applied by Gosden and Webb
(1994) in New Guinea. The authors integrate archaeological and geomorphological
analysis, to explore the effect of the anthropogenic and natural processes on the
formation of the landscape. The results are reinforced with ethnographic data from the
modern stilt houses of the neighboring New Guinea villages.

Moreover, Pétrequin (1989) at the site III Clairvaux-les-Lacs offers a detailed description
of natural and anthropogenic deposits and applies sedimentological and chemical
analyses in a thorough spatial and temporal extent. The complex sedimentation processes
of the multiple facies are revealed, which can be found within a single occupation layer;
at the same time the effects of human activity on sedimentation processes are identified.
The above studies bring to light the significance of interdisciplinary stratigraphic analysis
in understanding the interaction of natural and anthropogenic processes within lacustrine
environments.

In a finer scale, the microscopic examination of complex lacustrine stratigraphic data
aims to distinguish the subtle sedimentary changes, differentiate fine post-depositional
processes and most prominently observe the relationships and arrangements of the
cultural materials in their natural context (Mallol, 2006). Soil micromorphology analysis
of formation processes have been sporadically applied in wetlands i.e. the Lower
Paleolithic site of Ubeidiya, in Israel (Mallol 2006), the Bronze age settlement in
Lithuania, (Ismail-Meyer, 2014), the Neolithic lake dwelling sites in Switzerland (Ismail-
Meyer et al., 2013), and the lake dwelling site of Dispilio, in Greece (Karkanas et al.,
2011), in order to explore several aspects of the depositional context of the
archaeological assemblages within lacustrine and marshy contexts and determine the
extent to which natural processes have distorted the anthropogenic signal. Moreover, by
revealing the internal relation of grains, their micro-laminations and alterations, soil
micromorphology constitutes a supplement to classical sedimentary analysis, as it helps
qualifying the quantitative results of granulometry and thermogravimetric analysis, giving
a further insight into particle size distribution, sorting and skewness (Farrand, 2001).
These studies aim to reconstruct the fine-scale syndepositional - postdepositional
environments of the archaeologically rich layers and identify diverse microfacies, which
include lacustrine, marshy, terrestrial, anthropogenic and mixed deposits. In this way, it is
proven that soil micromorphology constitutes a valuable tool not only for establishing
the depositional origin of the archaeological remains, but also for assessing their degree
of post-depositional disturbance, as well as for gaining information of the natural context.
of the anthropogenic sediments.

3.2.2. The lake level reconstructions

The lake level reconstructions constitute a significant part of the lakeside sites studies, as they contribute to the understanding of site formation processes and simultaneously attribute to the discussion on human adaptations and selection strategies. Several methodological tools have been used for this purpose.

Water level fluctuations may occur on different time scales ranging from short-term (e.g. wind-driven oscillations) to annual, inter-annual and inter-decadal (Coops et al., 2003); several factors including morphometry and catchment characteristics, climate and water management can affect the extent and duration of water oscillations. Water level fluctuations in closed basins are mostly a function of the balance between precipitation and evaporation. In addition, water level fluctuations can be controlled by changes in subsurface inflows and outflows, particularly in karst areas. Wet/dry climatic alternations may also be recorded in the sediments of closed-basin lakes by varying amounts of evaporitic salts and carbonate concretions, deposited as the lake volume expands and contracts. In this framework, many approaches have been applied, in order to infer an accurate record of past changes of lakes hydrology.

3.2.2.1. Vegetation reconstruction

Botanists use water depth as a determinant factor of lake vegetation and therefore the rapid changes in species composition related to water depth are thought to produce distinct zones characterized by one or more plant species zonation patterns (Keddy, 1983, Keddy and Reznicek, 1986); changes in vegetation patterns have been interpreted as the result of water level fluctuations (Gopal, 1986, Keddy and Reznicek, 1986, Bohncke and Wijmstra, 1988, Roberts and Wright, 1993, Magny, 2004,).

However, the high variability and instability of the hydrological component of the lacustrine environments results in a vegetation community, which is highly susceptible to other interference. Thus, factors such as soil erosion and sedimentation, topography, substrate type, wave action, latitude, water quality, fire, water currents, exposure, and length of time since the last high or low water phase (Keddy and Reznicek, 1986), which directly or indirectly influence the water regime changes, result in rapid alteration of the vegetation patterns structure (Gopal, 1986). Moreover, the role of wave energy in controlling the distributions of aquatic macrophytes has often been qualitatively discussed. Waves may have direct effects on vegetation through removing biomass;
individual flooding events are also important in segregating the plant communities (Casanova and Brock, 2000). The biological effects in lakes are greatest in shallow water and littoral areas, where even small changes in water levels can result in the conversion of large areas of a standing-water environment in air exposed habitats (Wantzen et al., 2008).

The study of carbonate concretion morphotypes, based on modern analogues, can give accurate indications of past lake level fluctuations (Magny, 2004). Other markers can also be used to reconstruct past variations in water levels, for instance microfossils (diatoms, chrysophyte cyst, benthic cladocera, planktonic cladocera and chironomid) (Lotter et al., 1997) and foraminifera (Asioli et al., 1996).

3.2.2.2. Seismic profiles
Another method of analysis of lake level fluctuations is that of seismic profiles (Johnson et al., 1987, Seltzer et al., 1998, Abbott et al., 2000, Anselmetti et al., 2006,). Geophysical reflection seismic surveys provide quantitative data on sediment geometry, type, and stratigraphy, as well as depositional processes (Scholz and Rosendahl, 1988). In closed basins that lack surface outflows, seismic stratigraphic analysis can be used to reconstruct past lake level fluctuations (Abbott et al., 2000), however there are two factors that affect the interpretation of acoustic records from shallow lakes. First, acoustic signals may be obscured by exsolved gas from decomposition of in situ organic matter. A second problem occurs, when sediment thickness exceeds the water depth, and ringing of the sonic signal, within the water column masks the seismic stratigraphy by overprinting multiples. Despite these complications, the acoustic stratigraphy is often remarkably correlative with the physical and geochemical stratigraphy obtained from the sediment cores, due to the high impedance contrasts between different sediment facies encountered in lacustrine basins. Mapping unconformities is particularly important, because it documents periods of non-deposition and/or erosion and can be used to reconstruct lake level changes. Thinning or thickening of seismic units, document lateral changes in sedimentation rate. Furthermore, depending on the study objectives, seismic stratigraphies can be used to help choose the best coring sites to yield cores with high temporal resolution (high sedimentation rate, continuous sedimentation), long time sequences (low sedimentation rate, continuous sedimentation), or evidence of specific environmental changes (lake level fluctuations, or unconformities). Geomorphological and seismic signals of past lake level changes are difficult to date and to correlate to basin sediment facies, therefore the seismic profile data are always combined to detailed sedimentary and chronostratigraphic studies.
3.2.2.3. Sedimentology

Sedimentologists use mainly lithology, (Hyne, 1978, Digerfeldt, 1986, Dearing, 1997, Campbell, 1998, Dean 1999, Chen et al., 2004,) and organic/calcium carbonate content analysis (Hyne, 1978, Kristensen, 1990, Platt and Wright, 1991, Dean, 1999, Heiri et al., 2001, Schnurrenberger et al., 2003) as markers, whose changes indicate water level fluctuations. Grain size analysis of minerogenic lake sediments has been used as an indicator of water depth; coarse grains are typically found proximal to the shoreline (Digerfeldt, 1986); smaller sediment grain size implies higher lake levels (Chen et al., 2004).

However, it is suggested that in open lakes, where the level is controlled by the outlet sill, lake level and area fluctuations are often minimal compared to the fluctuations in closed lakes (Campbell et al., 1994) and in these cases the water level is not the main factor affecting the grain size (Chen et al., 2004). Changes in the coarseness of sediments in open lakes may be controlled by factors other than the relatively unvarying proximity to shoreline (Dearing and Foster, 1993, Dearing, 1997). These factors include wave influences (minimal in deep lakes) and slumping or turbidity currents that transport coarser shallow-water sediments into deeper water (Campbell, 1998). In these cases, the coarse sediment supply increases with inflow and fine-grained sediments are removed from the water column by outflow, with increasingly fine sediments being retained and deposited as stream flow declines.

The above proxies are often combined to isotopic data, which give indications on the aridity and moisture of the lacustrine setting. Reconstruction of past moisture conditions is based on stratigraphic measurement of the oxygen isotope signal in the sedimented carbonate shells of aquatic invertebrates (Talbot, 1990, Wolfe et al., 2001). By the 1990s, advances in stable isotope mass spectrometry had facilitated the use of small sample sizes and permitted rapid analysis, making this technique ideal for generating high-resolution reconstructions of past changes in moisture availability. However, the isotopic data are indicative of lake level fluctuations only in the case of closed lakes, when the lake level is controlled mainly of precipitation evaporation processes.

Organic matter is another proxy used for lake level reconstructions, being however amongst the most unstable common sedimentary materials (Talbot and Livingstone, 1989). Organic materials represent the residue remaining after the degradation and alteration of aquatic and watershed biota and reflect the transport of sediment, the burial
history and the redox conditions at the site of deposition. Local environments control the relative proportions of contributing biota and hence influence the production and preservation of organic matter. Changes in paleolimnological and paleoclimatic conditions are thereby recorded in the overall character of organic matter in sediments deposited at different times (Meyers, 1990). Organic matter can be measured by geochemical analysis of bulk sediment. High TOC content suggests preservation of unstable organic matter in an oxygen-poor environment. Exposure of these sediments to oxidizing conditions, therefore implies a significant fall in lake level (Bengtsson and Enell, 1986).

As with the organic content the percentages of calcium carbonate are higher in low water levels and become lower in deeper locations (Digerfeldt et al., 1992). Based upon the correlation between concentrations of carbonate and of organic carbon, the variations in the down core concentrations may result from changes in lake water level (Meyers and Benson, 1988). Concerning the relation between lithology and organic carbon and calcium carbonate, coarse sediments commonly have lower concentrations of organic carbon than do fine-sized lake deposits (Meyers, 1990). Because deeper parts of the lake bottom experience less water turbulence, their sediments will be finer in size and more likely to contain lake-derived biogenic carbonates. The concentrations of organic carbon (OC) and CaCO₃ in lake sediments are however often inversely related. This relation occurs in surface sediments from different locations in the same lake and with depth in Holocene sediments. CaCO₃ may further dilute the concentration of organic matter somewhat and produce calcareous sediments. Sediments in the littoral and sub-littoral areas of hard-water lakes usually contain less organic matter and such more CaCO₃ than profundal sediments. The accumulation rates of organic matter and CaCO₃ in lake sediments are delicately balanced between the rates that they are produced in the epilimnion and the rates that organic matter is decomposed and CaCO₃ is dissolved in the hypolimnion (Dean, 1999). Although increased organic productivity due to eutrophication may increase the pH of the lake water and cause greater precipitation of CaCO₃, the decomposition of the produced organic matter in the hypolimnion causes much greater dissolution of precipitated CaCO₃.

3.2.3. Conclusions
This chapter constitutes an overview of the theoretical framework of wetland archaeology from the advent of the discipline at the mid-19th century to nowadays. The
approaches reviewed range from traditional descriptive studies on the position of the lake dwellings, to environmentally and demographically deterministic theoretical concepts; an array of studies use theories borrowed from the evolutionary anthropological paradigm. Empirical approaches following analogies of the ethno-archaeological paradigm are applied in certain case studies; the anthropological theories and behavioral approaches are also here considered.

There seems to be a lacuna on the theoretical evolution of the lake dwelling studies as an independent discipline compared to the broad theoretical archaeological discussion. Thus, there is a prevalence of descriptive approaches on the lake villages’ studies; the interpretations followed and the research questions posed are generally within the functionalistic premise, failing to set the archaeological data in a cultural, chronological and geographical contextual framework. Furthermore, there is little attempt to explore how people interacted with the dynamic microenvironments through time and how the continuities and changes in the occupationally history of the sites could reflect environmental, cultural and social aspects.

These changes, activities and practices are difficult to trace archaeologically through regional, landscape targeted approaches. As already mentioned the differing natural processes create diverse depositional conditions (Lillie et al., 2007); at the same time, human intervention is versatile, as the anthropogenic material and the interaction to the natural environment, in which it is included, can result in the formation of discrete microenvironments. As such, only site-scale detailed and interdisciplinary approaches will contribute to the configuration of these human induced micro-environments.

This type of approach demands a combination of methodological tools of diverse resolutions, which will provide accurate information on each level of analysis. Therefore, the contribution of sedimentological studies is vital for understanding the broad environmental processes and to elucidate the ecological choices of the pile dwellers in relation to the lacustrine habitats and the land potentials.

These lake level reconstructions contribute to the assessment of the impact of water energy and water level on the formation and preservation of the archaeological record. On the other hand, a high resolution methodological tool, as soil micromorphology would shed new light on the understanding of the intricate site formation processes prevailing in lake sites including the profound depositional and post depositional
processes. This type of analysis reveals aspects of the cultural and social history of the site by tracing the human activities, the episodes and the discontinuities in the life cycle of the settlement with exceptional resolution. The study of these episodes, not only sheds new light on the events per se, but also offers fascinating examples of human strategies, which are vital for the better understanding of the evolution of prehistoric societies.