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Resilience and persistence of ancient societies in the face of climate change: a case study from Late Bronze Age Peloponnese

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ABSTRACT

Instances of resilience and persistence in ancient societies during periods of climate stress are necessary as counter weights to simplified collapse archaeology. The authors offer an evaluation of societal trajectories during the Late Bronze Age (LBA) in the Peloponnese against the backdrop of recently available local climate data. By considering climate volatility as well as climate change, the long-term perspective suggests that the end of the LBA should be viewed in light of the socio-environmental mismatches that developed during its earlier phases. Varying socio-political complexity and population densities are preconditioning components for inherent resilience under climate stress and climate impacts cannot be determined by climate conditions alone. While arid climate does not equal negative societal change, beneficial climate conditions may be favourable in the relative short term while at the same time supporting an ultimately unsustainable economy that proved detrimental in the long term.

KEYWORDS

Climate change impact; resilience; socio-political structures; socio-environmental dynamics; Late Bronze Age; Greece

Introduction

Understanding how humans perceive and react to climate change at different time scales was recently singled out as one of 25 grand challenges for archaeology in a crowd-sourcing enterprise (Kintigh et al. 2014). Such issues are intimately linked to questions of the resilience and persistence of societies through time (Kok et al. 2016), making up another set of grand challenges established as results of the same enterprise. To understand such important and highly complex questions, it stands clear that focus on the potentially negative effects of climate change or of short-term ‘climate events’ alone will never produce entirely satisfactory insights. Yet, the archaeology of collapse remains the most visible research field dealing with such questions in a variety of geographical areas (Tainter 1988; McAnany and Yoffee 2010; Faulseit 2016; Middleton 2017; Weiss 2017a). Aegean archaeological studies have followed suit and often tie findings from the Aegean sphere into societal transformation on an Eastern Mediterranean scale (Middleton 2010; Cline 2014; Knapp and Manning 2016). The Late Bronze Age (LBA) in the Eastern Mediterranean was an expansive period with palatial economies and highly complex societies developing in several regions, all interconnected through wide-reaching contact networks. Many of these societies, including the Mycenaean societies on the Greek mainland, went through comprehensive changes towards the end of the LBA, resulting in the deconstruction of palatial economies, a down-scaling of hierarchies and socio-political-economic disintegration. The idea that climate may

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have had a role in the changes seen at the end of the LBA has been suggested for a long time (cf. Knapp and Manning [2016], with references). This idea, however, has recently gained in strength, and aridity is now seen by some researchers as the primary driver behind these processes of societal change (Drake 2012; Kaniewski, Guiot, and Van Campo 2015; Kaniewski and Van Campo 2017; Weiss 2017b). More rarely is climate raised in relation to the 500 years preceding this change, during which, for instance, the societies on the Greek mainland went through comprehensive socio-political changes that in many ways set the scene for the changes recorded towards the end of this period.

In the present study, therefore, we follow recent researchers who highlight the benefits of long-term perspectives on coupled human–environment dynamics (Redman and Kinzig 2003; Schoon et al. 2011; Nelson et al. 2016; Armstrong et al. 2017). We revisit the LBA – or Late Helladic (LH) – archaeological record from the Peloponnese against the backdrop of recent advances in paleoclimatology from the area (Finné et al. 2017). By incorporating the full span of the LBA from the Middle Helladic (MH) III to the LH IIIC (i.e. ~1800 to ~1050 BC), the view is expanded from the one-sided perspective on ‘collapse’ to a more wholesale evaluation of the sustainability of Peloponnesian societies over the course of 750 years (Table 1). Our ‘long-term’ perspective, however, stands short in comparison to millennial-scale studies addressing issues of socio-environmental dynamics (e.g. Lawrence et al. [2016]; Allcock [2017]), highlighting the need to adjust the temporal scope in relation to research questions, data availability and research disciplines involved (Lane 2015). By moving beyond ‘events’ in favour of more long-term human–environmental processes we also acknowledge the dating uncertainties attached to both archaeological and climatological chronologies, making very high-resolution correlations problematic (Finné and Weiberg 2018; cf. Knapp and Manning [2016]). Here, we follow established chronologies for Greek mainland LBA (Manning 2010), but these are not unchallenged. Specifically, the debate in the Aegean area concerns inconsistencies between historical ‘low’ dating and radiocarbon based ‘high’ chronologies and mainly affects the first half of the LBA and especially the LH I period, before the alternatives converge around 1500 BC (Bietak 2003; Manning et al. 2006; Manning 2007).

The temporal scope of any study will also influence the level of contextual detail that can be encompassed in article form. The present study is conducted primarily on a socio-political level, aiming to outline general socio-political trends alongside those of climate variability and change. The socio-political history of the Peloponnese is marked by pulses of consolidation and fragmentation, surges of intensification (i.e. a greater investment of labour) followed by politico-economic simplification (Butzer 2005; Weiberg et al. 2016). Such patterns and their cyclicity are commonly recognized in many contexts around the world, with or without a specific climate concern (Marcus 1998; Yoffee 2010; Gronenborn et al. 2014; Kennett and Marwan 2015; Allcock 2017). Long-term perspectives are vital for a complete view of such processes and are an important contribution

Table 1. Relative chronology of the LBA in the Peloponnese together with suggested dates for an absolute chronology – in years BC and years before present (BP) where the present is AD 1950 (Manning 2010; Voutsaki, Dietz, and Nijboer 2009).

Relative chronology	BP	BC	Duration in years
MH III	3750–3650	1800–1700	100
LH I	3650–3585	1700–1635	65
LH II	3585–3370	1635–1420	215
LH IIIA	3370–3280	1420–1330	90
LH IIIB	3280–3150	1330–1200	130
LH IIIC	3150–3025	1200–1075	125

from history to our present day of similar concerns, albeit with unprecedented global scope (Costanza et al. 2012). Archaeological indicators of socio-political cyclicality in the Peloponnese are temporal variations in population density (number and distribution of settlements), investments in infrastructure (settlements, roads and landscaping efforts) and textual sources, primarily, supply evidence for administrative control functions (socio-political hierarchies and tax systems). The sum of these indicators will give an estimate of the pressure on resources, their use and the control thereof, and by extension, the vulnerability of the socio-political structures in each phase to unforeseen or unpredictable external, or internal, threats (cf. Kok et al. [2016]).

The effects of different socio-political structures on the effectiveness and decision-making abilities of ancient societies have been discussed in several contexts over recent years (Tainter 2000; Gunderson and Holling 2002; Parkinson and Galaty 2007; Blanton 2010; Marston 2015). There seems to be some consensus that societal connectedness – the interdependence between different actors and between aspects of society – increases in parallel with growing societal complexity. Following the perspective of resilience thinking (Holling 2001; Redman and Kinzig 2003), such interdependencies may in the long run lead to overconnectedness and a growing rigidity within the system that increase the likelihood that a ‘stability threshold’ will be transgressed, moving the system into a vulnerable state (Blanton 2010; Marston 2015). Before such a transgression occurs, however, these societies will be highly efficient, with connectedness safeguarding the availability of alternatives to amend situations that threaten the sustainability of set ways of life. Increased vulnerability can develop when resource management becomes too fixed to hinder adaptation, creating a form of path dependency and lock-in effects (Schoon et al. 2011), in the end leading to mismatches when emphasis is put on the ‘efficiency of function rather than long-term existence of function’ (Marston 2015, 596). This model has a bearing on evaluations of agricultural strategies as well as socio-political structures, with the latter often influencing the former.

Climate setting

Paleoclimate information from the Peloponnese comes from a variety of proxies preserved in mainly two types of natural archives: sediments and speleothems. In recent years a number of new paleoclimate records have been made available from the Peninsula (e.g. Heymann et al. [2013]; Finné et al. [2014, 2017]; Unkel et al. [2014]; Katrantsiotis et al. [2016]). With the addition of these records, uncertainties relating to dating have been reduced and the temporal resolution of the paleoclimate data has improved (Finné and Weiberg 2018). This in turn means that better comparisons between paleoclimate data and the rich archaeological record from the Peloponnese can be undertaken. In this paper we make use of a stable oxygen isotope ($\delta^{18}\text{O}$) record from a stalagmite from Mavri Trypa Cave located on Schiza Island just off the SW coast of the Peloponnese (Figures 1 and 2). This record has been interpreted as documenting a sequence of wetter and drier conditions. Currently, it is the most precisely dated and best resolved paleoclimate record for the LBA from the Peninsula. During the LBA the dating uncertainties range from 16 to 60 years (2σ corrected) and the temporal resolution varies between 1 and 25 years with a mean of 6 years per sample (Finné et al. 2017). Although there are clear differences in the climate between the western and the eastern Peloponnese at present, the climate is generally controlled by the same larger-scale processes linked to atmospheric circulation and prevailing moisture transport (Xoplaki et al. 2000; Maheras and Anagnostopoulou 2003). Therefore, the information from Mavri Trypa, in the western part, gives important information about the

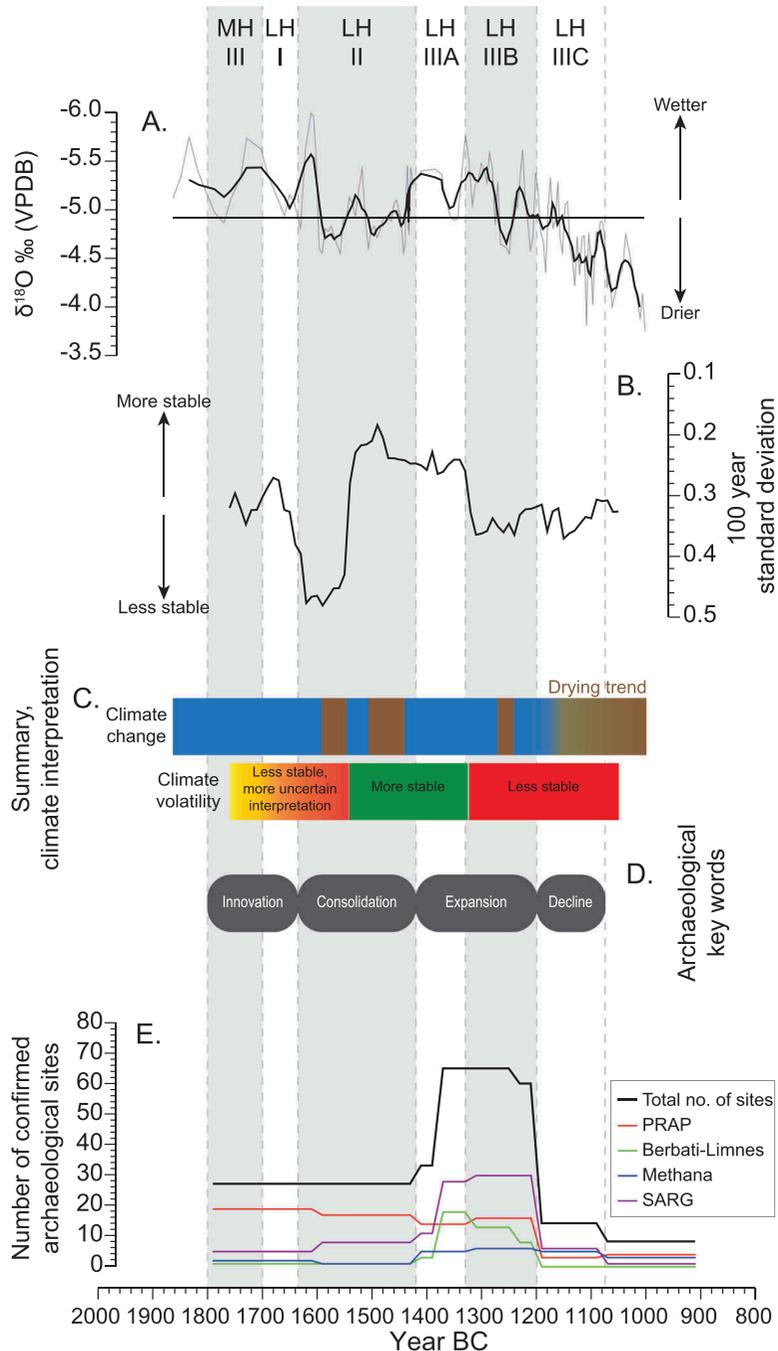


Figure 1. (a) Stable oxygen isotope data from Mavri Trypa Cave interpreted to reflect variability in rainfall; (b) Standard deviation in stable oxygen values in 100-year blocks with a new block starting every 10 years; (c) Summary of climate interpretations. Blue and brown bar shows wetter (blue) and drier (brown) climate conditions. Green and red bar shows more stable (green) and less stable (red) climate conditions. Yellow to orange segment indicates period of less stable conditions but the interpretation is less secure (see text for details); (d) Summary of the archaeological interpretations made in this paper, presented as keywords. Please note that these interpretations are based on the socio-political level of scale that is the focus of this paper – for more details see main text; (e) Number of archaeological sites identified in selected intensive surveys on the Peloponnese in the designated transect (Wells and Runnels 1996: Berbati-Limnes; Mee and Forbes 1997: Methana; Jameson et al. 1994: Southern Argolid Exploration Project [SARG]; Davis et al. 1996: Pylos Regional Archaeological Project [PRAP]).¹ Black bold line provides the aggregated total of sites.

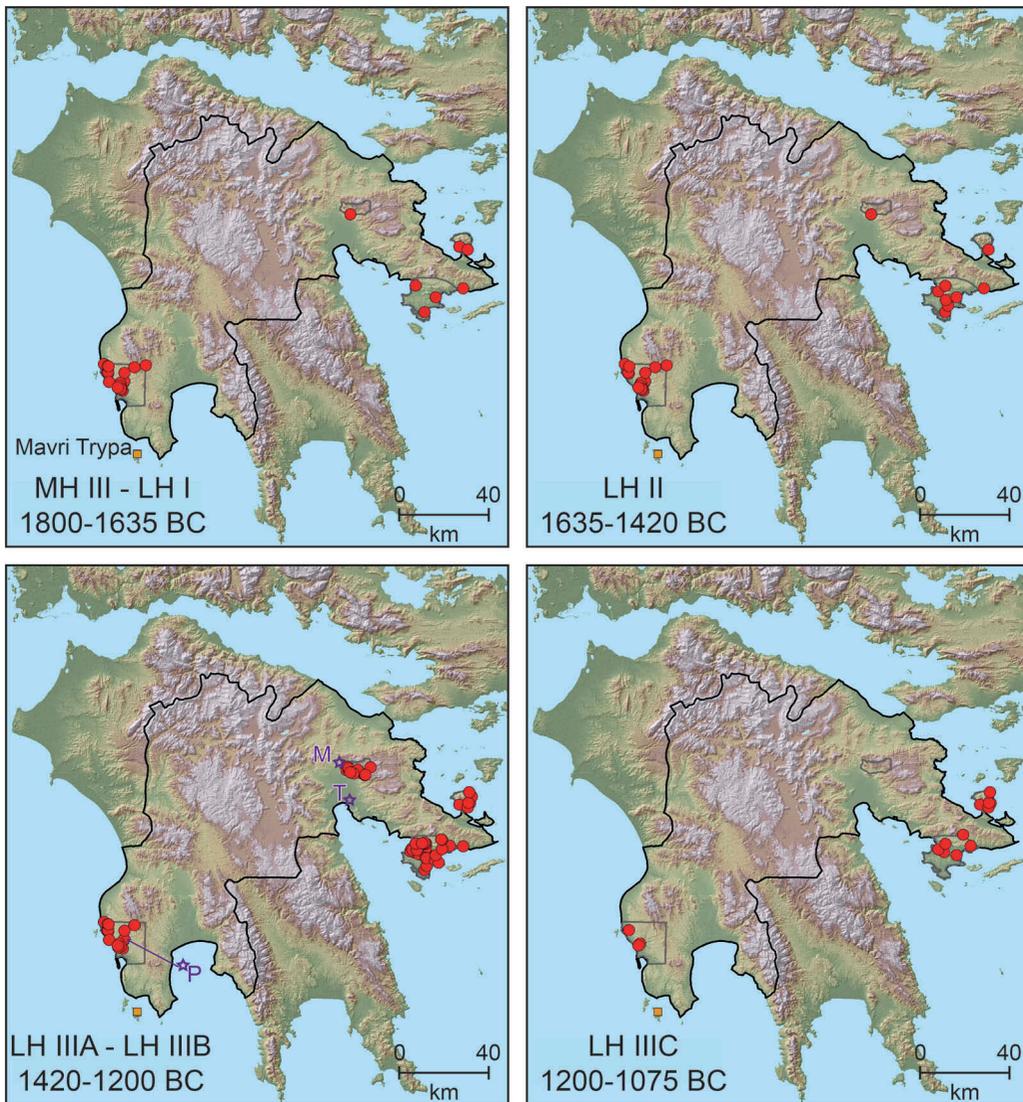


Figure 2. Location of Mavri Trypa Cave (yellow square) and distribution of archaeological sites identified in selected intensive surveys on the Peloponnese in designated transect (black line) (see Figure 1(e)). Selection of surveys is based on chronological resolution of the intensive surveys and excludes surveys that provide too coarse a resolution for the LBA interval. Grey lines mark the outline of the intensive survey universes but note that not all areas within these survey universes were surveyed. In the LH IIIA-B map, purple stars mark the location of Mycenaean palaces within the transect area: M for Mycenae; T for Tiryns; and P for Nestor's Palace of Pylos.

climate further east by providing a local baseline from which micro-regional variations within the Peloponnese may be understood. The information from Mavri Trypa nuances the understanding of the climate situation during the LBA and it now seems clear that this period experienced both wetter and drier conditions (cf. Weiberg et al. [2016]).

The stalagmite from Mavri Trypa formed discontinuously during the last 4600 years and growth hiatuses have been linked to sustained periods of arid conditions. During the LBA, however, conditions evidently remained moist enough to sustain continuous growth. Following an extended growth hiatus, the stalagmite starts growing again around 1860 BC (Figure 1(a)). At this time, the $\delta^{18}\text{O}$ record shows clear evidence for wetter conditions. Two periods of drier conditions follow during LH II, between ca. 1600 to 1550 BC and ca. 1510 to 1440 BC. Wetter climate conditions then return during LH IIIA and the first half of LH IIIB. An abrupt period of drier conditions of around two decades, centred on 1250 BC, disrupts the wetter conditions in the middle of LH IIIB. Following this abrupt and short period, there was a return to wetter conditions, followed by a clear general trend towards more arid conditions after ca. 1225 BC. The stable oxygen isotope record shows that conditions became very dry around 1130 BC, i.e. from mid-LH IIIC. The stalagmite from Mavri Trypa Cave stopped growing at ca. 1000 BC probably in response to the dry conditions.

The paleoclimate record from Mavri Trypa does not only provide important insights into periods of wetter and drier climate conditions, it also allows us to investigate climate stability during the LBA. For this analysis we follow a similar approach to Akers et al. (2016) and calculate the standard deviations for the stable oxygen isotopes in 100-year blocks, with a new 100-year block every 10 years for the growth period between ca. 1860 and 1000 BC (Figure 1(b)). It has been suggested that trends in the standard deviation of the stable oxygen isotope values reflect trends and changes in climate stability (Akers et al. 2016). The result of this analysis indicates that the stability of the climate varied during the LBA and we suggest that three periods can be discerned (Figure 1(c)). A first period from 1760 to 1540 BC is one of less climate stability. Within this period, however, between 1640 and 1550 BC the results are strongly influenced by large and rapid isotopic changes that may not be directly related to hydro-climatic variability, and thus this period should be interpreted with caution. A second period from 1540 to 1330 BC, i.e. the second half of LH II and LH IIIA, is one of relatively stable climate conditions, i.e. reduced inter-annual and inter-decadal variability. A third period begins at 1330 BC; this is also one of less stability and it lasts until growth terminates at ca. 1000 BC.

Contextualization: climate and society

If we are content with the suggestion that the noted changes in climate were of the magnitude and scale to have had an impact on human lives and economies, we can move on to discuss the implications of climate variability and change during the LBA in the Peloponnese. The present reconstruction as outlined in Figure 1(c) includes both dry and wet periods and we will structure the discussions accordingly. Before we go ahead, however, we need to give some thought to the way climate change and climate variability are likely to have impacted human societies. Above all, people in the past would not have acted on long-term climate change but on short-term weather variability impacting their set ways of life (Halstead and O'Shea 1989; Roberts 2011; Middleton 2017, 137). What additional value can the above evaluation of climate stability bring to the overall view of climate and society during the LBA?

Long-term change or short-term variability

A major risk in any agrarian society located in arid or semi-arid settings, such as the Peloponnese, is insufficient rainfall, where too little rain (or too much if at the wrong time of year) could severely

impact agricultural yields, potentially leading to food shortages. Variability in food supply would have occurred at different spatial and temporal scales, and with varying relative intensity (Halstead 1989). The effect of rainfall variability is further aggravated in regions like the Peloponnese, where the topography thwarts extensive irrigation schemes and rainfed farming has been the rule (Foxhall 1995), until the highly unsustainable water management of modern times (Green and Lemon 1996).

Present-day meteorological data from the Peloponnese is characterized by strong interannual variability in rainfall amounts (Maheras and Anagnostopoulou 2003). There are few reasons to believe the situation was different during the LBA. Interannual variability in rainfall in this type of environment means that the output from a mainly rainfed agricultural system will vary both in and between years (Halstead 1989). Some years will produce bountiful harvests while other years will have reduced harvests that need to be supplemented by surpluses from preceding 'good' years or by exchange to avoid food shortages, following a regular pattern. Overall, this system may be fully sustainable over the centuries. Interannual variability in rainfall in combination with an overall reduction in average rainfall, however, has been hypothesized to mean that the frequency of 'bad' years increases and yields during good years decline, making it more difficult to fill up the stores to use in case of harvest failure (Roberts 2011, fig. 1.2c).

Interannual variability in rainfall poses a risk, the risk of failed harvests and subsequent food shortage. It is clear that ancient societies developed buffering mechanisms to counter the potential negative effects of both short-term and long-term variability (Halstead 1989; Marston 2011, 2015; Kennett and Marwan 2015). The temporal scale and magnitude of climate volatility, however, had important implications for the predictability and the success rate of any such societal strategies to deal with variability (Halstead 1989; Roberts 2011; Kennett and Marwan 2015). Reduced interannual variability means less risk and likely increased predictability. During arid periods with more stable conditions, it may be suggested that yields probably go down but stability would allow people to develop risk management strategies to secure reasonable outputs (Halstead 1989; Marston 2011). One can also imagine that one measure would be to adjust expenditure to decreased returns. Stable conditions then would enhance predictability and the possibility to temporarily adjust economic activities/take ameliorating measures. However, actual changes to human life styles, not just ameliorating strategies when the need arises, require that the weather variability is recognized as a long-term or permanent shift in climate (Roberts 2011).

In view of the above considerations of climate change and variability during the LBA, it is possible to identify two periods characterized by seemingly more favourable climate conditions (wet and primarily stable), and two periods of less benign climate circumstances (dry and stable, and dry and variable) (Figure 1). In the following, we will survey these periods in more detail, sampling the archaeological records in order to give an overview of the societal processes during these periods and investigate the potential influence of climate, if any, on these processes.

Wetter climate conditions

The beginning of our sequence, the Middle Bronze Age (MBA) and the beginning of the LBA (MH III–LH I), was a period marked by the appearance of material culture that suggests a growing accumulation of wealth (Wright 2004; Voutsaki 2010, 2016; Fitzsimons 2011). The MH III–LH I period is one of expanded possibilities at all levels of society: an opening up towards external partners and a likely increase in the links between different players, socially, economically and politically. These processes develop in parallel with the Neopalatial period on Crete, and the

Peloponnesian communities were very likely positively influenced by these developments, as suggested by the presence of Minoanizing pottery and iconography, and Minoan imports present in MH III–LH I graves (Wright 2008; Rutter 2010). The period can be characterized by the increasing size and architectural definition of settlements, some of which were fortified (Loader 1995). Reserved burial areas outside the settlement became the rule but the mortuary sphere was still marked by high diversity of burial types (shaft graves, chamber tombs, tumuli and tholoi) (Cavanagh and Mee 1998; Fitzsimons 2011). There is an increase in settlement numbers, variable between regions (Figure 1(e)), but perhaps more noteworthy is the resettlement of many locations in the inland, abandoned since the end of the EBA (300–400 years earlier) (Rutter 2001, 131).

More studies are needed to understand what caused these changes but it seems likely that the centralization of wealth was brought on in part by the desire of the mainlanders to adhere to a new value system centred on gift exchange, most probably introduced by the Minoan palaces as a strategy to secure allies (Parkinson and Galaty 2007; Wright 2008; Maran 2011; Voutsaki 2016). But where did this wealth come from? Voutsaki dismisses local agricultural resources in favour of diplomatic exchanges to explain the unprecedented wealth displayed in some MH III–LH I graves (Voutsaki 2016, 75). Yet, even if the impetus to break with the conscious austerity of the previous periods may have come from abroad, the means to do it will need to have come from within the mainland communities. Following Voutsaki's reasoning, the means came from a reversal of a previous under-production and under-exploitation of resources, and hence a realization of the untapped potential of the established agricultural regime. Based on present knowledge of Peloponnesian climate it is of interest that these developments now can be seen against a backdrop of wetter climate conditions. Wetter conditions are likely to assist expansion and intensification of agricultural practices, which in turn can enable the production of a surplus and by extension an increased economic potential to be channelled towards expansion in other sections of the society. Any such economic leeway could in effect help foster innovation, opportunism and the level of specialization and diversification that the archaeological material of the period indicates.

There are similarities between the MH III–LH I period and the LH IIIA some 200 years later in that they were both periods of intensified activities and external contacts. The 100 years that corresponds to the LH IIIA period also unfolded against a backdrop of generally wet conditions. In contrast to MH III–LH I, however, these conditions seem to have been quite stable and definitely followed upon a period of pronounced arid conditions (with a breaking point around 1440 BC). During this period, the first Mycenaean palaces were constructed (Wright 2006) and Mycenaean cultural ways spread across the Aegean and beyond, as exemplified primarily by the appearance and spread of pottery (Rutter 2010). The palaces were regional centres governing the surrounding territory through a complex web of interdependencies (Galaty, Nakassis, and Parkinson 2011). A population rise can be surmised from the increased size of settlements and particularly the number of archaeological sites that peaked towards the end of the LH IIIA period (from around 1350 BC/3300 BP) (Figures 1(e) and 2). This expansive settlement pattern of the second half of the LH IIIA, continuing into the LH IIIB period, contrasts with the more contracted settlement pattern in MH III–LH I and LH II (even if there are notable regional variations), as well as in the subsequent post-palatial LH IIIC and Early Iron Age (Figure 2). Palatial control – or the general expansion of economies in LH IIIA – also developed in parallel with an extensification and diversification of agricultural strategies. This is a hypothesis based on the introduction of new field crops (millet and spelt, and new emphasis on flax and bread wheat) (Kroll 2000; Valamoti 2011, 2016) and an increased emphasis on cattle, assumed to be in part at least put to use as draft animals enabling

the cultivation of larger fields, potentially rendering an increase in the total output of agriculture (Halstead 1999).

In a time of generally favourable climate conditions, such a strategy has good potential for success and could supply the resources needed for a growing and increasingly complex palatial economy. The spatial diversification would also allow utilization of different types of micro-environments and as such potentially function as a risk-management strategy (Marston 2011), mitigating minor or short-term rainfall shortages in some areas. With the arrival of a less predictable climate, the situation must have become more difficult. Under such circumstances, the impact of socio-political structure and the resources of the leading sections of society become important. By the beginning of the LH IIIB period the stable conditions gave way to greater rainfall variability, although isotope values still signal overall relatively wet conditions. This change to a more volatile climate situation is seen during a period when it appears that the available resources were stretched to their limits. The archaeological record of the final 100 years of the Mycenaean palatial period seems to signal more of everything. The sheer scale of the resources put into the enhancement of both the built and the natural landscape certainly suggests an intensification of palatial interventions. Among the large-scale enterprises were the palaces and their fortifications, road networks and dams (Hope Simpson and Hagel 2006). The limited written Linear B records give evidence of a strong control over some land and its resources and over part of the revenues of others (Killen 1998; Halstead 2001). Even with the variable climate and including a 20-year-long arid period that can be firmly placed in LH IIIB, and thus a generation or so before the palaces are destroyed (Finné et al. 2017), it must be concluded that at face value the Mycenaean societies appear to have sustained much of their resourcefulness. It might be that grand-scale accomplishments had a far higher price than the socio-political leaders perhaps realized (Maran 2009; Knapp and Manning 2016), but the LH IIIB events signal what our next example will show even more clearly: that aridity or less favourable climate conditions do not equal ‘collapse’.

Drier climate conditions

The transition from MH III–LH I to LH II can be placed in close chronological correspondence to a decrease in climate stability, a decrease which, however, should be interpreted with caution. It seems clear, however, that the stable and dry climate conditions during most of LH II (1600–1440 BC) were considerably different than the wetter conditions during the preceding MH III–LH I period or the stable and wet conditions during the LH IIIA period. LH II was a 200-year-long period characterized by a drier climate. In all archaeological accounts, however, LH II was a period of slow but steady societal expansion (Wright 2008). Increasingly during the LH II period, there are signs of socio-political stabilization and a consolidation of the societal structure that would characterize the Mycenaean palatial era in the following centuries. One indication to this effect is the standardization of the ceramic repertoire throughout the Peloponnese (Rutter 2010, 2015). At this point the stylistic diversity of MH III–LH I ceramics, building on old Middle Helladic traditions and with many connections to Minoan Crete, is given up for a general adoption of the lustrous decorated dark-on-light wares that would be one of the main identifiers of Mycenaean culture. At this time, instead of being a recipient of external stimuli, the mainland communities begin to assert themselves abroad (Wright 2008; Rutter 2010). Another indication is the construction of many tholoi, a tomb type that spread from early examples in Messenia and would be the main elite burial type in LH II–LH III throughout the mainland (Voutsaki 2010; Fitzsimons 2011). Although Mycenae is renowned for a large number of these monumental graves, leaders in many

burgeoning centres in the Argolid, the region around Mycenae, built tholoi at this point (Voutsaki 2010, 2016). During this period many of these settlements in the Argolid reached their acme in terms of socio-political position. It has been argued that the consolidation of central settlements (not all developing into palaces), beginning in MH III–LH I and amplifying in LH II can be connected to the increasing size of the territory of these settlements and a ‘need to centralize authority and the economy and to administer community activities’ (Wright 2008, 249, but see Foxhall [2014] for the potential heterogeneity of the territory and territorial authority). This move from innovation (MH III–LH I) to consolidation (LH II) can thus be seen as the likely continuation of the explorative processes during the preceding period. Once the prevailing climate conditions are added into the picture, this shift could also signify attempts to safeguard the state of affairs in the face of drier conditions and decreasing outputs. The fact that the LH II period was dry but also generally stable is a circumstance that would benefit predictability and perhaps the possibility to adjust ways of life accordingly.

What about the end of the Mycenaean palatial period? The transition from LH IIIB to LH IIIC in the relative chronology marked the end of the reign of the Mycenaean palaces. The palaces themselves were destroyed and the former palatial control of selected aspects of the economy disappeared (Middleton 2010; Knapp and Manning 2016). The breakdown of palatial control meant the discontinuation of monumental construction, highly standardized pottery production and other enterprises that called for high inputs of capital and (specialist) labour, and the end of Linear B as an administrative tool. The dry period around 1250 BC (3200 BP), which predates the destruction of the palaces by at least a generation, may have helped destabilize the palatial authority and may thus have been one of multiple factors behind the disappearance of the Mycenaean palatial economies (Finné et al. 2017). Following the breakdown of the Mycenaean palatial economies, however, climate became progressively more arid (Figure 1(c)). In combination with less stable climate conditions, this period resembles the worst scenario outlined by Roberts (2011), with overall reduced harvests that even during good years were unable to make up for the increased frequency of dry years with insufficient yields. A variable dry climate combined with a clear trend towards increasingly more arid conditions would have been a severe threat to a society already destabilized by the discontinuation of the palatial administration. These circumstances likely also provide an explanation for why any attempts to restore a palatial system remained unsuccessful (Finné et al. 2017). The continued building activities at places like Tiryns in the Argolid (Maran 2009, 2015), however, are among the increasing evidence suggesting that some Mycenaean ways of life were still upheld but also that the communities through resourcefulness and innovation actively shaped their ways of life to match new societal circumstances (Maran 2015; Lantzas 2016).

Discussion: the abilities and vulnerabilities of LBA societies

Even with the correlations and suggestions made above, it is still quite possible to see the Late Helladic societal developments addressed above as progressing as they did without giving climate, and climate change, any explanatory value. Until very recently, due to the lack of situated climate information, this was more or less the only way even though climate data from further afield has been used at times for discussions of socio-environmental trajectories on the Greek mainland specifically (Maran 1998; Fuchs 2007), as well as the Greek mainland within a more general Eastern Mediterranean framework (Drake 2012; Knapp and Manning 2016; Kaniewski and Elise 2017). We can thus establish that climate change had little or no impact, or, we can allow for the possibility that it did have some impact and begin to look for features of the society that helped to utilize or

to ameliorate the climate circumstances, outlining the abilities and vulnerabilities of LBA societies. The vulnerability of ancient societies to climate change, especially, has been the focus of recent research (Schoon et al. 2011; Nelson et al. 2016; Kok et al. 2016; Kennett and Marwan 2015). An assessment of the vulnerabilities of LBA societies on the level of detail suggested by Kok et al. (2016) will not be attempted, however, since 'vulnerability is the outcome of multiple stressors and multiple actors in multiple contexts that can occur at various spatial and time scales' (Kok et al. 2016, 231). Any comprehensive considerations of these factors are beyond the scope of this paper and calls for in-depth studies of each of the identified periods. Here, in view of the interpretational level of the present article so far, we will limit ourselves to the reigning socio-political situation and its potential as a mechanism for coping with and making use of the effects of climate change. The result is an estimation of the different levels of resilience (defined as a measure of the vulnerability of that system to unexpected or unpredictable shocks [Holling and Gunderson 2002, 33]) within these ancient societies.

The temporal oscillations on the scale of societal complexity through the Peloponnesian LBA (Figure 1(d)), find interesting parallels with the functions of the 'adaptive cycle' (Holling 2001; Holling and Gunderson 2002; Redman and Kinzig 2003), within which connectedness and resilience are negatively correlated. Generally, there is a consensus for growing societal complexity from MH III to LH IIIB, although the definitions and theories used differ. Parkinson and Galaty define the socio-political structures of MH mainland as possibly chiefdoms, developing into incipient states in LH I-II, and very networked states in LH III (Parkinson and Galaty 2007, Table 2). Voutsaki defines a shift from a kinship economy in MH I-II to more status-driven structure in MH III-LH II, with a focus on the extended kin group and 'expanding networks of exchanges and alliances' (Voutsaki 2016, 77), to the controlled palatial economy in LH IIIB (Voutsaki 2010). Wright argues for the appearance of chiefdoms and the centralization of power and authority in MH III-LH II, replacing unstable factional leaderships in MH I-II (Wright 2008, 244). On a general level, thus, MH III-LHI was a formative period, a smorgasbord of innovation and diversity from which certain aspects were favoured through a process of consolidation during LH II and early LH IIIA, resulting in the socio-economically integrated system of uniformity and centralized control that characterize the LH IIIA-B period. The LH IIIC period constitutes a disintegration of palatial control and discontinuation of the process towards increasingly higher complexity during the preceding centuries. The 750-year period covered by our study can thus be seen as a slow cycle from release and reorganization in MH III-LH I, throughout the phases of exploitation (LH II-LH IIIA) and conservation (LH IIIB) to release and reorganization again in LH IIIC-EIA.

The level of resilience is likely to have been high during most of the LBA sequence. MH III-LH I was a formative period without rules (Wright 2006, 15; cf. Holling [2001]), and if the spread of tholoi as well as the level of ceramic standardization (cf. Nelson et al. [2011]) are taken as proxies for socio-political organization, LH II communities, although socially stratified, were still loosely organized regionally. This starts to change in LH IIIA, but the period LH II-LH IIIA as a whole displays many of the characteristics of the exploitation phase of the adaptive cycle; it is a period of growth and the accumulation of resources, connectivity and potential increases, diversity is still high and the system is open for external ideas (cf. Holling and Gunderson [2002]). In all, the Peloponnese in LH II-LH IIIA could be argued to be made up from a system of largely self-sustainable local power entities. Patterns of life were certainly more loosely arranged than they would be a century later during LH IIIB and the population density considerably lower in most regions. The system as a whole was therefore more likely to find workable alternatives or to

balance supply and demand in the time of diminishing returns, such as during the stable but arid climate conditions indicated by the Mavri Trypa record.

It is commonly argued that it was the growing needs of the regional centres and their need to control their expanding territories that necessitated centralization and specialized management (e.g. Wright [2008]). But, as argued by Voutsaki, '[c]entralization is not foremost a measure of power, but also a symptom of the fragility of the system' (Voutsaki 2010, 104). With the establishment of the palatial system in late LH IIIA–B, Mycenaean society developed from a largely communal organization to a more exclusionary system (Parkinson and Galaty 2007), a process that finds parallels in the transition from exploitation to conservation in the adaptive cycle. Indications of exclusionary tendencies can, for example, be found in the differences between the LH I and LH III architecture (Pantou 2014). Connectedness also increased (Parkinson and Galaty 2007; Voutsaki 2010). Even if the agricultural economy remained self-sustainable on a regional scale, smaller communities in palatially controlled regions were now linked to the palace in a network of interdependencies (Halstead 1999; Galaty, Nakassis, and Parkinson 2011). It is very likely that the stable wet climate conditions during the start of this period, from the end of LH II and throughout LH IIIA, aided this development. Most probably, however, it was the higher level of centralization of the decision-making bodies in the LH IIIA–B that facilitated the control needed to put the increased resources to large-scale use.

The more variable climate during LH IIIB may have made the function of the centralized decision-making bodies all the more important. Voices have been raised for the view that late LH IIIB palatial society was no longer a well-functioning system, statements for which Maran has provided an overview and outlined a strong rebuttal (Maran 2009, with references). The leading sections of Mycenaean society clearly retained their ability to mobilize human and natural resources. Such control mechanisms may have been vital for the upkeep of the established order, in particular in the face of the generally less favourable climate situation around *ca.* 1250 BC. The large-scale building programmes and landscape-engineering projects, as well as the administrative control suggested by the Linear B records, however, can also be read as conservative measures to uphold the status and authority of the Mycenaean elites (Whitelaw 2001; Maran 2009), a path-dependency that there was little potential to break from (cf. Schoon et al. [2011]). It may be that it was the strong interconnectedness and an increasing rigidity of its structures that in the end caused the demise of the palatial economies. As was recently suggested by Maran (2009), the main ingredient in 'the recipe of disaster' may have been the fact that the rulers of the Mycenaean kingdoms did not recognize the heavy toll their economic system and the costly building projects took on society (cf. Butzer [2005, 1779, 1797]). When the destructions happened, the system could not stand the strain and could not muster the needed resources to rebuild at the same scale as before. Climate variability, coupled with the arid decades around 1250 BC, is likely one of a concatenation of crises that eventually led to socio-political simplification (Butzer 2005, 1797). In a more positive light, however, the physical destructions of the palaces may have been the window of opportunity needed to 'escape' from an unsustainable socio-political structure (Holling 2001, 397). Such opportunities as well as the changes themselves would have been variably perceived between different groups of society, and may have been less sought by some, but could conceivably have re-activated resourcefulness across scales. Even in Tiryns, where there is considerable rebuilding soon after the destruction of the palatial structures, the finds suggest more discontinuity than continuity, and a reinvention of Mycenaean culture rather than reconstruction of what constituted Mycenaean cultural ways before the destructions (Maran 2015).

Conclusions: the resilience and persistence of ancient societies

The aim of this paper has been to evaluate the impact of the long-term perspective on our appreciation of the variable impact of climate change on human societies, an assessment further facilitated by comparing the periods against the backdrop of recently available climate information. Our results confirm the usefulness of this perspective as it highlights the potential for alternate scenarios in the face of climate change (Butzer 2012; Figure 1). Varying socio-political complexity, uniformity and population density come forth as preconditioning components and indicators for the inherent resilience of these societies under climate stress. In parallel, the long-term perspective offered in this paper shows that there is no unequivocal link between drier climate conditions and societal decline. The outcome of climate stress cannot be determined from the climate conditions alone. Long-term societal change should not be seen in isolation but needs to be contextualized within the framework of societal structures in place at different times. Furthermore, information about short-term climate variability should be incorporated. Climate volatility appears as a strong amplifier of the effects of climate change more generally, as recently argued by Kennett and Marwan (2015) based on case-studies in the Mexican and Andean highlands. Their conclusion that ‘stable climate conditions favour the formation of agrarian states, while persistently volatile climatic conditions can contribute to the episodic collapse of these complex societies’ (Kennett and Marwan 2015, 1), finds good parallels in the present case study.

Aridity and high variability in rainfall are likely to have contributed to the combined pressure on the Mycenaean palatial economies in LH IIIB and in the end possibly to the final dissolution of Mycenaean culture in LH IIIC. No such claim can be made in relation to the arid conditions during much of LH II, which did not have any lasting effect on societal expansion. The correspondence between the return to wetter conditions just before the end of the LH II period (around 1440 BC) and the period of renewed expansion in the generations thereafter may thus be purely coincidental, but it could also be part of the explanation for the renewed expansion in LH IIIA. In the case of LH II, we argue that the lower levels of societal complexity made the society of this period less sensitive to arid conditions. The aridity before 1440 BC, however, may have been less favourable for additional expansion. We suggest that the stable and wet climate during LH IIIA facilitated renewed and enhanced expansion. On the one hand, then, climate change provided in extension some of the conditions for the establishment of the palatial system on the Peloponnese. On the other, the realization of the potential for expansion supplied by a benign climate would likely not have been accomplished without the control functions already present in the LH II societies (cf. Kennett and Marwan [2015]).

A scenario of climate volatility can instead be applied to the LH IIIB period, but even more so to the LH IIIC period during which the final process towards the disintegration of the Mycenaean culture and socio-political fragmentation took place. We would like to forward the idea that the LH IIIC and Early Iron Age communities suffered from legacy effects due to socio-environmental mismatches that developed during earlier phases of the LBA (cf. Marston [2015, 597]). The same can to some degree be argued also for LH IIIB in a sense that the processes during LH IIIA ushered in an ultimately unsustainable economic system. The changing climate conditions towards the end of LH II provided the necessary setting to enable the accumulation of resources required for the more heterarchical socio-political situation in LH II to evolve into the full-scale palatial system. This palatial system thrived over 200 years of diverse climate conditions and appears to have retained decisiveness throughout this period, but it is likely that increasing costs and reductions in resilience ultimately shaped the end.

In summation, although actual causality between climate and societal change may very well be impossible to ascertain (Kintigh and Ingram 2018), arguments can certainly be made for climate variability as an amplifier of processes born from internal societal circumstances. Our results, however, stand as strong support for such environmental components as secondary to any socio-political factors, and that 'alternate pathways point to important qualities of resilience' (Butzer 2012; Figure 1). The next step will be to associate the climate information from Mavri Trypa with the detailed archaeological data from various parts of the Peloponnese at much higher chronological resolution – a first example of this, based around SW Messenia, was presented in Finné et al. (2017). Going into more chronological detail will mean that shorter time periods are investigated (with continued respect for the chronological uncertainties involved) and that more factors and potential indicators of societal resilience and vulnerability can be explored. Such perspectives would also allow a wider and more inclusive view of society than the socio-political perspective adopted here, allowing for different workings of resilience between various groups in a society. Such in-depth studies will also provide better opportunities to further explore leads and lags between climate and archaeological data, which in turn will act as a first step towards a richer understanding of correlation and causality. LH IIIA stands out as a period of utmost interest, much less understood and rarely discussed in relation to climate and may thus be an interesting point of departure.

Notes

1. Survey data was collated as part of the Domesticated Landscapes of the Peloponnese (DoLP) project and follow the NE to SW transect utilized for that project. Among the published intensive surveys, only the Laconia survey (Cavanagh et al. 1996) falls outside the transect. The surveys utilized represent those projects presently published with enough detail within the stipulated transect.

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No potential conflict of interest was reported by the authors.

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References

- Akers, P. D., G. A. Brook, L. B. Railsback, F. Liang, G. Iannone, J. W. Webster, P. P. Reeder, H. Cheng and R. L. Edwards. 2016. "An Extended and Higher-Resolution Record of Climate and Land Use from Stalagmite MC01 from Macal Chasm, Belize, Revealing Connections between Major Dry Events, Overall Climate Variability, and Maya Sociopolitical Changes." *Palaeogeography, Palaeoclimatology, Palaeoecology* 459 (October): 268–288. doi:10.1016/j.palaeo.2016.07.007.
- Allcock, S. L. 2017. "Long-Term Socio-Environmental Dynamics and Adaptive Cycles in Cappadocia, Turkey during the Holocene." *Quaternary International, Adaptive Cycles in Archaeology* 446 (August): 66–82. doi:10.1016/j.quaint.2017.06.065.
- Armstrong, C. G., A. C. Shoemaker, I. McKechnie, A. Ekblom, P. Szabó, P. J. Lane, A. C. McAlvay, et al. 2017. "Anthropological Contributions to Historical Ecology: 50 Questions, Infinite Prospects." *PLOS ONE* 12 (2): e0171883. doi:10.1371/journal.pone.0171883.
- Bietak, M. 2003. "Science versus Archaeology: Problems and Consequences of High Aegean Chronology." In *The Synchronisation of Civilisations in the Eastern Mediterranean in the Second Millennium B.C. II: Proceedings of the SCIEM 2000–Euroconference, Haindorf, 2nd of May–7th of May 2001*, edited by M. Bietak and E. Czerny, 23–33. Contributions to the Chronology of the Eastern Mediterranean 4. Wien: Verlag der Österreichischen Akademie der Wissenschaften.
- Blanton, R. E. 2010. "Collective Action and Adaptive Socioecological Cycles in Premodern States." *Cross-Cultural Research* 44 (1): 41–59. doi:10.1177/1069397109351684.
- Butzer, K. W. 2005. "Environmental History in the Mediterranean World: Cross-Disciplinary Investigation of Cause-And-Effect for Degradation and Soil Erosion." *Journal of Archaeological Science* 32 (12): 1773–1800. doi:10.1016/j.jas.2005.06.001.
- Butzer, K. W. 2012. "Collapse, Environment, and Society." *Proceedings of the National Academy of Sciences* 109 (10): 3632–3639. doi:10.1073/pnas.1114845109.
- Cavanagh, W. G., and C. Mee. 1998. *A Private Place, Death in Prehistoric Greece*. Studies in Mediterranean Archaeology 125. Jonsered: Paul Åströms Förlag.
- Cavanagh, W. G., J. Crowel, R. M. W. Catling, and G. Shipley. 1996. *The Laconia Survey: Continuity and Change in a Greek Rural Landscape*. Annual of the British School at Athens Supplementary Volume 26–27. London: British School at Athens.
- Cline, E. H. 2014. *1177 B.C.: The Year Civilization Collapsed*. Princeton: Princeton University Press.
- Costanza, R., S. van der Leeuw, K. Hibbard, S. Aulenbach, S. Brewer, M. Burek, S. Cornell, et al. 2012. "Developing an Integrated History and Future of People on Earth (IHOPE)." *Current Opinion in Environmental Sustainability, Open Issue* 4 (1): 106–114. doi:10.1016/j.cosust.2012.01.010.
- Davis, J. L., S. E. Alcock, J. Bennet, Y. Lolos, C. W. Shelmerdine, and E. Zangger. 1996. "The Pylos Regional Archaeological Project: Internet Edition." <http://classics.uc.edu/prap/>
- Drake, B. L. 2012. "The Influence of Climatic Change on the Late Bronze Age Collapse and the Greek Dark Ages." *Journal of Archaeological Science* 39 (6): 1862–1870. doi:10.1016/j.jas.2012.01.029.

- Faulseit, R. K., ed. 2016. *Beyond Collapse: Archaeological Perspectives on Resilience, Revitalization, and Transformation in Complex Societies*. Center for Archaeological Investigations, Occasional Papers 42. Carbondale, Illinois: Southern Illinois University Press.
- Finné, M., and E. Weiberg. 2018. "Climate Change and Ancient Societies: Facing up to the Challenge of Chronological Control." In *The Resilience of Heritage: Cultivating a Future of the Past. Essays in Honour of Professor Paul Sinclair*, edited by A. Ekblom, C. Isendahl, and K.-J. Lindholm. Studies in Global Archaeology 23. Uppsala: Uppsala University.
- Finné, M., K. Holmgren, C.-C. Shen, H.-M. Hu, M. Boyd, and S. Stocker. 2017. "Late Bronze Age Climate Change and the Destruction of the Mycenaean Palace of Nestor at Pylos." *PLOS ONE* 12 (12): e0189447. doi:10.1371/journal.pone.0189447.
- Finné, M., M. Bar-Matthews, K. Holmgren, H. S. Sundqvist, I. Liakopoulos, and Q. Zhang. 2014. "Speleothem Evidence for Late Holocene Climate Variability and Floods in Southern Greece." *Quaternary Research* 81 (2): 213–227. doi:10.1016/j.yqres.2013.12.009.
- Fitzsimons, R. D. 2011. "Monumental Architecture and the Construction of the Mycenaean State." In *State Formation in Italy and Greece: Questioning the Neoevolutionist Paradigm*, edited by N. Terrenato and D. C. Haggis, 75–118. Oxford: Oxbow Books.
- Foxhall, L. 1995. "Bronze to Iron: Agricultural Systems and Political Structures in Late Bronze Age and Early Iron Age Greece." *The Annual of the British School at Athens* 90: 239–250. doi:10.1017/S006824540001618X.
- Foxhall, L. 2014. "Households, Hierarchies, Territories and Landscapes in Bronze Age and Iron Age Greece." In *The Cambridge Prehistory of the Bronze and Iron Age Mediterranean*, edited by A. BernardB. Knapp and P. van Dommelen, 417–436. Cambridge: Cambridge University Press.
- Fuchs, M. 2007. "An Assessment of Human versus Climatic Impacts on Holocene Soil Erosion in NE Peloponnese, Greece." *Quaternary Research* 67 (3): 349–356. doi:10.1016/j.yqres.2006.11.008.
- Galaty, M. L., D. Nakassis, and W. A. Parkinson, eds. 2011. "Redistribution in Aegean Palatial Societies." *American Journal of Archaeology* 115 (2): 175–244. doi:10.3764/aja.115.2.0175.
- Green, S., and M. Lemon. 1996. "Perceptual Landscapes in Agrarian Systems: Degradation Processes in North-Western Epirus and the Argolid Valley, Greece." *Ecumene* 3 (2): 181–199. doi:10.1177/147447409600300204.
- Gronenborn, D., H.-C. Strien, S. Dietrich, and F. Sirocko. 2014. "'Adaptive Cycles' and Climate Fluctuations: A Case Study from Linear Pottery Culture in Western Central Europe." *Journal of Archaeological Science, the World Reshaped: Practices and Impacts of Early Agrarian Societies* 51 (November): 73–83. doi:10.1016/j.jas.2013.03.015.
- Gunderson, L. H., and C. S. Holling, eds. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington, DC: Island Press.
- Halstead, P., and J. O'Shea. 1989. "Introduction: Cultural Responses to Risk and Uncertainty." In *Bad Year Economics: Cultural Responses to Risk and Uncertainty*, edited by P. Halstead and J. O'Shea, 1–7. Cambridge: Cambridge University Press.
- Halstead, P. 1989. "The Economy Has a Normal Surplus: Economic Stability and Social Change among Early Farming Communities of Thessaly, Greece." In *Bad Year Economics: Cultural Responses to Risk and Uncertainty*, edited by P. Halstead and J. O'Shea, 68–80. Cambridge: Cambridge University Press.
- Halstead, P. 1999. "Surplus and Share-Croppers: The Grain Productions Strategies of Mycenaean Palaces." In *Meletemata: Studies in Aegean Archaeology Presented to Malcolm H. Wiener as He Enters His 65th Year*, edited by P. P. Betancourt and M. H. Wiener, 319–326. Aegaeum 20. Liège: Université de Liège.
- Halstead, P. 2001. "Mycenaean Wheat, Flax and Sheep." In *Economy and Politics in the Mycenaean Palace States: Proceedings of a Conference Held on 1-3 July 1999 in the Faculty of Classics, Cambridge*, edited by S. Voutsaki and J. T. Killen, 38–50. Cambridge Philological Society Supplementary Volume 27. Cambridge: Cambridge Philological Society.
- Heymann, C., O. Nelle, W. Dörfler, H. Zagana, N. Nowaczyk, J. Xue, and I. Unkel. 2013. "Late Glacial to Mid-Holocene Palaeoclimate Development of Southern Greece Inferred from the Sediment Sequence of Lake Stymphalia (Ne-Peloponnese)." *Quaternary International* 302 (July): 42–60. doi:10.1016/j.quaint.2013.02.014.
- Holling, C. S. 2001. "Understanding the Complexity of Economic, Ecological, and Social Systems." *Ecosystems* 4 (5): 390–405. doi:10.1007/s10021-001-0101-5.
- Holling, C. S., and L. H. Gunderson. 2002. "Resilience and Adaptive Cycles." In *Panarchy: Understanding Transformations in Human and Natural Systems*, edited by L. H. Gunderson and C. S. Holling, 25–62. Washington, DC: Island Press.

- Hope Simpson, R., and D. K. Hagel. 2006. *Mycenaean Fortifications, Highways, Dams and Canals*. Studies in Mediterranean Archaeology 133. Sävedalen: Paul Åströms Förlag.
- Jameson, M. H., C. N. Runnels, T. H. Van Andel, and M. H. Munn. 1994. *A Greek Countryside: The Southern Argolid from Prehistory to the Present Day*. Stanford, CA: Stanford University Press.
- Kaniewski, D., and E. Van Campo. 2017. "3.2 Ka BP Megadrought and the Late Bronze Age Collapse." In *Megadrought and Collapse: From Early Agriculture to Angkor*, edited by H. Weiss, 161–182. New York, NY: Oxford University Press.
- Kaniewski, D., J. Guiot, and E. Van Campo. 2015. "Drought and Societal Collapse 3200 Years Ago in the Eastern Mediterranean: A Review." *Wiley Interdisciplinary Reviews: Climate Change* 6 (4): 369–382. doi:10.1002/wcc.345.
- Katrantsiotis, C., E. Norström, K. Holmgren, J. Risberg, and A. Skelton. 2016. "High-Resolution Environmental Reconstruction in SW Peloponnese, Greece, Covering the Last c. 6000 Years: Evidence from Agios Floros Fen, Messenian Plain." *The Holocene* 26 (2): 188–204. doi:10.1177/0959683615596838.
- Kennett, D. J., and N. Marwan. 2015. "Climatic Volatility, Agricultural Uncertainty, and the Formation, Consolidation and Breakdown of Preindustrial Agrarian States." *Philosophical Transactions of the Royal Society A* 373 (2055): 20140458. doi:10.1098/rsta.2014.0458.
- Killen, J. T. 1998. "The Role of the State in Wheat and Olive Production in Mycenaean Crete." *Aevum* 72 (1): 19–23.
- Kintigh, K. W., J. H. Altschul, M. C. Beaudry, R. D. Drennan, A. P. Kinzig, T. A. Kohler, W. F. Limp, et al. 2014. "Grand Challenges for Archaeology." *American Antiquity* 79 (1): 5–24. doi:10.7183/0002-7316.79.1.5.
- Kintigh, K. W., and S. E. Ingram. 2018. "Was the Drought Really Responsible? Assessing Statistical Relationships between Climate Extremes and Cultural Transitions." *Journal of Archaeological Science* 89 (January): 25–31. doi:10.1016/j.jas.2017.09.006.
- Knapp, A. B., and S. W. Manning. 2016. "Crisis in Context: The End of the Late Bronze Age in the Eastern Mediterranean." *American Journal of Archaeology* 120 (1): 99. doi:10.3764/aja.120.1.0099.
- Kok, M., M. Lüdeke, P. Lucas, T. Sterzel, C. Walther, P. Janssen, D. Sietz, and I. de Soysa. 2016. "A New Method for Analysing Socio-Ecological Patterns of Vulnerability." *Regional Environmental Change* 16 (1): 229–243. doi:10.1007/s10113-014-0746-1.
- Kroll, H. 2000. "Agriculture and Arboriculture in Mainland Greece at the Beginning of the First Millennium BC." *Pallas* 61–68.
- Lane, P. J. 2015. "Just How Long Does 'Long-Term' Have to Be? Matters of Temporal Scale as Impediments to Interdisciplinary Understanding in Historical Ecology." In *The Oxford Handbook of Historical Ecology and Applied Archaeology*, edited by C. Isendahl and D. Stump. Oxford: Oxford University Press. <http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199672691.001.0001/oxfordhb-9780199672691-e-5?print=pdf>
- Lantzas, K. 2016. "Reconsidering Collapse: Identity, Ideology, and Postcollapse Settlement in the Argolid." In *Beyond Collapse: Archaeological Perspectives on Resilience, Revitalization, and Transformation in Complex Societies*, edited by R. K. Faulseit, 459–485. Center for Archaeological Investigations Occasional Papers 42. Carbondale, Illinois: Southern Illinois University Press.
- Lawrence, D., G. Philip, H. Hunt, L. Snape-Kennedy, and T. J. Wilkinson. 2016. "Long Term Population, City Size and Climate Trends in the Fertile Crescent: A First Approximation." *PLOS ONE* 11 (3): e0152563. doi:10.1371/journal.pone.0152563.
- Loader, N. C. 1995. "The Definition of Cyclopean: An Investigation into the Origins of the LH III Fortifications on Mainland Greece." PhD thesis, Durham University, Durham. <http://etheses.dur.ac.uk/5374/>
- Maheras, P., and C. Anagnostopoulou. 2003. "Circulation Types and Their Influence on the Interannual Variability and Precipitation Changes in Greece." In *Mediterranean Climate*, edited by H.-J. Bolle, 215–239. Regional Climate Studies. Berlin: Springer Verlag.
- Manning, S. W. 2007. "Clarifying the 'High' V. 'Low' Aegean/Cypriot Chronology for the Mid Second Millennium BC: Assessing the Evidence, Interpretive Frameworks, and Current State of the Debate." In *The Synchronisation of Civilisations in the Eastern Mediterranean in the Second Millennium B.C. Proceedings of the SCIEM 2000-2nd EuroConference, Vienna, 28th of May-1st of June 2003 III*, edited by M. Bietak, E. Czerny, I. Kaplan, and A. Schwab, 101–137. Wien: Verlag der Österreichischen Akademie der Wissenschaften.
- Manning, S. W. 2010. "Chronology and Terminology." In *The Oxford Handbook of the Bronze Age Aegean (ca. 3000-1000 BC)*, edited by E. H. Cline, 11–28. Oxford: Oxford University Press.

- Manning, S. W., C. B. Ramsey, W. Kutschera, T. Higham, B. Kromer, P. Steier, and E. M. Wild. 2006. "Chronology for the Aegean Late Bronze Age 1700-1400 B.C." *Science* 312 (5773): 565–569. doi:10.1126/science.1125682.
- Maran, J. 1998. *Kulturwandel Auf Dem Griechischen Festland Und Den Kykladen Im Späten 3. Jahrtausend v. Chr. : Studien Zu Den Kulturellen Verhältnissen In Südosteuropa Und Dem Zentralen Sowie östlichen Mittelmeerraum In Der Späten Kupfer- Und Frühen Bronzezeit*. Universitätsforschungen Zur Prähistorischen Archäologie 53. Bonn: Habelt.
- Maran, J. 2009. "The Crisis Years?: Reflections on Signs of Instability in the Last Decades of the Mycenaean Palaces." *Scienze dell'Antichità* 15 (15): 241–262.
- Maran, J. 2011. "Lost in Translation: The Emergence of Mycenaean Culture as a Phenomenon of Glocalization." In *Interweaving Worlds: Systemic Interactions in Eurasia, 7th to 1st Millennia BC*, edited by T. C. Wilkinson, S. Sherratt, and J. Bennet, 282–294. Oakville, CT: Oxbow Books.
- Maran, J. 2015. "Tiryns and the Argolid in Mycenaean Times: New Clues and Interpretations." In *Mycenaeans up to Date: The Archaeology of the North-Eastern Peloponnese : Current Concepts and New Directions*, edited by A.-L. Schallin and I. Tournavitou, 277–293. Skrifter Utgivna Av Svenska Institutet I Athen-4° 56. Stockholm: Svenska Institutet i Athen.
- Marcus, J. 1998. "The Peaks and Valleys of Ancient States: An Extension of the Dynamic Model." In *Archaic States*, edited by G. M. Feinman and J. Marcus, 59–94. Santa Fe, NM: School of American Research Press.
- Marston, J. M. 2011. "Archaeological Markers of Agricultural Risk Management." *Journal of Anthropological Archaeology* 30 (2): 190–205. doi:10.1016/j.jaa.2011.01.002.
- Marston, J. M. 2015. "Modeling Resilience and Sustainability in Ancient Agricultural Systems." *Journal of Ethnobiology* 35 (3): 585–605. doi:10.2993/etbi-35-03-585-605.1.
- McAnany, P. A., and N. Yoffee. 2010. *Questioning Collapse: Human Resilience, Ecological Vulnerability, and the Aftermath of Empire*. Cambridge: Cambridge University Press.
- Mee, C., and H. A. Forbes, eds. 1997. *A Rough and Rocky Place: The Landscape and Settlement History of the Methana Peninsula, Greece: Results of the Methana Survey Project, Sponsored by the British School at Athens and the University of Liverpool*. Liverpool: Liverpool University Press.
- Middleton, G. D. 2010. *The Collapse of Palatial Society in LBA Greece and the Postpalatial Period*. Oxford: Archaeopress.
- Middleton, G. D. 2017. *Understanding Collapse: Ancient History and Modern Myths*. New York, NY: Cambridge University Press.
- Nelson, M. C., M. Hegmon, S. R. Kulow, M. A. Peeples, K. W. Kintigh, and A. P. Kinzig. 2011. "Resisting Diversity: A Long-Term Archaeological Study." *Ecology and Society* 16 (1): 25. doi:10.5751/ES-03887-160125.
- Nelson, M. C., S. E. Ingram, A. J. Dugmore, R. Streeter, M. A. Peeples, T. H. McGovern, M. Hegmon, et al. 2016. "Climate Challenges, Vulnerability, and Food Security." *Proceedings of the National Academy of Sciences* 113 (2): 298–303. doi:10.1073/pnas.1506494113.
- Pantou, P. A. 2014. "An Architectural Perspective on Social Change and Ideology in Early Mycenaean Greece." *American Journal of Archaeology* 118 (3): 369–400. doi:10.3764/aja.118.3.0369.
- Parkinson, W. A., and M. L. Galaty. 2007. "Secondary States in Perspective: An Integrated Approach to State Formation in the Prehistoric Aegean." *American Anthropologist* 109 (1): 113–129. doi:10.1525/aa.2007.109.1.113.
- Redman, C. L., and A. P. Kinzig. 2003. "Resilience of past Landscapes: Resilience Theory, Society, and the Longue Durée." *Conservation Ecology* 7 (1): 14. doi:10.5751/ES-00510-070114.
- Roberts, N. 2011. "'Living with a Moving Target': Long-Term Climatic Variability and Environmental Risk in Dryland Regions." In *Sustainable Lifeways: Cultural Persistence in an Ever-Changing Environment*, edited by N. F. Miller, K. M. Moore, and K. Ryan. Penn Museum International Research Conferences 3. Philadelphia, PA: University of Pennsylvania Press.
- Rutter, J. B. 2001. "The Prepalatial Bronze Age of the Southern and Central Greek Mainland." In *Aegean Prehistory: A Review*, edited by T. Cullen, 95–147. Boston: Archaeological Institute of America.
- Rutter, J. B. 2010. "Mycenaean Pottery." In *The Oxford Handbook of the Bronze Age Aegean (Ca. 3000-1000 BC)*, edited by E. H. Cline, 415–429. Oxford: Oxford University Press.
- Rutter, J. B. 2015. "Ceramic Technology in Rapid Transition. The Evidence from Settlement Deposits of the Shaft Grave Era at Tsoungiza (Corinthia)." In *The Transmission of Technical Knowledge in the Production of Ancient Mediterranean Pottery: Proceedings of the International Conference at the*

- Austrian Archaeological Institute at Athens 23rd-25th November 2012*, edited by W. Gaus, G. Klebinder-Gauß, and C. von Rüden, 207–223. Wien: Österreichisches Archäologisches Institut.
- Schoon, M., C. Fabricius, J. M. Anderies, and M. Nelson. 2011. "Synthesis: Vulnerability, Traps, and Transformations—Long-Term Perspectives from Archaeology." *Ecology and Society* 16 (2): 24. doi:10.5751/ES-04184-160224.
- Tainter, J. A. 1988. *The Collapse of Complex Societies*. New Studies in Archaeology. Cambridge: Cambridge University Press.
- Tainter, J. A. 2000. "Problem Solving: Complexity, History, Sustainability." *Population and Environment* 22 (1): 3–41. doi:10.1023/A:1006632214612.
- Unkel, I., A. Schimmelmann, C. Shriner, J. Forsén, C. Heymann, and H. Brückner. 2014. "The Environmental History of the Last 6500 Years in the Asea Valley (Peloponnese, Greece) and Its Linkage to the Local Archaeological Record." *Zeitschrift Für Geomorphologie, Supplementary Issues* 58 (2): 89–107. doi:10.1127/0372-8854/2014/S-00160.
- Valamoti, S. M. 2011. "Flax in Neolithic and Bronze Age Greece: Archaeobotanical Evidence." *Vegetation History and Archaeobotany* 20 (6): 549–560. doi:10.1007/s00334-011-0304-4.
- Valamoti, S. M. 2016. "Millet, the Late Comer: On the Tracks of *Panicum Miliaceum* in Prehistoric Greece." *Archaeological and Anthropological Sciences* 8 (1): 51–63. doi:10.1007/s12520-013-0152-5.
- Voutsaki, S. 2010. "From the Kinship Economy to the Palatial Economy: The Argolid in the Second Millennium BC." In *Political Economies of the Aegean Bronze Age: Papers from the Langford Conference, Florida State University, Tallahassee, 22-24 February 2007*, edited by D. J. Pullen, 86–111. Oxford: Oxford Books.
- Voutsaki, S. 2016. "From Reciprocity to Centricity: The Middle Bronze Age in the Greek Mainland." *Journal of Mediterranean Archaeology* 29 (1): 70–78. doi:10.1558/jmea.v29i1.2299.
- Voutsaki, S., S. Dietz, and A. J. Nijboer. 2009. "Radiocarbon Analyses and the History of the East Cemetery, Asine." *Opuscula. Annual of the Swedish Institutes at Athens and Rome* 2: 31–52. doi:10.30549/opathrom-02-03.
- Weiberg, E., I. Unkel, K. Kouli, K. Holmgren, P. Avramidis, A. Bonnier, F. Dibble, et al. 2016. "The Socio-Environmental History of the Peloponnese during the Holocene: Towards an Integrated Understanding of the Past." *Quaternary Science Reviews* 136 (March): 40–65. doi:10.1016/j.quascirev.2015.10.042.
- Weiss, H., ed. 2017a. *Megadrought and Collapse from Early Agriculture to Angkor*. New York, NY: Oxford University Press.
- Weiss, H. 2017b. "Megadrought, Collapse, and Causality." In *Megadrought and Collapse from Early Agriculture to Angkor*, edited by H. Weiss, 1–31. New York, NY: Oxford University Press.
- Wells, B., and C. N. Runnels, eds. 1996. *The Berbati-Limnes Archaeological Survey, 1988-1990*. Skrifter Utgivna Av Svenska Institutet I Athen-4° 44. Stockholm: Svenska institutet i Athen.
- Whitelaw, T. 2001. "Reading between the Tablets: Assessing Mycenaean Palatial Involvement in Ceramic Production and Consumption." In *Economy and Politics in the Mycenaean Palace States: Proceedings of a Conference Held on 1-3 July 1999 in the Faculty of Classics, Cambridge*, edited by S. Voutsaki and J. T. Killen, 51–79. Cambridge Philological Society Supplement 27. Cambridge: Cambridge Philological Society.
- Wright, J. C. 2004. "The Emergence of Leadership and the Rise of Civilization in the Aegean." In *The Emergence of Civilisation Revisited*, edited by J. C. Barrett and P. Halstead, 64–89. Sheffield Studies in Aegean Archaeology 6. Oxford: Oxbow Books.
- Wright, J. C. 2006. "The Formation of the Mycenaean Palace." In *Ancient Greece from the Mycenaean Palaces to the Age of Homer*, edited by S. Deger-Jalkotzy and I. S. Lemos, 7–52. Edinburgh: Edinburgh University Press.
- Wright, J. C. 2008. "Early Mycenaean Greece." In *The Cambridge Companion to the Aegean Bronze Age*, edited by C. W. Shelmerdine, 230–257. New York: Cambridge University Press.
- Xoplaki, E., J. Luterbacher, R. Burkard, I. Patrikas, and P. Maheras. 2000. "Connection between the Large-Scale 500 hPa Geopotential Height Fields and Precipitation over Greece during Wintertime." *Climate Research* 14 (2): 129–146. doi:10.3354/cr014129.
- Yoffee, N. 2010. "Collapse in Ancient Mesopotamia: What Happened, What Didn't." In *Questioning Collapse: Human Resilience, Ecological Vulnerability, and the Aftermath of Empire*, edited by P. A. McAnany and N. Yoffee, 176–203. Cambridge: Cambridge University Press.