Mobility as resilience capacity in northern Alpine Neolithic settlement communities

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1. Introduction

Resilience has recently become an insightful conceptual framework that helps scholars explore how communities respond to external shocks, such as environmental changes. In prehistoric archaeology, this notion has primarily been investigated using the Resilience Theory (RT) and the Adaptive Cycle model (AC), developed by Gunderson and Holling, which are applied to adaptive systems in order to understand the source and role of change (2002; see e.g. Bradtmöller et al. 2017; Redman 2005; Redman and Kinzig 2003). However, such systems-theoretical approaches, which derive from ecology and psychology, bear the danger of leading to a top-down application of deductive models when appropriated to the fragmented archaeological sources. In other words, the risk is to assume the RT and AC model first and then to fit archaeological data within those assumptions.

In this paper, we propose an alternative, inductive bottom-up approach in which we define resilience as a set of adaptive capacities grounded in social practices that enabled communities to cope with and respond to challenges. Our definition is based on the one proposed by Norris and colleagues (2008) but appropriated for practice theoretical social archaeological approaches as explained in chapter 3. We use the Neolithic wetland sites from the Three-Lakes Region in the northern Alpine foreland of western Switzerland as a case study. These sites provide an abundance of archaeological and palaeoecological information, which can be used to examine the resilience of settlement communities to climate fluctuations. We will evaluate whether a causal relationship might have existed between climate changes in the period between 3600 and 3200 BCE and an observable decline of settlement activities on the shores of the large lakes (Heitz et al. in press; Laabs 2019). In addition to year-accurate reconstructions of settlement histories, we will apply statistical significance tests on archaeological and palaeoclimatic time series to question the correlation and causality between settlement activities and climate fluctuations. Besides the settlement frequency curve (Laabs 2019), we will use the radioactive beryllium-10 isotope (Be10) content in the GISP2 ice core from the Greenland Ice Sheet (Nussbaumer et al. 2011; Steinhilber et al. 2009) and the ∂18O values of well-dated speleothems (Atsawawaranunt et al. 2018) as proxies for temperature and precipitation, respectively. The inferred hypothesis, i.e. that periodically rising lake levels led to the flooding of former inhabitable spaces on the lakes' shore zones and forced communities to relocate their settlements to the hinterland, will further be tested. Therefore, we apply multivariate statistics to pollen data to evaluate human influence on vegetation (land clearing) taken as settlement activity beyond the shores of large lakes. In addition, we examine the relevance of transformations in pottery styles as further indicators for spatial mobility.

2. Challenges of Resilience Theory and Adaptive Cycle models in archaeology

System-theoretical models of resilience originally conceptualised in ecological research, such as Gunderson and Holling's resilience theory (RT) on social-ecological systems (SES) (Gunderson and Holling 2002; Holling and Gunderson 2002), have been extensively used within archaeology (Bradtmöller et al. 2017; Redman 2005; Redman and Kinzig 2003). In RT, resilience is defined as "the capacity of a social-ecological system to absorb or withstand perturbations and other stressors such that the system remains within the same regime, essentially maintaining its structure and functions" (Resilience Alliance 2020). As an operational tool, the AC model presumes that systems pass through different predefined phases (e.g. Carpenter and Gunderson 2001): the r-phase of exploitation (or growth phase); the K-phase of conservation, in which a destabilising event (or tipping point) may occur; the Ω-phase of release, where the system might also collapse and the α-phase of reorganisation, if the SES has not collapsed. 'Connectedness', the degrees of flexibility of connections in the system, and 'potential', the number and kinds of future options available (actual or potential resources) are the model's driving parameters.

There are several challenges when applying RT and AC to prehistoric archaeology. The definition of resilience as cited above is noted by Olsson et al. 2015 as contributing to the ambiguity of the term (see also Heitz et al. in press). Beyond that, one major issue concerns the identification of suitable archaeological indicators or proxies matching the model's driving parameters 'connectedness' and 'potential' beyond random arbitrariness. Furthermore, the predefined phases of AC models and their deductive identification in prehistoric contexts lead to a predetermined and limited view of the possible dynamics and rhythms of social transformation in the past, as only cyclical rhythms and patterns of change are assumed and examined, neglecting linear processes, for example. For this reason, we consider this uncritical application of RT and AC models to prehistoric archaeology to be problematic because its application leads to the fitting of past societal transformations to the model or to the model's distortion beyond recognition. In summary, transferring RT and AC to prehistoric contexts bears the danger of stepping 1) into the trap of a strong environmental determinism (Arponen et al. 2019; Olsson et al. 2015) and 2) in a one-sided, deductive, top-down application and projection of predefined theoretical models onto the past. This criticism, however, does not reject resilience as a valuable field of research in its totality but targets the systems-theoretical approach of RT and the methodological challenges of the AC.

3. Resilience and spatial mobility

Following psychological research, we will use the concept of 'community resilience' developed by Norris and colleagues (2008: 130), which is understood as "a process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance". Resilience is thereby conceptualised as an ability or capability of a social entity—the community—and thus rather a process than an outcome. In their framework, resilience emerges from a set of adaptive capacities (economic, social, cultural, communicative, and competence resources) to cope with collectively experienced disasters. Their rather narrow definition of disasters as events with acute onsets (Norris et al. 2008, 128) would limit archaeological research drastically. For reasons of traceability and precise dating, we propose also to include challenges that unfold during longer temporal processes. Furthermore, we find their conceptual distinction between 'resistance', 'resilience' and 'vulnerability' helpful as an interpretative framework (Norris et al. 2008: 130, fig.1): 'Resistance' occurs "when resources are sufficiently robust, robust, redundant, or rapid to buffer or counteract the immediate effects of the stressor such that no dysfunction occurs"; in contrast, 'resilience' occurs when a return to functioning happens that is "adapted to the altered environment"; finally, 'vulnerability' occurs when "resources were not sufficiently robust, redundant, or rapid to create resistance or resilience, resulting in persistent dysfunction". Hence, resistance and resilience are successful processes of coping with challenges, while vulnerabilities emphasise unsuccessful processes of coping.

The more detailed, conceptualizations of resilience provided by Norris and colleagues, which target the experience of the community when faced with such disasters or challenging events, are difficult to be directly transferred into prehistoric archaeology beyond hypothesising, because we do not have access to past actors' experiences. Instead, we want to emphasise that it is important to contextualise resilience by making explicit who is resilient to what, and what is to be researched in specific case studies (cf. Leach 2008; Cutter 2016). Therefore, we examine the resilience (adaptive coping capacities) of lakeshore settlement communities when facing periodic, climate-driven lake level changes beyond the usual seasonal fluctuations that threatened their settlements and ultimately submerged their potential settlement spaces. Their practice of frequently relocating their settlements equipped them with an adaptive coping capacity and allowed them to secure the continuation of their livelihood. Accordingly, the resilience of the settlements' communities is evaluated by examining the materiality of their settlements.

The materiality of the spatial mobility of settlement communities is taken as one possible resilience capacity and will serve as an epistemological entry point to the research on how past communities coped with challenges. The concepts of mobility used here are based on our previous theoretical considerations (Heitz 2017, 2018). We define 'spatial mobility' as the overcoming of geographical distances while changing between different units of a context (Burmeister 2013; Frello 2008: 26, 28; Salazar 2016: 1–2; Schiller and Salazar 2013: 185, 187). Understood in a gradual sense as two idealised extremes on a continuum of potential mobility, 'spatial immobility' is the counterpart of 'spatial mobility'—just like 'stasis' is the counterpart of 'movement'. When drawing on the materiality of settlements i.e. remains of houses, jetties and palisades, as is done in this paper, spatial mobility can be accessed by examining the spatiality and temporality of the settlement construction histories as well as the settlement relocations over time.

4. Climate-induced changes in Neolithic lakeshore settlement practices in the Alpine Space around 3400 BCE

The northern Alpine foreland is characterized by a high density of exceptionally preserved wetland settlements on lakeshores and in bogs, inhabited by early farming communities from the 4th millennium BCE onwards (Hafner 2013; Menotti 2013). In the waterlogged archaeological layers, house timbers, bridges, palisades, and fences are preserved, offering temporally high-resolution data. There is evidence that houses had elevated floors which were supported by piles and which might have been raised over wet or watery lakeshore zones. In some optimal cases, we are able to decipher lifetime histories of the settlements' construction and duration on a yearly basis by means of dendrochronological dating (Billamboz 2013; Bleicher 2015: 278–279; Kibblewhite et al. 2015: 250–251). In addition, there are so-called dryland sites—remains of settling activities and scatter finds—in the hinterland, which are much less well preserved and researched. In the following, they are considered as a whole for the entire Late Neolithic, since they cannot be assigned to shorter periods due to the lack of dendrochronological dating.

The subsistence of lakeshore settlement communities was based on farming and animal husbandry, but included a considerable share of horticulture and foraging (Bogaard et al. 2013; Ebersbach 2003; Jacomet 2006, 2007; Jacomet et al. 2016; Schibler 2008). Diversification, intensification, stockpiling and bartering have been suggested as their economic risk minimisation strategies (Jacomet and Schibler 2010). Hence, these communities lived a rather flexible economic lifestyle, as is also reflected in their frequent spatial mobility in terms of settlement relocations on the lakeshores. The settlements had lifespans of only a few years to decades, with houses showing evidence of annual repairs and settlements growing and shrinking in size over time (Ebersbach 2010; Hofmann 2013; Hafner 2019). The spatio-temporal investigations, i.e. dendroarchaeological analyses of the felling dates and the location of the piles within the settlement ground plans, show that the settlement practice was based on an elaborated settlement system with quasi-periodic repopulation of former settlement sites. (Billamboz et al. 2014; Bolliger 2018; Laabs 2019; Suter and Francuz 2010). Settlements were abandoned every few years and newly built just further up or down on the lakeshores. Also, the stylistic plurality of pottery found in some of these settlements indicates not only that frequent residential mobility was a characteristic of these generally sedentary agrarian communities, but also their translocality and cultural plurality (cf. Heitz 2018; Heitz and Stapfer 2016).

4.1. Failed settlement attempts around 3400 BCE?

The foundation and successive growth of the settlements, which indicate a gradual influx of inhabitants, can be traced to the year in the case of two completely excavated settlements in western Switzerland around 3400 BCE (Crivelli et al. 2012; Hafner and Suter 2000; Stapfer 2019; Suter 2017): Murten, Pantschau at Lake Morat (range of dendrochronological data 3428-3415 BCE) and Sutz-Lattrigen, Riedstation at Lake Bienne (range of dendrochronological data 3393-3388 BCE) (fig. 1). Both share very similar settlement layouts and construction histories, which provide information on typical settlement construction practices at that time. In the first (founding) year only two or three houses were built. This pioneering phase was followed by a construction boom in the subsequent years, in which the settlements grew within presumably previously defined layouts. The growth indicates that members of the settlement communities moved to the new location successively, following the first group of pioneers. Once the settlements had reached their full size, repairs of the existing houses—and a few buildings constructed later—mark their occupation phase until abandonment (Ebersbach et al. 2017; Hafner 2019; Hofmann 2013; Laabs 2019).

Although both settlements were fully established, only the Pantschau site seems to have gone through the usual lifespan of a settlement, namely from foundation to several years of utilization and final abandonment (fig. 2). At the site of Riedstation, no signs of a longer occupation could be attested; felling dates of timber revealed the lack of repair activities. The extremely short duration of this settlement is a strong indication that the inhabitants had to leave it unexpectedly (Hafner 1992: 47–54). Besides this early-abandoned settlement there are two cases of discontinued settlement attempts at the nearby sites of Sutz-Lattrigen, Hauptstation-Innen (3412 BCE) and Sutz-Lattrigen, Neue Station (3390-3389 BCE), where only two houses were constructed and the settlement places abandoned thereafter. Not two isolated, but one isolated house, was excavated at the site of Cham Eslen (Lake Zug) and interpreted as being of a special economic function based on micromorphological, archaeozoological and botanical data (Gross and Huber 2018). For Sutz-Lattrigen, Hauptstation-Innen and Neue Station, however, there is no evidence that would support a special economic function or seasonal use there. We would rather propose the interpretation, the two houses at the latter sites are indications of failed settlement attempts: these dwellings did not make it past the pioneering test phase of a settlement's viability at its new location and thus are interpreted as failed settlement attempts. Interestingly, this coincides with a general decline in settlement activities and a sharp climate deterioration around 3400 BCE (Hafner et al. 2016: 118).

4.2. Climate-induced challenges and lakeshore settlement decline around 3400 BCE

For communities settling on the shores of large lakes, climatic fluctuations might have been challenging. There is an ongoing debate about how Holocene climate variability is related to lake level fluctuations (cf. Bleicher 2013; Magny 2004), but this discussion is primarily of a methodological nature; so far there are still too few reliable independent indicators of lake level changes. Changes in temperature and precipitation may have resulted in shifts in the dynamics of the accumulation and melting of water stored as ice. These circumstances are likely to have caused considerable fluctuations in lake levels (Nussbaumer et al. 2011) and flooding of inhabitable places on the shores. For the time around 3400 BCE, several proxies indicate a period of cooler conditions (fig. 3): the radioactive beryllium-10 isotope (Be10) content in the Greenland GISP2 ice core (Nussbaumer et al. 2011; Steinhilber et al. 2009), the Δ14C residue curve (Reimer et al. 2004), and the total solar insolation (TSI) curve (Steinhilber et al. 2012). Further, cooling is indicated in the Alps by the advance of glaciers and the sharp tree-line decrease below 2200 m a.s.l. (Nicolussi 2009) and, in the northern Atlantic Ocean, by the advance of Arctic icebergs marked by ice rafting debris (IRD) (Bond et al. 2001; Holzhauser 2010). Furthermore, the homogeneity curve (HGK) of tree ring widths of central/western Europe (Schmidt and Gruhle 2003), the δO18 values of well-dated speleothems (Atsawawaranunt et. al. 2018), and the supra-regional drought indicator curve (Wanner et al. 2011) indicate more humid conditions right after 3400 BCE.

To assess the coincidence of the settlement decline around 3400 BCE and the climate deterioration, we have conducted a significance test on the correlations of peaks in the time series of the felling phases of all dendrochronologically dated Neolithic settlements at Lakes Morat, Neuchâtel and Bienne (Laabs 2019), as well as on the palaeoclimatic proxies, using the δO18 values of well-dated speleothems (winter precipitation) and the beryllium-10 isotope (Be10) content in ice core GISP2 (solar activity and temperature) (fig. 4). The chosen statistical procedure was inspired by a Monte Carlo approach proposed by Kintigh and Ingram (2018), which tests how likely it is that the observed real-world coincidence of climate and cultural events can be explained by a random arrangement. Details on the treatment of data and method are in phase of publication (Heitz et al. in press).

In Figure 4, the precursor coincidence indicates how often transformations in settlement practices followed a previous climate event. The trigger coincidence rate indicates that a climate event might have triggered transformations in settlement practices. Both indicators can be tested by random permutation of the intervals of events and were significant in all tested cases. The coincidence of the local maxima of settlements on the lakeshores around 3700, 3570, as well as the short-term small increase in settlements by 3380 BCE with the cold periods, the Be10 maxima at 3686, 3559 and 3360 BCE are significantly non-random ($p = 0.02$ and $p = 0.01$). Fluctuations in the curve of δ18O oxygen isotope concentrations between 3500 and 3200 BCE indicate winter precipitation that also significantly, and non-randomly, coincides with the settlement decline around 3450 and 3280 BCE in the Three-Lakes Region ($p = 0.01$ and $p = 0.02$). In conclusion, for the time period between 3700 and 3200 BCE, the lakeshores were densely settled in cold and dry periods during which winter precipitations were locked up in Alpine glaciers, leading to lower lake levels that provided many shallow areas and dry spaces for lakeshore settlements (fig. 5). On the contrary, the settlement declined during warmer periods with higher precipitation, probably caused by rising lake levels for decades and thus the flooding of settlement areas. After 3200 BCE, a more stable and long-lasting reoccupation of the lakeshores can be observed in a longer period of rather warm, but also drier climate conditions.

These findings suggest that the piles and elevated floors of lakeshore houses might have been, as such, effective ways of coping in terms of resisting seasonal water level changes of presumably about 2 to 4 m during rainy summers. However, the settlements' architecture was not suitable for coping with climate-driven long-term lake level rises of higher magnitudes, which led to the submergence of formerly inhabited lakeshores.

5. Settlement relocation as a social practice and resilience capacity

The question arises of what happened to the settlement communities during these phases of hardship, when their inhabited spaces were flooded and their livelihoods seemed to be threatened. Since the lakeshores were repopulated immediately after the lake level dropped again, we hypothesise that the settlements were repeatedly relocated to the hinterland of the lakes as a resilience practice. These areas are archaeologically less researched, but settlements are attested for the period between 3900 and 3000 (fig. 6). In general, archaeological features, single, and scattered finds that can only be broadly dated to the Neolithic are regularly found in the hinterland, indicated by the density estimations in blue in fig. 6. Due to bad preservation conditions, many sites cannot be dated with the same accuracy as wetland sites. Therefore, we considered two other indicators to test the hypothesis: 1) the evidence of settlement activity in the hinterland based on pollen data; 2) the stylistic (dis) continuities in pottery production.

5.1. Signs of settlement activity in the hinterland based on pollen data

It is a generally accepted assumption that the higher the population density in an area, the greater the human influence (Lechterbeck et al. 2014), and that the population density of an area is closely related to the agricultural area (Zimmermann et al. 2004). Indications of land clearing in pollen diagrams can therefore provide additional proxies for population dynamics.

Since a single pollen profile represents a combination of (extra-) local and regional signals, we have combined different pollen diagrams for supra-regional analyses deriving from 5 small lakes in the hinterland of the large alpine lakes (fig. 7): Le Loclat (Hadorn 1992, 1994), Moossee (Rey et al. 2019a, 2019b), Burgäschisee (Rey et al. 2019a, 2019b), Soppensee (Hajdas and Michczynski 2010; Lotter 1999), Rotsee (Lotter 1988a, 1988b, 1990). The data were extracted from the neotoma-database (Williams et al. 2018; there record numbers 26632, 40454, 46280, 40955, 44723, 4382). The pollen percentage data, based on a pollen sum of all terrestrial taxa of the individual sites, were combined into a single data set (fig. 8a). Only terrestrial pollen taxa with a frequency of larger then 1/3 and, if present, with an average frequency of at least larger than 0.1 percent were selected to reduce the potential disturbance by rare species. Cereal pollen was kept explicitly as an important anthropogenic indicator.

We applied a Principal Component Analysis (PCA) according to the method proposed by Feeser et al. (2019) and scaled the relative pollen percentages of each taxon by z-scores standardization. In palaeoecology, multivariate ordination techniques such as PCA can be used to reveal underlying gradients within the data (Feeser et al. 2019; Hinz et al. 2012). Due to the spread of beech (*Fagus*), there is a strong explainable gradient in the data set, which would obscure the desired result. To eliminate this, we decided to perform a Partial Constrained PCA. The result of the partial PCA, including the pollen data between 7000 and 1 cal BCE, shows that 20.5 percent of the variability in the data set is explained by the first axis (second axis accounts for 12.6 percent, (fig. 8b). Taxa with high scores on the first axis include, besides wild grass-types, classical anthropogenic indicators (e.g. *Cerealia*, *Urtica*, *Artemisa* and

Plantago); negative scores are generally attributed to arboreal taxa, in line with other studies (cf. Behre 1981). Since dark mesophilous beech-fir forests can be assumed to be the natural vegetation of our study area (cf. Rey et al. 2017), an increased landscape openness is interpreted to reflect human influence on the natural vegetation. Since each sample is absolutely dated, the dates on the x-axis can be plotted against the openness value on the y-axis to get a time series for land clearing.

The first land opening took place in the early Neolithic, reaching a peak during the first half of the 4th millennium BCE (fig. 9a). Regarding the period 3900-3300 BCE, there are positive indications for a proposed mobility to the hinterland as a resilience strategy when the lakeshores were not habitable, since a partially inverse correlation becomes apparent (fig. 9b): when the settlement of the lakeshores decreased, the land opening increased supra-regionally. This regime seemed to last for about 600 years, until 3400-3300 BCE and the phase of failed settlement attempts in the Three-Lakes Region. In the following phase, any relationship between land opening and lakeshore settlement can no longer be seen. Most likely, a stable hinterland settlement had developed, resulting in indications of a continuous open landscape.

It is important to emphasise that settlement activities beyond the wetlands are less well known archaeologically. One of the reasons are the very different preservation conditions in mineral soils, where organic remains, such as the wooden piles of houses, and, consequently, precise dendrochronological dating, are lacking. However, based on the findings from the pollen data for 3400 BCE, there is likely no general decline in settlement activity in the hinterland during periods of high lake levels but there is an increase while settlement activity is low or has ended at the lakeshores. This strengthens the hypothesis that the settlers moved from the lake to the hinterland during this period. The loss of settlement spaces at the lakeshores during rising lake levels meant an increased effort to appropriate new settlement territory. Interestingly, in climatically more favorable times, communities relocated their settlements along the lakeshores every few years (Ebersbach 2013; Suter and Francuz 2010), probably for cultural, social, or economic reasons that are so far unknown. The high degree of mobility in their basically sedentary lifestyle in terms of a settlement practice might have made them resilient and less vulnerable and therefore able to relocate their settlements to the hinterland in periods of rising lake levels.

For the time around 3400 BCE, we can conclude that the spatial mobility which was incorporated into their settlement practice was most likely a resilience capacity. It helped settlement communities to continue their existence and to secure their livelihood, even in times of climate-induced destruction of settlement areas on the shores of the large Alpine lakes.

5.2. Signs of continuity in pottery production practices

A second strengthening argument for the temporal relocation of settlements to the hinterland can be made when examining the transformations in pottery styles over time. Figure 10 shows selections of pottery designs important to the spectra deriving from ten dendrochronologically dated lakeshore settlements in the Three-Lakes-Region (Hafner and Suter 2003: 10, Abb. 4a). 'Designs' are defined here as intentional combinations of pottery body shapes, forms of bases and rims, attached eyelets and nubs as well as incised and impressed decorative features. A total of 355 vessels having fully or nearly fully reconstructable semi-profiles were considered for macroscopic observations based on published pottery drawings (see Hafner and Suter 2003: Abb. 4a; Stöckli 2009: Taf., 32A, Taf. 33–34, Taf. 35B, 36–38B). This first rough qualitative examination already shows that, despite the temporal interruptions in settlement activity on the lakeshores, there seems to be an overall continuation regarding the stylistic aspects of pottery production, at least during the 'settlement gap' of 3500-3400 BCE: although there is a general reduction in the diversity of different pottery designs towards a dominane of pot-shaped vessels, and despite the fact that the pots bases become increasingly flat from 3700 BCE onwards, the pots in particular show strong similarities in their design, having barrel-shaped bodies with short rims and attached knobs (Stöckli 2009: 102). Regarding the second 'gap' of 3350-3200 BCE, the stylistic continuity is less certain but still highly likely. Further in-depth studies on the transformations of pottery diversity that might clarify this aspect are subject to the current research projects (Heitz 2020; Hafner 2021).

6. Discussion

Sedentary early farming communities living on the shores of the large lakes of the northern Alpine foreland in the 4th millennium BCE were not only challenged by small, seasonal lake level fluctuations but were also repeatedly threatened by decadal climate changes that presumably caused lake level changes of a higher magnitude. The architecture of the houses on piles and, in some cases, their presumably elevated floors can be seen as a coping capacity to 'resist' seasonal level fluctuations. Furthermore, settlements were abandoned every few years and seem to have been rebuilt at places further up or down the lakeshores. The successive erecting of houses during the settlements' founding phases as well as the stylistic plurality of pottery are strong indicators that spatial mobility was a characteristic of these settlement communities and their dwelling practices. Mobility was thus a social practice. Beyond this, we have observed periods in which lakeshores seem to have been abandoned as settlement spaces, which was probably caused by non-seasonal rising lake levels.

Based on the significance test on the correlation of climatic events and settlement activities conducted here, the following scenario can be inferred for the Three-Lakes Region in the period between 3600-3200 BCE: lakeshores were densely settled during cold and dry periods when lake levels were presumably low—as precipitations were locked up in glaciers, which provided vast shores for settlement spaces. Rising temperatures and intense winter precipitation triggered the rise of lake levels and the submergence of settlement spaces for decades, forcing communities to abandon their settlements successively. This finally seems to have led to temporal interruptions of settlement activities near lakeshores around 3450 and 3280 BCE. Incomplete and failed settlement attempts around 3415 and 3385 BCE provide evidence of the challenges that the communities must have faced during climatic fluctuations and environmental changes. As we have shown by examining settlement densities and the land opening in the hinterland, the Neolithic communities were severely affected, but probably not in a fatal way: there is evidence that they relocated their settlements to, in this regard, safer spaces beyond the shores of the lakes. In this case, their general social practice of moving their settlements every few years provided them with an adaptation capacity and thus a resilience strategy that enabled them to re-establish security in times of hardship caused by submerged settlement spaces. Related to the definition proposed by Norris et al. 2008 (see section 3), the communities' temporary move to the hinterland can be interpreted as an adaptive process, in which spatial mobility—as an integral part of settlement practice—and social cohabitation made them capable of restoring security and keep functioning after settlement attempts at the lake shores had failed. Furthermore, the pollen data, but also the continuity in pottery production over time, show that the population did not significantly decline, but that settlement activities were shifted to the hinterland. The communities resettled the lakeshores as soon as the conditions had become more favourable. Wetland settlement practices were not abandoned in the long run and communities didn't suffer persistent dysfunction. On the contrary, their social and cultural resources of settlement practices were sufficiently robust to be resilient and to endure those temporarily altering environmental changes. Spatial mobility in terms of settlement relocations should thus, in our opinion, be considered a capacity of resilience that emerged out of habitual social practice of settling in dynamic waterscape worlds, on the shores of lakes with constantly changing levels.

7. Conclusions and further directions

As the case study presented here shows, it is crucial in resilience research to reflect on the chosen conceptualization of the term. The research designs should also make explicit what kind of challenge or threat is at the centre of the study, which entities are being examined for resilience and what their resilience capacities relate to. If one takes the 'settlement communities' as the entity under investigation, settlement relocations from the lakeshores to the hinterland can be interpreted as resilience capacity using the theoretical framework of Norris et al. 2008. On the contrary, if one takes the 'lakeshore settlements' as the entity under investigation, it could be concluded that they did no longer function when lake levels had risen too high. Accordingly, one could argue that this hints more at a failed resilience process than at the successful mitigation of floods. A successful outcome of a resilience process could have been that the communities altered their house constructions, but there is no archaeological evidence for this. However, these assessments of resilience and vulnerability are not contradictory or exclusive: while the settlement communities were resilient by moving to the hinterland and settling on dry land, their way of dwelling at the lakeshore was vulnerable to climate-induced periodic lake level risings of a higher magnitude. But even then, this settlement practice on the lakeshores was not completely abandoned, but merely interrupted.

The narrative proposed here includes presumed lake level changes. The current state of research does not allow us to find more evidence (past flood levels of the lakes) to support our interpretation that the only option of surviving together as a community was to retreat to the wider landscape. Our interpretation also focuses largely on the climatic triggers. Due to limited space in this paper, we did not test for other reasons for the observable settlement decline at the lakeshores, such as socio-political reasons, health issues or overexploitation or land use rights, which are discussed by other scholars (see e.g. Baum et al. 2020; Billamboz 2014; Ebersbach 2002; 2010; 2013; Jacomet et al. 2016; Trachsel 2005). What is also missing in these studies, as well as in the one presented here, are multiproxy-approaches in this field that overcome monocausal explanations. These could be worthwhile paths to follow in future research.

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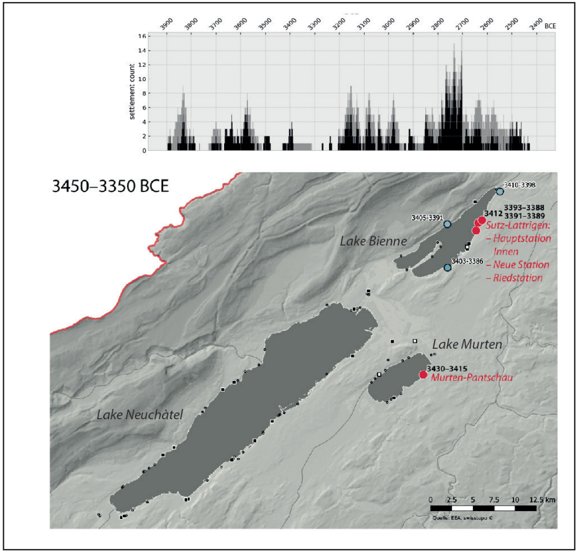
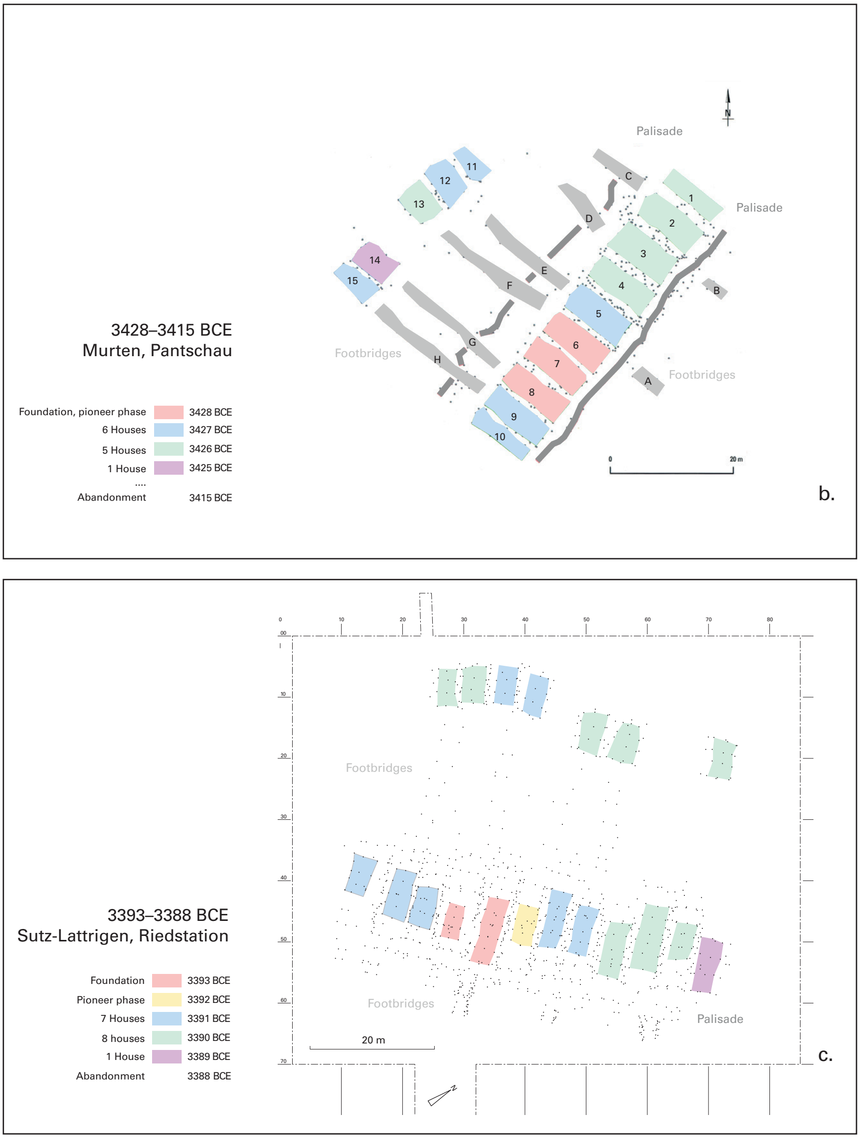
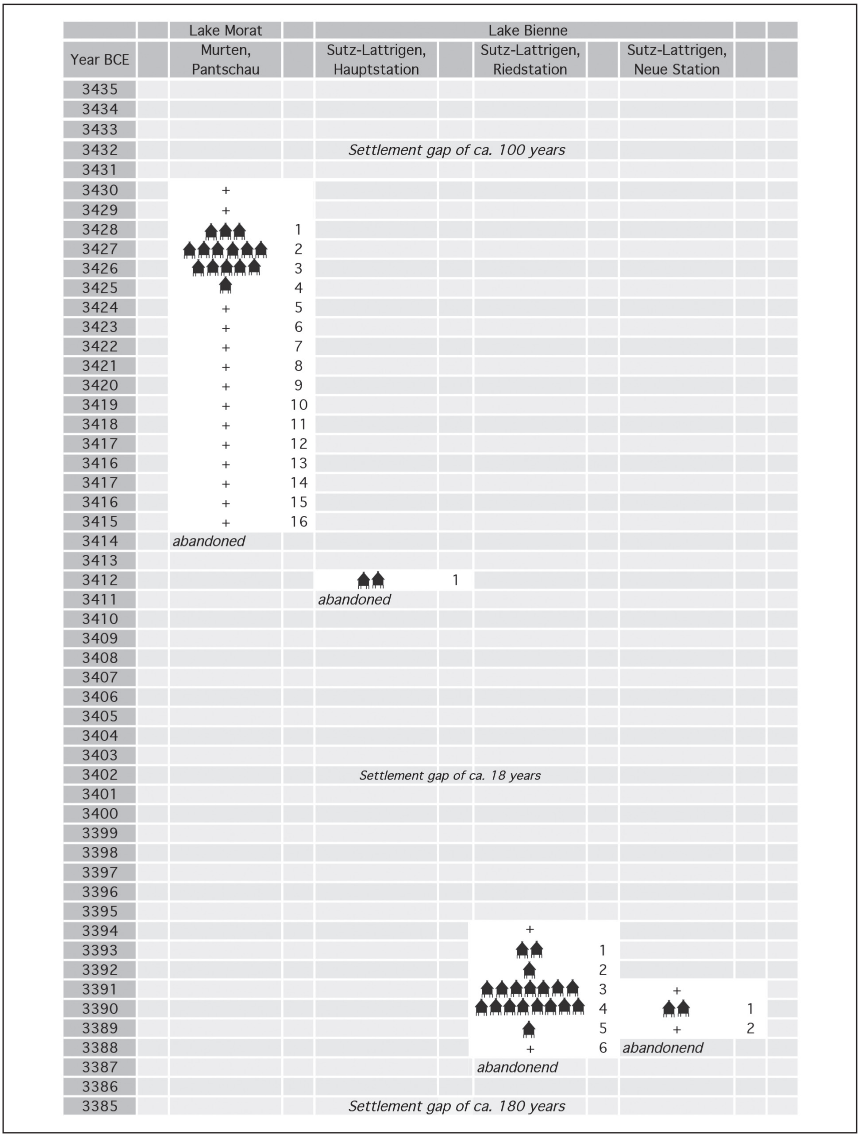


Fig. 1a.
Map of dendrochronologically dated sites and settlement frequencies in the Three-Lakes Region around 3400 BCE with precise felling dates in black and uncertain ones in grey (after Laabs 2019).



Figs 1b and 1c.
Settlement layouts and histories of the sites of Murten, Pantschau (b) Sutz-Lattrigen, Riedstation (c) (after Crivelli et al. 2012; Hafner 1992).



		Lake Morat		Lake Bienne				
Year BCE		Murten, Pantschau		Sutz-Lattrigen, Hauptstation		Sutz-Lattrigen, Riedstation		Sutz-Lattrigen, Neue Station
3435								
3434								
3433								
3432				*Settlement gap of ca. 100 years*				
3431								
3430		+						
3429		+						
3428		⌂⌂⌂	1					
3427		⌂⌂⌂⌂⌂⌂	2					
3426		⌂⌂⌂⌂⌂	3					
3425		⌂	4					
3424		+	5					
3423		+	6					
3422		+	7					
3421		+	8					
3420		+	9					
3419		+	10					
3418		+	11					
3417		+	12					
3416		+	13					
3417		+	14					
3416		+	15					
3415		+	16					
3414		*abandoned*						
3413								
3412				⌂⌂	1			
3411				*abandoned*				
3410								
3409								
3408								
3407								
3406								
3405								
3404								
3403								
3402				*Settlement gap of ca. 18 years*				
3401								
3400								
3399								
3398								
3397								
3396								
3395								
3394						+		
3393						⌂⌂	1	
3392						⌂	2	
3391						⌂⌂⌂⌂⌂⌂⌂	3	+
3390						⌂⌂⌂⌂⌂⌂⌂⌂	4	⌂⌂ 1
3389						⌂	5	+ 2
3388						+	6	*abandonend*
3387						*abandonend*		
3386								
3385				*Settlement gap of ca. 180 years*				

Fig. 2. The temporality of settlements as well as incomplete and failed settlement attempts. Felling dates of single piles (+) indicate ongoing settlement activities (figure by Albert Hafner and Caroline Heitz).

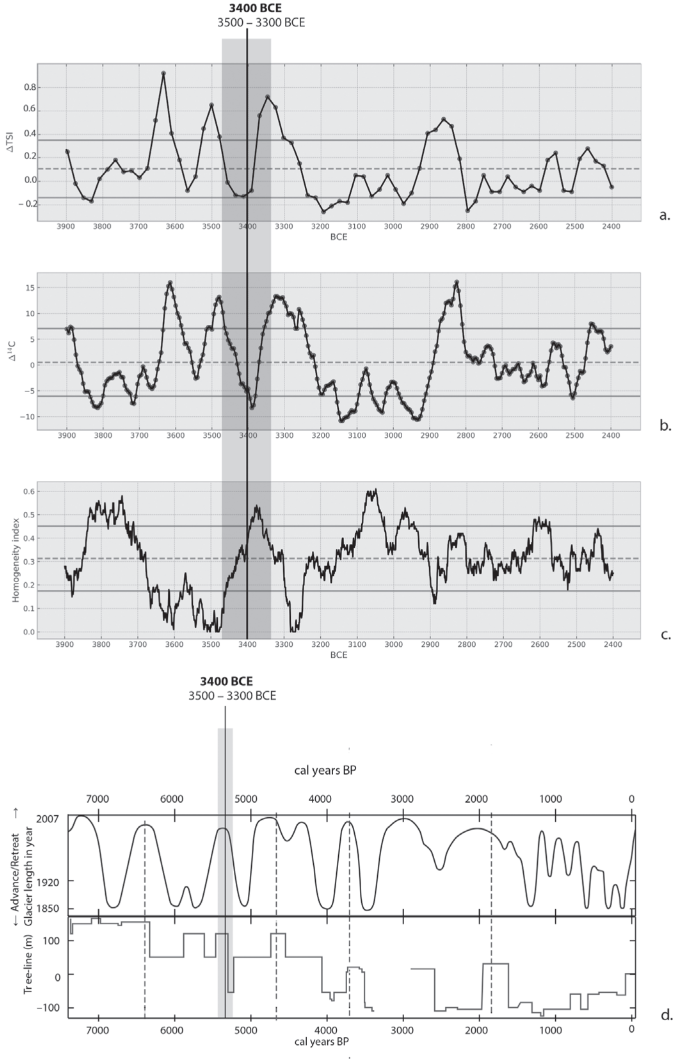


Fig. 3. Palaeoclimatic proxies indicating a cold period around 3400 BCE. a) Total solar insolation (ΔTSI) curve after Steinhilber et al. 2012; b) Δ14C residue curve after Reimer et al. 2004; c) homogeneity curve (HGK) after: Schmidt and Gruhle 2003; d) alpine glacier advances/retreats after Nussbaumer et al. 2011 and tree line of eastern central Alps relative to today after Nicolussi 2009 (figure by Albert Hafner, Julian Laabs and Caroline Heitz).

Fig. 4. Comparison and significance tests for the correlation of the settlement intensity curve with the Be10 (a) and the δO18 (b) time series. Absolute frequencies of contemporaneous settlements were summed up as a proxy for settlement or population activity on the lakeshores (figure by Martin Hinz and Caroline Heitz).

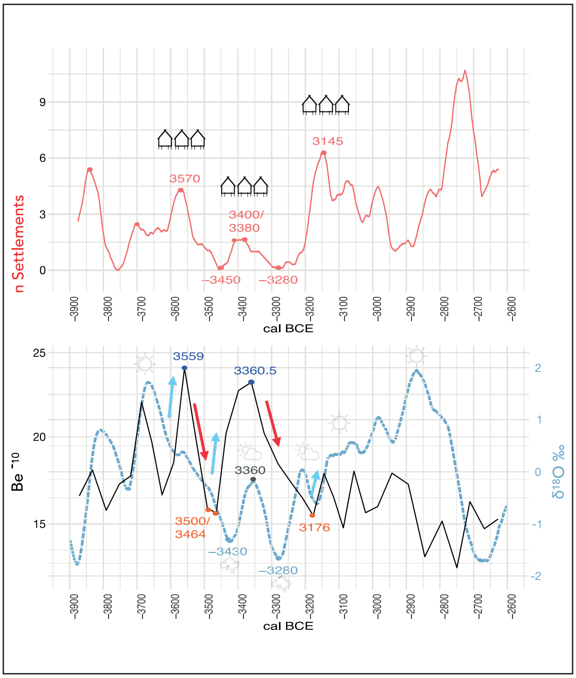


Fig. 5.
Interpretation of the causality between climate fluctuations and settlement activities in the Three-Lakes Region in the period around 3400 BCE. House symbols peaks and lows of settlement activities that tested for correlation (a). Weather symbols correspond to the δO18 indicated climatic periods of dry (sun), moderate (cloudy) and wet (snow cloud) conditions that correspond with changes in settlement behaviour. The blue (cold condition) and red (warm condition) markers represent those events in the Be10 record that were tested and found to be related to increased/decreased settlement activity (b) (figure by Caroline Heitz and Martin Hinz).

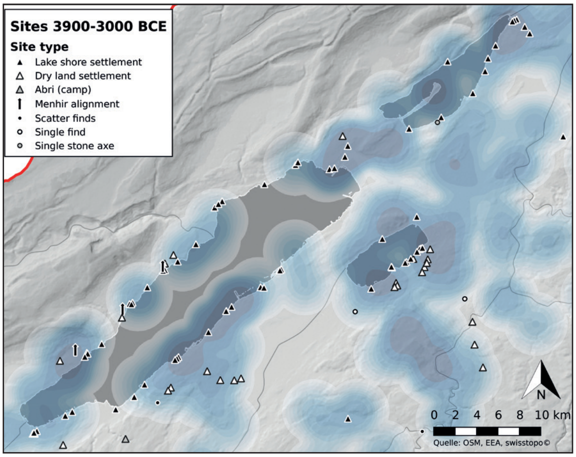


Fig. 6.
Map of archaeological sites in the Three-Lakes Region and its hinterland dating typologically to between 3900 and 3000 BCE and kernel density estimation in blue for all sites and finds that can only be dated roughly to the Neolithic (colour intensity corresponds with the site intensity) (figure by Julian Laabs).

Fig. 7. Sites of the pollen data used in this study (figure by Martin Hinz).

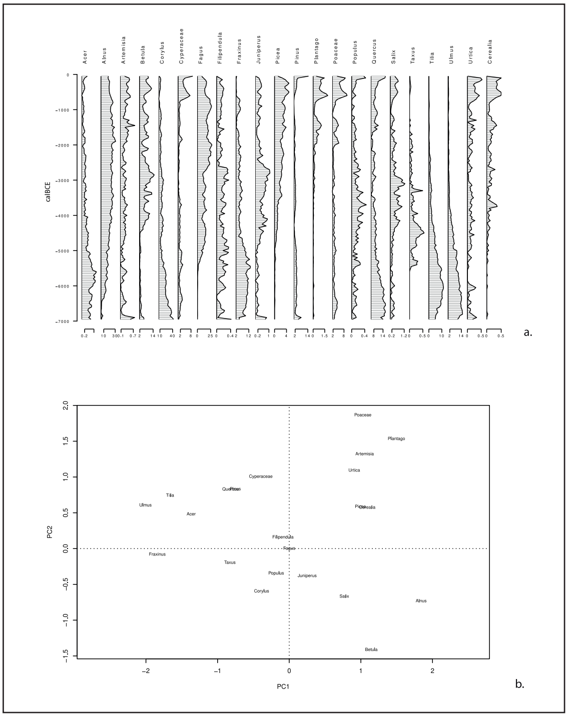


Fig. 8.
Mean Pollen Diagram for all 6 sites with taxa used in the PCA (a); PCA ordination plot of taxa scores for data set spanning 5000–1 cal BCE. The first axis (PC1) mainly separates taxa of the forest (left) from non-arboreal pollen taxa (right) (b) (figure by Martin Hinz).

Fig. 9. Mean PCA Spectra scores for data of the five pollen sites. Black curve gives smoothed average values, grey bars indicate the standard deviation across all sites (see text for details) (a); Mean PCA Spectra scores for the data from the five pollen sites, black with grey bars indicate the standard deviation across all sites, plotted against the smoothed number of settlements at the lakes of the Three Lake Region (red), during the time period 4100–2000 cal BCE (b) (figure by Martin Hinz).

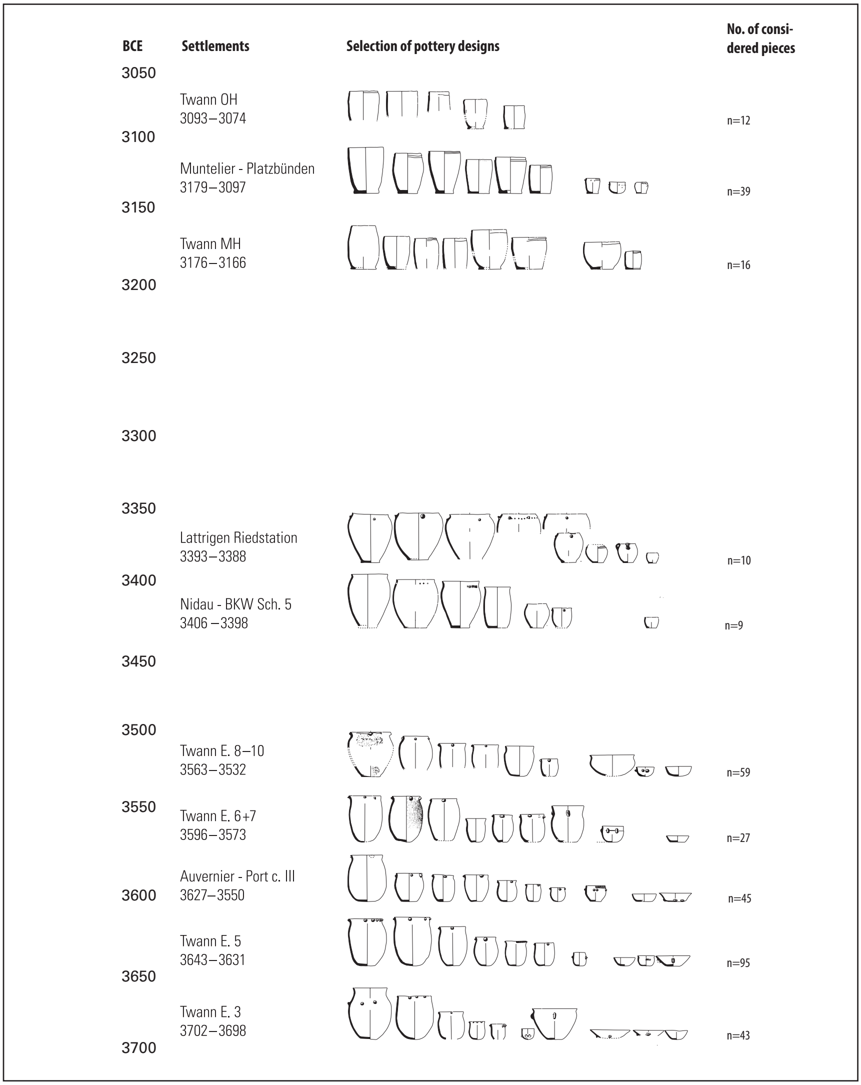


Fig. 10. Selection of pottery designs deriving from dendrochronologically dated sites in the Tree-Lakes-Region showing continuous transformations despite temporal interruptions (after Hafner and Suter 2003).