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The 4.2 ka Event and the End of the Maltese "Temple Period"

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The small size and relatively challenging environmental conditions of the semi-isolated Maltese archipelago mean that the area offers an important case study of societal change and human-environment interactions. Following an initial phase of Neolithic settlement, the "Temple Period" in Malta began ~5.8 thousand years ago (ka), and came to a seemingly abrupt end ~4.3 ka, and was followed by Bronze Age societies with radically different material culture. Various ideas concerning the reasons for the end of the Temple Period have been expressed. These range from climate change, to invasion, to social conflict resulting from the development of a powerful "priesthood." Here, we explore the idea that the end of the Temple Period relates to the 4.2 ka event. The 4.2 ka event has been linked with several examples of significant societal change around the Mediterranean, such as the end of the Old Kingdom in Egypt, yet its character and relevance have been debated. The Maltese example offers a fascinating case study for understanding issues such as chronological uncertainty, disentangling cause and effect when several different processes are involved, and the role of abrupt environmental change in impacting human societies. Ultimately, it is suggested that the 4.2 ka event may have played a role in the end of the Temple Period, but that other factors seemingly played a large, and possibly predominant, role. As well as our chronological modelling indicating the decline of Temple Period society in the centuries before the 4.2 ka event, we highlight the possible significance of other factors such as a plague epidemic.

Keywords: Malta, collapse, climate, abrupt, aridity, extreme events, plague, radiocarbon

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INTRODUCTION

The Maltese archipelago, covering 316 km^2 in the central Mediterranean (**Figure 1**), has a rich archaeological record. The Temple Period [~5.8–4.3 thousand years ago (ka)] is, as its name suggests, most famous for its thirty or so megalithic "temples" (**Figures 1**, **2**), as well as other sites such as the Ħal Saflieni hypogeum (**Figure 3**), and has been widely discussed in the literature (e.g., Trump, 1966, 2002; Evans, 1971; Bonanno, 1986, 2017; Bonanno et al., 1990; Cilia, 2004; Malone et al., 2009a, 2020b; Sagona, 2015; Fenech et al., 2020). Renfrew (1973, p. 161) for instance suggested that temples "lay claim to be the world's most impressive prehistoric monuments."

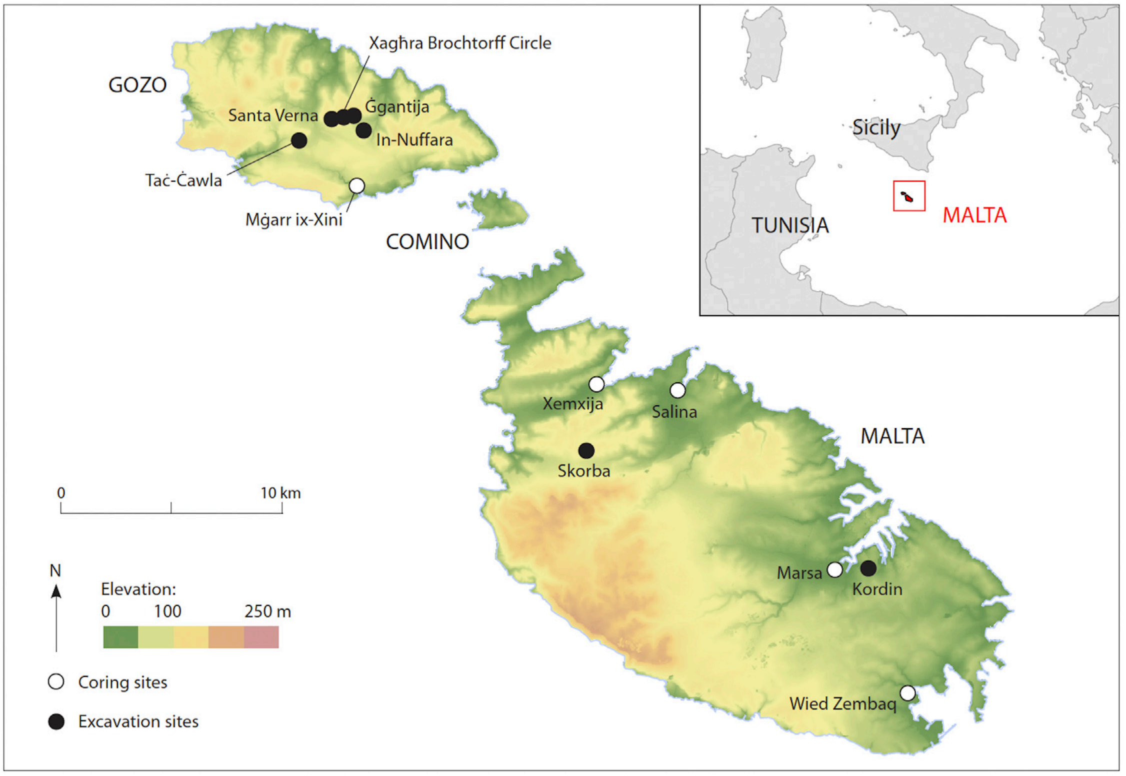

FIGURE 1 | Map of key archaeological sites and palaeoenvironmental coring sites (reproduced from Malone et al., 2020b; CC-BY-ND licence).

FIGURE 2 | Examples of Maltese megalithic "temples." Top: Ħaġar Qim, Bottom: Mnajdra. Human scale: 107 cm high.

FIGURE 3 | Part of the remarkable Ħal Saflieni hypogeum, where passages and chambers were dug out to create a long-term Temple Period burial site. (Photo courtesy of Heritage Malta. Photo credit: Clive Vella. Copyright image not to be reused without permission of Heritage Malta).

Various possible reasons for the end of the Temple Period have been suggested, including famine, drought, disease, the arrival of new groups of humans, and societal unrest (e.g., Trump, 1966, 1976, 2002; Evans, 1971; Bonanno, 1986, 1993, 2017; Stoddart et al., 1993; Malone and Stoddart, 2013; Broodbank, 2015; Cazzella and Recchia, 2015; Sagona, 2015). While traditionally seen as a "collapse" of "catastrophic suddenness" (Trump, 1976, p. 605), in recent years some have suggested that the end of the Temple Period is better seen as a more gradual process (e.g., Cazzella and Recchia, 2015; Sagona, 2015; Pirone, 2017; McLaughlin et al., 2018). Sagona (2015, p.115) for instance suggests that people "turned their back on the old way of life because they had an economic alternative." Conversely, the similar timing of the end of the Temple Period and the 4.2 ka climatic event has been suggested to indicate a possible correlation (e.g., Broodbank, 2015; McLaughlin et al., 2018; Grima et al., 2020).

The 4.2 ka event is widely discussed as a short-term, decadal to centennial, climate change event (see also Stewart et al., this volume). Others, however, have also seen it as a longer-term episode from ~4.3 to 3.8 ka. To some, the 4.2 ka event can be seen as a "global megadrought" (e.g., Weiss, 2015, 2016, 2017; Ran and Chan, 2019). In the case of the Mediterranean region and surroundings, it has been argued that from the Atlantic to Mesopotamia it was a coherent and synchronous climate event which saw an abrupt decline in precipitation (e.g., Weiss, 2015, 2016, 2017; Adams, 2017). However, others have pointed to considerable climatic variability at this time (e.g., Kaniewski et al., 2018; Bradley and Bakke, 2019). In several parts of the world there were actually wetter rather than drier conditions at 4.2 ka (e.g., Railsback et al., 2018). Even in and around the Mediterranean which is often regarded as a key area where the 4.2 ka event caused drought, there were areas where precipitation seemingly increased, such as parts of the Maghreb, Iberia, and the Balkans (e.g., Bini et al., 2019; Zielhofer et al., 2019). There are various possible reasons for this apparent discord. Precipitation in the Mediterranean primarily reflects winter rainfall as a result of the North Atlantic Oscillation. The weakening of this is seen as the reason for drought induced by the 4.2 ka event, yet how this interacts with other climate systems may be complex (e.g., Di Rita et al., 2018; Bini et al., 2019; Perşoiu et al., 2019). While driven by North Atlantic circulation, much of the precipitation in the Mediterranean reflects local cyclogenesis that is influenced by the climatic conditions of the surrounding areas, such as the position of the Intertropical Convergence Zone (ITCZ) and the North African high-pressure cell to the south of the Mediterranean (e.g., Rohling et al., 2015).

While some of the apparent complexity of Mediterranean palaeoclimate may reflect poor chronological resolution of palaeoenvironmental archives, it does seem that climate varied considerably around the Mediterranean around 4.2 ka (e.g., Di Rita et al., 2018; Kaniewski et al., 2018; Bini et al., 2019; Finné et al., 2019; Perşoiu et al., 2019; Peyron et al., 2019). As discussed in **Supplementary Material 1**, records from Sicily and Italy frequently indicate arid conditions in the later third millennium BC, but the details of this vary considerably. In some records, peak aridity is ~4.4 ka, while in others it is ~4 ka. Unpacking the extent to which such variation reflects chronological uncertainty, microtopographic and geographic variability, and genuine regional scale climate differences is a challenging exercise.

The Mediterranean and surroundings saw significant societal changes around 4.2 ka. In areas such as southern France (Carozza et al., 2015) and Italy (Leonardi et al., 2015; Pacciarelli et al., 2015; Stoddart et al., 2019) the transition from the Chalcolithic to the Bronze Age occurred around this time. The more generally discussed changes putatively relating to the 4.2 ka event occurred within the Bronze Age societies of the eastern Mediterranean (e.g., Jung and Wenninger, 2015; Adams, 2017; Lawrence et al., 2021; Palmisano et al., 2021), as the transition to the Bronze Age occurred earlier here. The end of the Old Kingdom in Egypt has long been suggested to relate to aridity at 4.2 ka (e.g., Bell, 1971; Williams, 2019), as has the collapse of the Akkadian Empire (e.g., deMenocal, 2001; Weiss, 2015, 2016, 2017). In the case of the Akkadians for instance, it has been claimed that an estimated reduction in rainfall of 30–50% in Mesopotamia in less than 5 years caused the "sudden, abrupt, unforeseen" collapse of the Akkadian Empire (Weiss, 2015, p. 39).

Other researchers have, however, raised concerns regarding correlation between these societal changes and aridification at 4.2 ka. Moreno García (2015), for instance, suggests that the end of the Old Kingdom was actually driven by political conflict between central and regional powers in Egypt (see also Kanawti, 2003). Likewise, the Akkadian Empire was under both external pressure, such as the regular incursions of the Gutians from the Zagros Mountains, and internal pressure, as shown by the "Great Rebellion" a few years before 4.2 ka, which was only put down by killing thousands of people (Tinney, 1985).

While critics of "environmental determinism" may highlight such political and historically contingent aspects, it remains true that significant and seemingly synchronous changes did occur in several societies around 4.2 ka (e.g., Broodbank, 2015). It is also the case that for both Egypt (e.g., Stanley, 2019) and Mesopotamia (e.g., Carolin et al., 2019) there is environmental evidence of significant climate change around 4.2 ka. Clearly though, the way that environmental change impacts human societies depends on a variety of aspects of resilience and vulnerability. Palmisano and others (2021, p. 23), for instance, highlight evidence for population decline around 4.2 ka in many parts of Southwest Asia, yet suggest that this should be "viewed in the context of the preceding demographic boom." In other words, in regions where such booms had not occurred, and consequently had not given rise to urban areas reliant on other areas for food supply, we should expect different societal reactions to the 4.2 ka event. From rural and non-elite perspectives, the 4.2 ka may have been felt very differently (e.g., Schwarz, 2007; Chase et al., 2020). Likewise, other areas saw very different kinds of change to those seen in Egypt and Mesopotamia. For instance, while mainland Greece shows indications of collapse (e.g., Wiener, 2014), on Crete there was an increase in social complexity and a seemingly prosperous society at 4.2 ka (Wiener, 2014; Broodbank, 2015; Manning, 2017). Given the distinctive societal characteristics which were common to Mediterranean islands, such as Cyprus and Malta, we might expect distinct responses to the 4.2 ka event in such settings. We see here a particular perspective on the theme of islands as pertinent natural "laboratories" (e.g., Sahlins, 1955; Mead, 1957; Evans, 1973, 1977; Malone et al., 2020b).

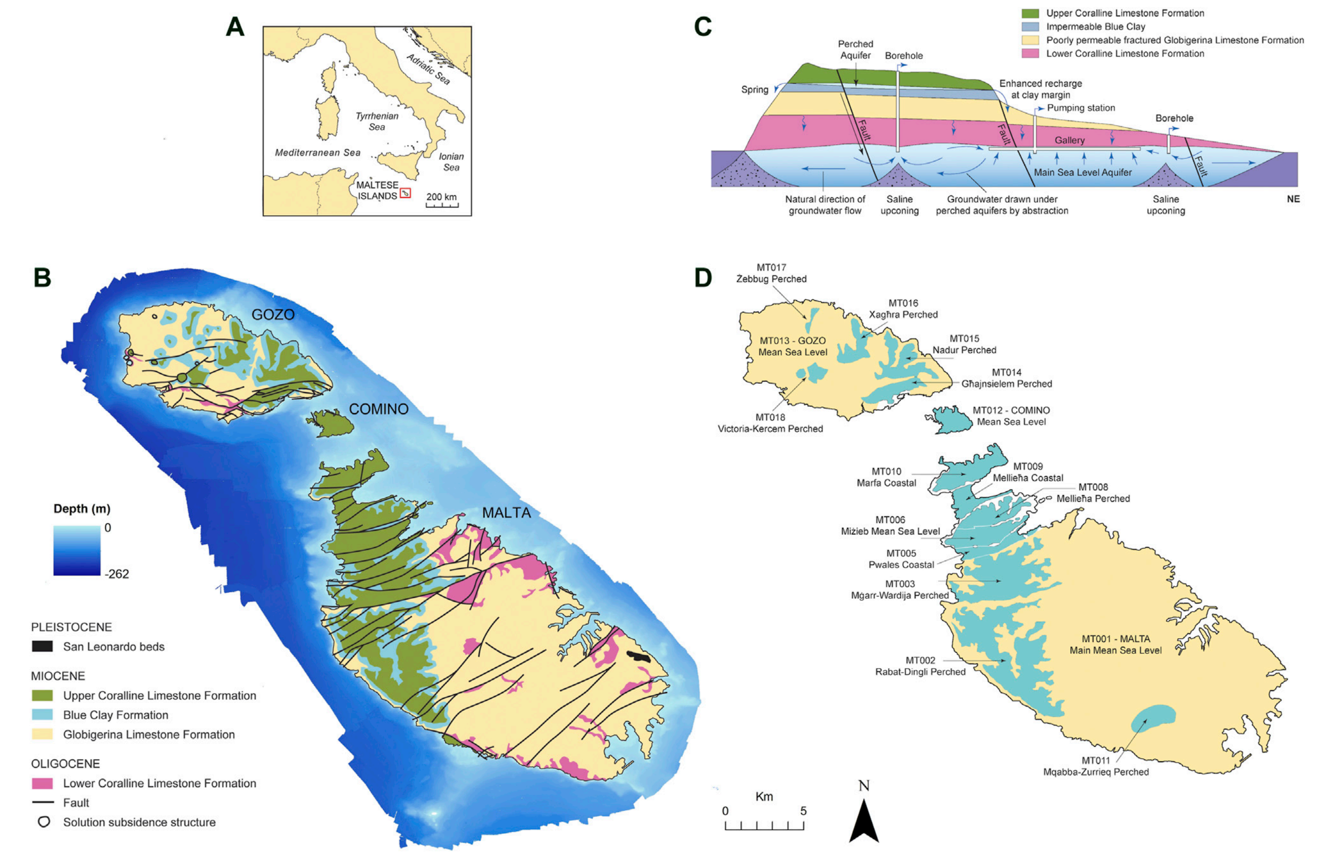

FIGURE 4 | The location **(A)**, geology, faulting, and bathymetry **(B)**, and aquifer structure **(C,D)** of the Maltese Islands (Geological map redrawn from Oil Exploration Directorate, 1993; Bathymetric map from ERDF LIDAR data, 2012; aquifer data from Malta Resource Authority, 1994).

Finally, an important lesson in the dangers of assumed correlation comes from the east Mediterranean Levant. There the "collapse" of urbanised Early Bronze Age society had traditionally been suggested to correlate with the end of the Old Kingdom of Egypt, that is with the 4.2 ka event. However, radiocarbon dating in recent years has pushed back the end of the Early Bronze Age III to several centuries before 4.2 ka, at around 4.5 ka (e.g., Genz, 2015; Adams, 2017; Greenberg, 2017; Höflmayer, 2017). Rather than collapse, it seems more a case of adaptation. Specific examples such as that of the southern Levant, and the general risks in "wiggle matching" processes which occurred within several centuries of each other should be kept in mind.

Against this background, we now turn to Malta. Our aim is to explore the end of the Temple Period, including the idea that this relates to the 4.2 ka event. We review various relevant aspects of geology, material culture, chronological modelling, agriculture and water management, trade and connectivity, and the possibility of a plague epidemic.

Maltese Geology, Climate, and Ecology

The Maltese Archipelago consists of two main islands, Malta (246 km^2) and Għawdex (Gozo) (67 km^2), along with several smaller islets. Malta is located just under 100 km south of Sicily, 300 km east of Tunisia, and 350 km north of Libya (**Figures 1**, **4**). Geologically, the islands consist of an Oligo-Miocene (~30-5 million years ago) sequence of sedimentary rock formations (**Figure 4**) (e.g., Pedley et al., 2012; Scerri, 2019; Chatzimpaloglou et al., 2020a). Most of the sequence consists of limestone, with relatively hard, and karstic, Upper and Lower Coralline Limestones bracketing the sequence. Above the Lower Coralline Limestone is the Globigerina Limestone, which includes phosphatized hardgrounds, and limited chert. Overlying this is the Blue Clay Formation. Subsequent tectonic and geomorphological processes bring a complexity to the landscapes of the archipelago (Hunt, 1997; Schembri, 1997; Gauci and Schembri 2019).

As well as being resource poor in terms of raw material such as metal ores and knappable stone, Malta is a semi-arid region. Precipitation often takes the form of short but intense winter storms, with high evaporation during long and hot summers. Unfortunately, high-resolution palaeoclimatic and palaeoecological data is scarce for the Maltese Islands. Precipitation data for the recent past highlights the considerable variability in annual rainfall, which presumably also applied in the past. In the 1854–1995 period, for instance, the lowest annual rainfall recorded was 191 mm, while the highest was 1,031 mm (Schembri et al., 2009). Plotting annual

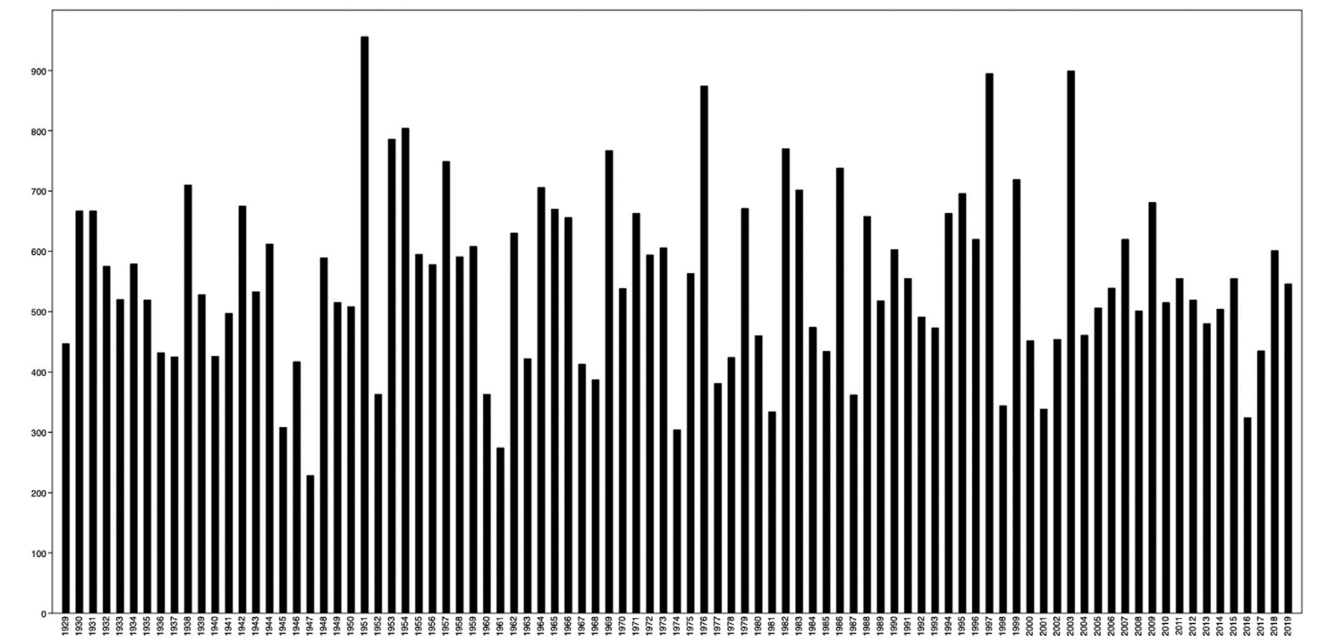

FIGURE 5 | Annual rainfall (mm) in Malta, 1929–2019 (Data provided by the National Meteorological Office, Malta International Airport).

precipitation data from 1929 to 2019 (data provided by the National Meteorological Office, Malta International Airport) further highlights this variability. The annual average for this period is 555.8 mm, yet variability is fairly high, as 25% of years had less than 447 mm, and 25% had more than 663 mm (**Figure 5**). Variability does not seem strongly patterned, in that while years vary considerably, this does not form decadal patterns. There is also important variation in the seasonality of rainfall; for instance, high or low levels of rainfall in the autumn are a significant component of annual differences.

Water availability, of course, does not only reflect precipitation, but also other factors such as infiltration and evaporation. Evaporation in Malta is high, particularly during the long summers. However, the geology and topography of the islands mean that relatively large aquifers are present (**Figure 4**). The impression of surface aridity can therefore be misleading, given the presence of year-round springs (e.g., Newbury, 1968). Likewise, in recent years the high flood runoff in the urban areas gives the impression that a large amount of rainfall may have been lost to the sea in the past. However, it actually appears that traditionally little water was lost to the sea in direct runoff (Singh, 1997).

The largest aquifer is located where infiltrating water meets sea level, the Mean Sea Level aquifer. This, however, is believed to only have begun to be accessed in the 17th century AD (Grima, 2016, p. 30), and only widely exploited from the 19th century (Buhagiar, 2008). Before this, the Perched Aquifers overlying the impermeable Blue Clay formation were important sources of water (Newbury 1968; Micallef et al., 2000). At least a proportion of the water in the Perched Aquifers seems to be decades old (Newbury, 1968; Stuart et al., 2010), suggesting that decades of aridity would be needed for springs to dry up. However, all is not equal given the varied topographic and hydro-geological structure of the islands. In Malta, for instance, springs are concentrated in the west, where the Blue Clay Formation is present (**Figure 4**), yet the best agricultural land is located in the centre and east (Alberti et al., 2018). Factors such as water management by humans are therefore key, as we will return to later.

In terms of Maltese palaeoclimate and palaeoecology, pollen records from cores taken in near-shore settings have been prominent (**Figure 1**). While valuable, there are a number of limitations to these records. These include the difficulties in separating natural and anthropogenic signals in pollen changes, preservational and taphonomic biases, and often poor chronological control. It is also important to note that insect pollinated plants rarely feature in the pollen records, yet the majority of Maltese plants are insect pollinated. In terms of chronological uncertainty, we describe below approximate dates as discussed in the various publications, but the uncertainties inherent in age-depth models based on a few chronometric estimates should be kept in mind.

Carroll et al. (2012) and Gambin et al. (2016) presented pollen records from sediment cores. The basic contradiction between these records highlights the complexity of the proxy, and of local climatic/ecological conditions. Gambin et al. (2016) record suggests relatively open conditions in the pre- and post-Temple periods, with wetter conditions at the peak of the Temple phase. In contrast, Carroll et al.'s (2012) record suggested that once humans were established in the pre-Temple Neolithic there has basically been a similar pattern in pollen over most of the last 7,000 years, with rapid deforestation and then a predominantly anthropogenic signal, dominated by rain-fed cereal agriculture. With the caveats about factors such as chronological resolution kept in mind, such studies may also indicate considerable spatial variability within the Maltese Islands, with the pollen records saying more about very localised vegetation patterns than about overall climate. An important point made by Carroll et al. (2012, p. 24), however, is that there was a substantial decline in cereal pollen around 4.3 ka, which they suggest may be linked to regional aridification. So dramatic was this change that they suggested that the record may indicate abandonment of the islands for a few centuries. Gambin and others (2016) suggested that the landscape became more open, and the climate more unstable, over a longer time period of ~4.5 to 3.7 ka.

More recently, as part of the FRAGSUS Project several new cores were recently published (Hunt et al., 2020) and pollen studied (Farrell et al., 2020). Here again, taphonomic biases are evident, and it is challenging to reconcile signals from the different cores. We will return later in the paper to some of the implications of the presence of particular taxa in these records, but for now our interest is in the general tendencies displayed. From the Salina Deep Core, Farrell and others (2020, p. 86) discuss a phase with an estimated age of ~4.5 ka as being marked by steppe vegetation, which was degraded compared to the previous phase, and changes indicating a more arid landscape and/or great grazing pressure. Other cores such as Salina 4 and Wied Żembaq 1 present a similar narrative, of a seemingly degrading landscape in the later half of the 3rd millennium BC. The Salina 4 and Wied Żembaq cores agree with the record of Carroll et al. (2012) for an absence or extreme rarity of cereal pollen, yet in Gambin et al. (2016)'s record, this was not the case. Farrell and others (2020) suggest that the decline in cereal pollen, and rise in tree and shrub pollen, may actually reflect changing agricultural/cultural practices rather than primarily climate, and perhaps the changing distribution of different activities in the landscape.

Mollusc data from the cores provides important palaeoecological information (Fenech et al., 2020; see also; Fenech, 2007; Schembri et al., 2009). Given the strongly local ecological tolerances of mollusc taxa and perhaps lesser taphonomic biases compared to pollen, variation in mollusc composition represents a key data source for Maltese palaeoenvironment. An important point is that there is little evidence from molluscs for leaf litter species in the earlier Holocene that would then indicate abrupt deforestation with the arrival of people and the start of the Neolithic (Fenech et al., 2020, p. 156). The changes visible in the Wied Żembaq 1 and 2 cores from ~4.3 ka are described by Fenech and others (2020, p. 128) as showing "aridification of the landscape, disappearance of freshwater streams; breakdown of denser vegetation, increase in erosion." Likewise, molluscs in the Xemxija core indicate aridification in the ~4.8 to 4.5 ka timeframe followed by a "prolonged drought" that Fenech et al. (2020, p. 153) suggest may correlate with the 4.2 ka event. This was shown by the abrupt disappearance of freshwater species such as *Oxyloma elegans* and *Bulinus truncatus.*

Finally, environmental change in the Maltese Islands would not merely have reflected the impacts of climatic change, but also other factors such as changing sea level and more abrupt events such as tsunamis and storms. The presence of large boulders, weighing up to 60 tonnes, which have been moved by the sea to several metres above sea level by either tsunamis or intense storms (Mottershead et al., 2014, 2019; Biolchi et al., 2016; Causon Deguara and Gauci, 2017; Mueller et al., 2019), indicate conditions which could have caused considerable damage in low-lying areas (See Marriner et al., 2017 for a wider Mediterranean perspective).

Given the limitations of the Maltese palaeoenvironmental archives, archives from the wider central Mediterranean region can also be used to cast light on the likely character of climatic change in the Maltese Islands at the end of the third millennium BC. We discuss this in **Supplementary Material 1**.

Recent Developments in Archaeological Research on the End of the Temple Period

Many key archaeological sites in Malta were excavated before the development of modern archaeological fieldwork methods, resulting in the loss of much information. Work in recent decades has generally been on a more modest scale, but some significant findings bring a new perspective to the end of the Temple Period. The current state of knowledge in terms of the chronology of major cultural changed (McLaughlin et al., 2020a) describes the Tarxien phase, the final clear phase of the Temple Period as dating to ~4.9 to 4.4 ka, with the early Bronze Age of the Tarxien Cemetery phase beginning ~4 ka. A crucial development is the idea of a phase in between, characterised as the Thermi phase, from ~4.4 to 4.2 ka.

The traditional view emphasised a clear and prolonged hiatus between the Tarxien phase of the Temple Period and the Tarxien Cemetery phase of the Early Bronze Age (e.g., Zammit, 1930). However, the identification of a distinctive pottery form, in a Maltese setting called "Thermi Ware," in both late Temple Period and Early Bronze Age contexts led to suggestions of continuity across these periods (e.g., Cazzella and Recchia, 2015; Sagona, 2015). Thermi Ware is characterised by a thickened rim, often with internal decoration, particularly triangles. It has long been recognised in Malta (e.g., Evans, 1953, 1971; Trump, 1966; Malone et al., 2009a) and the similarities to material from the Aegean, at sites such as Thermi and Troy, emphasised. The presence of Thermi Ware in Malta has been taken as indicating the arrival of small groups of people, perhaps ~4.4/4.3 ka (e.g., Copat et al., 2013; Recchia and Fiorentino, 2015). Aside from the example of two shards of purported Thermi Ware in Ġgantija layers at Skorba (Trump, 1966)—presumably these are intrusive, or the stratigraphy was more complex than recognised (e.g., Cazzella and Recchia, 2015)—Thermi Ware in Malta is exclusively known from the late Tarxien phase and subsequent Tarxien Cemetery phase. It has therefore recently been proposed to define a specific "Thermi Phase," which shows continuity of the Tarxien phase, but with the addition of Thermi Ware. Key to the increased role of Thermi Ware has been work at Tas-Silġ (Recchia and Cazzella 2011; Cazzella and Recchia 2012; Copat et al., 2013) and Taċ-Ċawla (Malone et al., 2020c).

Thermi Ware has often been discussed in relation to the Early Helladic II/III periods in the Aegean, but also shares close similarities with material from the Cetina Culture of the Balkan side of the Adriatic (e.g., Maran, 1998; Cazzella and Rechia, 2015; Pacciarelli et al., 2015; Rahmstorf, 2015; Recchia and Fiorentino, 2015). These similarities in pottery style, have been suggested to indicate a source in the Adriatic and spread to the Aegean, Italy, and Malta in the final centuries of the third millennium BC. The initial presence of small amounts of characteristic pottery, i.e., what is called Thermi Ware in Malta, has been taken to indicate not mass population movements, but rather the movement of small groups of "traders" and other kinds of specialists (Rahmstorf, 2015). Broodbank (2015) describes this spread across the Adriatic and into the wider central Mediterranean as an "eruption", correlating with the 4.2 ka event (p. 352). A crucial aspect here, bearing in mind the variable character and impacts of the 4.2 ka event, is that the Adriatic has the highest rainfall in the Mediterranean (Broodbank, 2015, p. 350). The spread of the "Cetina Culture" material culture may therefore reflect that some societies in this region were more environmentally buffered than others.

Recent excavations at Taċ-Ċawla in Gozo have yielded important new data (Malone et al., 2020c). Fieldwork in 2014 recovered 50,679 pottery shards, weighing almost 400 kg. The site was repeatedly occupied from the early Neolithic onwards. Of particular interest was the recovery of Thermi Ware from the site, not in large amounts ($n = 58$), but in association with Temple Period material at a site lacking subsequent Bronze Age activity, making reworking unlikely. Taċ-Ċawla demonstrates a late surviving (perhaps to ~4.2 ka) continuation of the Temple Period, but with the addition of Thermi Ware.

Another key aspect is that although sharing clear similarities with material from the Adriatic and Aegean, the geochemical characteristics of Thermi Ware pottery in Malta indicate that it was locally made (e.g., Malone et al., 2020d). There is also evidence for "hybrid" pottery, combining both typical Tarxien characteristics and typical Thermi/Cetina characteristics (Copat et al., 2013). The emerging view then suggests the arrival of small groups in the late Tarxien period, who may have played a role in triggering economic and social changes in the islands (e.g., Recchia and Fiorentino, 2015).

Tarxien is famous as the most intensely decorated of the Maltese temples, with various elaborate spiral designs and other decorations (e.g., Grima, 2001, 2003). It is possible that the boat engravings on a megalith from Tarxien South Temple (e.g., Pace, 2004; Sagona, 2015) represents the arrival of new people in Malta, although the age of the engraving is unclear (Fenwick, 2017; Tiboni, 2017). One point that we emphasise is that if the engravings were formed after the deposition of the sterile layer (i.e., in the Bronze Age or more recently), they could only have been done in a squatting position, and this low position would be unusual. Could these relate to the arrival of people associated with Thermi Ware? Perhaps analogously, at Kordin III temple, a large boat-shaped stone was placed across the opening of the central room, seemingly indicating a symbolic meaning (Grima, 2003; Pace, 2004). With currently available data it is challenging to situate such examples in the general corpus of Temple Period symbolism.

In closing this section, we note that the evidence suggests a two-stage process in which Thermi Ware marks the final chapter of the Temple Period, but there then seems to be a hiatus before the beginning of the Bronze Age proper from around 4 ka (e.g., McLaughlin et al., 2020a). It does not so much seem to be a process of continuity, then, but rather a more convoluted end of the Temple Period.

Destruction and Desecration? Damage to Temples and Their Contents

Another significant aspect in understanding the end of the Temple Period concerns evidence for fire and other damage in late Temple Period settings.

At this point it is useful to evaluate recent perspectives on what "temples" actually were. We use the word temple as an established shorthand, yet caution is needed in assuming their function. We can consider the function of temples from several scales. At a landscape scale, analyses of how they relate to various geographic elements have been considered by Grima (2004, 2008). A key point of this work is that temples appear as "liminal areas between the plains and the sea" (Grima, [2004], p. 245). Continued studies support this view, with Caruana and Stroud's (2020, p. 456) geographic information system (GIS) analysis suggesting to them that temples acted as "gateways between sea and land". We take this as a suggestion that temples played an important role in interactions between resident communities and groups arriving by boat.

At the site level, a "ritual" function is easy to suggest, often expressed in religious or cultic terms (e.g., Robb, 2001; Barrowclough, 2007), yet clarifying what exactly that means is challenging. The temples have often been described as indicating the growing power of a "priesthood" (e.g., Trump, 2002), and that part of the "collapse" of Temple Period society may relate to conflict between this priesthood and other social elements. This notion of internal social unrest has been discussed by authors including Bonanno and others (1990, p. 202–3) and Malone and Stoddart (2013). However, when we look at individual temples, it is also possible that significant functional changes occurred within the lifespans of the structure. It is possible that pragmatic aspects, such as food storage, were also involved in temples (e.g., Sagona, 2015). Many other possible functions can be imagined, from display zones for dead bodies before the remains were transferred to hypogea, to places where initiation rituals involving psychedelic drugs were carried out. There seems to be a rather contradictory relationship between the suggested social/ritual function of temples and their architecture. While they have been described using terms such as "administrative centres" (Renfrew, 1979) and "club houses" (McLaughlin et al., 2018), they have also been described as "low, confined spaces, dark, convoluted and probably amplifying sounds and smells" (Robb, 2001, p. 182). This seemingly contradictory character suggests, to us, a need for interpretive caution.

In contrast to ideas of chiefdoms and powerful priesthoods, some researchers have suggested a more egalitarian characterisation of Temple Period society (e.g., McLaughlin et al., 2018). Cazzella and Recchia (2015) emphasised the large

FIGURE 6 | Tarxien temple. Note fire damage (reddened areas).

numbers of people buried in hypogea, who surely could not all belong to an elite. Likewise, Thompson et al. (2020) discuss how the diversity of burial practices and high numbers of non-adult remains and approximately equal ratio of the sexes at the Xagħra Circle are consistent with an egalitarian society. Cazzella and Recchia (2015) also discussed how the final stages of construction at Tas-Silġ meant a "less confined scheme of entry" (p. 96), in contrast to the frequent idea that temples show increasing restriction of access to certain areas (e.g., Trump, 2002). There is likewise little evidence for inter-personal violence in the Temple Period (e.g., Magro-Conti, 1999; Thompson, 2019).

Against this seemingly peaceful and stable backdrop, several sites have produced findings indicating possible abrupt changes at the end of the Temple Period. At Tarxien extensive evidence of burning (**Figure 6**) has been suggested to reflect the possible destruction of the temple at the end of the Temple Period (e.g., Magro Conti, 1999; Trump, 2002). There are, however some significant caveats. In the Tarxien Cemetery phase of the early Bronze Age, Tarxien was reused by people who cremated the dead (Zammit, 1930). There has been discussion on the chronology of fire damage at Tarxien, some of which may have been earlier (e.g., Evans, 1971) and some later (Pace, 2004) than the end of the Temple Period. The possibility that there was a major fire at the end of the Temple Period is perhaps supported by the widespread signs of burning at the site, not merely where the Bronze Age deposits occurred, and stratigraphic observations. Evans (1971, p. 151), for instance, in discussing Zammit's notebooks, point out how in part of the site there was a "5 cm layer of black ash" just beneath the sterile layer which separates the Temple Period and Bronze Age deposits. In the paved outer apses of the Central Temple, fire damage may even be noted below floor level at a point where the paving is missing, raising the question of whether an earlier fire predates the paving of this area.

To Zammit (1928), the sterile layer discussed above was a natural deposit which slowly accumulated, suggesting that by the start of the Bronze Age the islands had long been abandoned. This view has been challenged from several perspectives. Firstly, it is clear that this deposit actually varies considerably across the site. As cited by Evans (1971, p. 150) from Zammit's notebook; for instance, in one spot the sterile layer was a "dark brown soil" 76 cm thick, elsewhere it was a 38 cm thick "grey or reddish-grey soil." The meaning of this lateral variability is unclear, and there have been different interpretations of Zammit's publications and notebooks, with Bonanno (1993) suggesting that the sterile layer was only found in the part of the site covered by the Bronze Age deposit, and Sagona (2015) arguing that Zammit suggested it covered the entire site. Trump (2002, p. 286) was happy to accept that the sterile "silt" later formed naturally, as Zammit suggested, but with the caveat that it could have happened much more rapidly than Zammit thought. Given the sterile nature of the deposit, it could represent a rapidly windformed deposit. Others have argued that the sterile layer was not natural at all, but had been deliberately deposited at the site. Evans (1971) and Bonanno (1993) suggested that it was taken there in the Bronze Age to create a flat base for the cemetery. Such a preparation may also have had ritual significance, arguably sealing in the powerful and potentially dangerous ritual potency of an earlier cultic system. Sagona (2015) suggests that the sediment was taken there at the end of the Temple Period as an act of "decommissioning." Available data make it impossible to finally resolve the age and formation process of the sterile layer.

Another category of findings relates to the possibly deliberate smashing of temples and objects such as figurines (Vella, 1999). Examples include Trump's (2002, p. 238) suggestion that at Skorba large pieces of rock had apparently been smashed out of the temple walls before the Bronze Age. At Tarxien, Zammit (1930, p. 79) interpreted the distribution of things like broken pottery in different parts of the site as suggesting that they were "broken intentionally before the collapse of the buildings." However, without good chronological resolution it is challenging to link signs of damage to the very end of the Temple Period. At Tas-Silġ, Cazzella and Recchia (2015) suggest the temple structure saw collapses during the Tarxien phase, which were not repaired, although activity continued at the site. Another interesting aspect here concerns the lack of surviving evidence for stone roofing material, given the general view that temples were originally roofed (e.g., Torpiano, 2004; Robinson et al., 2019). Sagona (2015, p. 130) sees this as another reflection of "decommissioning." Other possibilities include

FIGURE 7 | Statues and figurines from Malta. Left and centre: figurines from Ħaġar Qim (48.6 and 23.5 cm high), Right: Broken giant statue from Tarxien (1.1 m high, the complete statue might have been nearly 3 m high when complete). (All photos courtesy of Heritage Malta. Copyright images not to be reused without permission of Heritage Malta).

deliberate destruction of roofs to prevent use of the site or the possibility that roofs were made of wood and not stone (e.g., Robinson et al., 2019).

Figurines and statues are a major feature of Temple Period material culture (**Figure 7**) (e.g., Bonanno, 2004; Monsarrat, 2004; Vella-Gregory, 2005; Vella-Gregory, 2016; Malone and Stoddart, 2016). Several examples of possibly deliberate damage to them have been discussed. The giant statue at Tarxien (**Figure 7**) is commonly regarded as having been broken by recent quarrying activity (e.g., Zammit 1930; Evans, 1971), although this interpretation is not without ambiguities (e.g., Vella, 1999; Pace, 2004; Sagona 2015) and the possibility of earlier deliberate damage cannot be excluded. Another damaged statue, from the multi-period site of Tas-Silġ, offers stronger evidence for deliberate damage. Vella (1999) pointed out that the damage being accidentally caused by ploughing seems unlikely, as careful evaluation of the damaged surface shows marks from different tools. This suggests "purposeful mutilation," but it remains hard to say when this was done (see also Sagona, 2015, p. 132).

A final, key, example comes from the Xagħra Circle. In this case, a finely shaped statue over 60 cm high had been "smashed almost beyond recognition" (Malone et al., 2009b, p. 283) which seemingly "could not have occurred naturally" (Malone and Stoddart 2013, p. 77). These authors suggest this may represent an "act of closure," and emphasise the abandonment of the site around the same time as the damage. Other authors have agreed that the smashing of the statue was deliberate (e.g., Monsarrat, 2004; Bonanno, 2017). Crucially, the smashed statue pieces occur in excavated and dated contexts.

The precise location data for each fragment provided by Malone et al. (2009) shows the narrow vertical distribution of the fragments; 80% of the fragments are found within 30 cm of the mean elevation (**Supplementary Material 3**). Given the presence of statue pieces in features such as the "display zone," a depression up to 50 cm deep containing thousands of bones, a little vertical spread is unsurprising. We collated radiocarbon dates published by Malone et al. (2019) for contexts in which pieces of the smashed statue were found. A majority of the fragments were found in four key contexts (514, 783, 931, 942), while the rest were found in ones and twos in other contexts. A crucial point here is that radiocarbon ages calibrating to around 4.4–4.2 ka have a relatively large errors due to the slope of the radiocarbon calibration curve at this time. This means it is not possible to have ages with error ranges of less than hundreds of years. Some of the Xagħra Circle radiocarbon dates may therefore extend as late as 4.2 ka, but these estimates may be hundreds of years older given the error ranges. In such a situation, chronological modelling offers a useful way to understand such dates. The code and data for the chronological modelling described in this and the following section can be found at https://github.com/wccarleton/malta42 for R code, and doi: 10.5281/zenodo.5354992 for additional large data files.

To evaluate the chronology of the smashing of the Xagħra Circle statue, we used OxCal to create a set of Bayesian chronological models involving the statue-associated radiocarbon samples. This evaluated how discrete the cluster of statue-associated radiocarbon samples appeared to be in time. A very discrete cluster would lend support to the idea that the statue pieces remained in their initial depositional contexts, and can therefore be well dated. In contrast, more temporal dispersion and gradual tapering of sample dates toward the present would indicate the converse: that the statue pieces were redeposited and/or there was still active deposition into the statue-associated contexts for some time after the initial breaking. This exercise aims to both cast light on the date in which the statue was smashed, but also to use this as proxy for the chronology of the end of the Temple Period occupation of the site, as this seemingly occurred shortly after the smashing of the statue.

As discussed further in **Supplementary Material 2**, we compared four chronological models. The models differed in terms of the boundaries we specified for the start and end of the statue deposition process—these boundaries constitute the priors in Bayesian chronological models. Using the "Agreement Index" (Bronk Ramsey, 1995, 2008) we explored how well the data from the site fitted the different models. The best fitting model, as shown in **Figure 8**, has an initial "Tau" boundary followed by a terminal uniform boundary. This means that the group of samples contains some early material, followed by a gradual rise in the accumulation of samples, and then an abrupt termination. While different scenarios are consistent with the

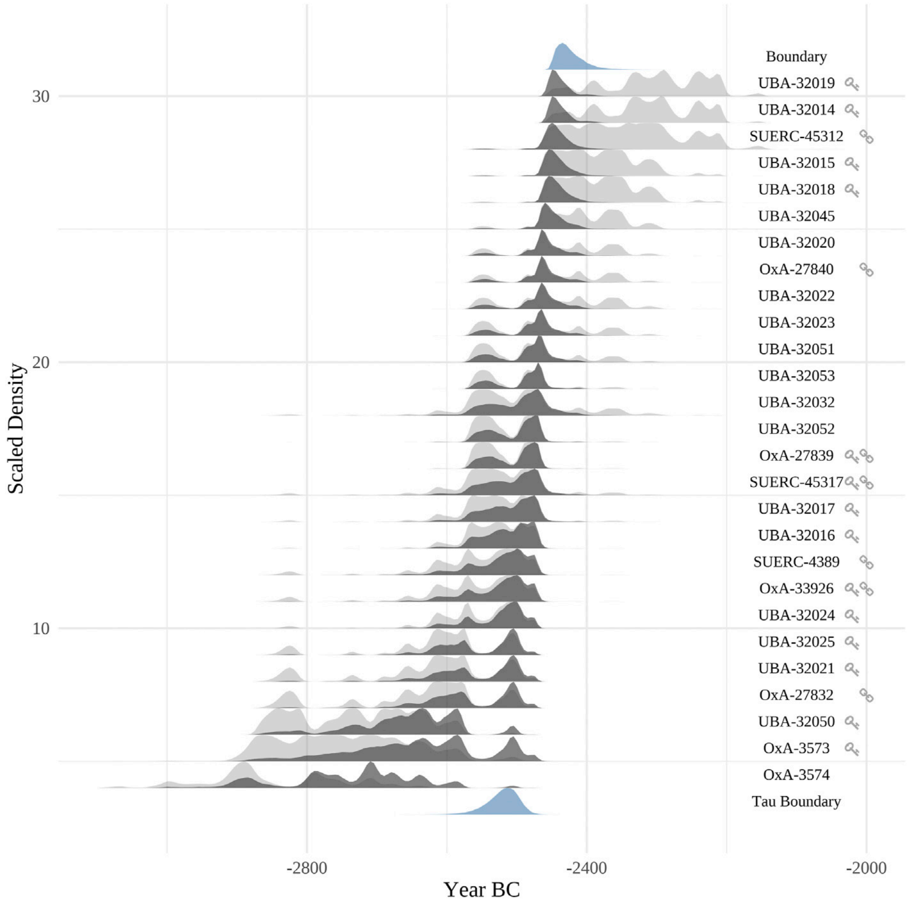

FIGURE 8 | Chronological modelling of radiocarbon dates associated with fragments of the broken Xagħra Circle statue. Blue distributions show start and end point of the preferred model in Oxcal. Key symbol shows samples from key contexts, link symbol shows samples which are from articulated remains.

most likely model (**Supplementary Material 2**), the probable scenario is that the statue was smashed at the end of the identified chronological period. The model suggests that the smashing occurred after 4.5 ka and before 4.4 ka. The key point that we emphasise here is that this suggests the breakage occurred centuries before the 4.2 ka event.

Chronological Modelling of the End of the Temple Period

The previous section highlighted the utility of chronological modelling to elucidate aspects of Maltese prehistory. Here we explore the wider utility of Maltese radiocarbon dates in the 5.5 to 3.75 ka timeframe (excluding radiocarbon estimates with large errors), with the aim of exploring the end of the Temple Period from the perspective of patterns in radiocarbon data. Recent research has added many archaeologically associated radiocarbon dates for the Maltese Islands (French et al., 2020a; Malone et al., 2020a). This means that a relatively large number of ages are available for a small landmass. However, just under half of the total number of dates are on human bones from the Xagħra Circle (Malone et al., 2019).

Our aim here is to explore the relationship between the frequency of Maltese radiocarbon dates through time—as a proxy for archaeologically visible human activity (see **Supplementary Table 1**)—and climate. We used a radiocarbon-dated event-count model (REC; Carleton, 2020; see also Stewart et al., 2021) to explore the relationship between Maltese radiocarbon-dated event counts and regional precipitation amounts. REC models have been developed as an alternative to the commonly used summed radiocarbon probability approach, which was critiqued by Carleton and Groucutt (2020). As discussed above in **Supplementary Material 1**, this is not a straightforward exercise as suitable climate data is not available from the Maltese Islands. We therefore evaluated regional climate records from nearby Sicily and Italy. The Sicilian records include useful records such as pollen profiles, but, as discussed above, the meaning of pollen records is often ambiguous, and published papers lack the kind of quantitative datasets needed for chronological modelling exercises. We therefore use oxygen isotope ($\delta^{18}O$) data from a speleothem from Renella Cave in central Italy as our climate proxy (Drysdale et al., 2006; Zanchetta et al., 2016). While a directly local archive remains desirable, using a high-resolution

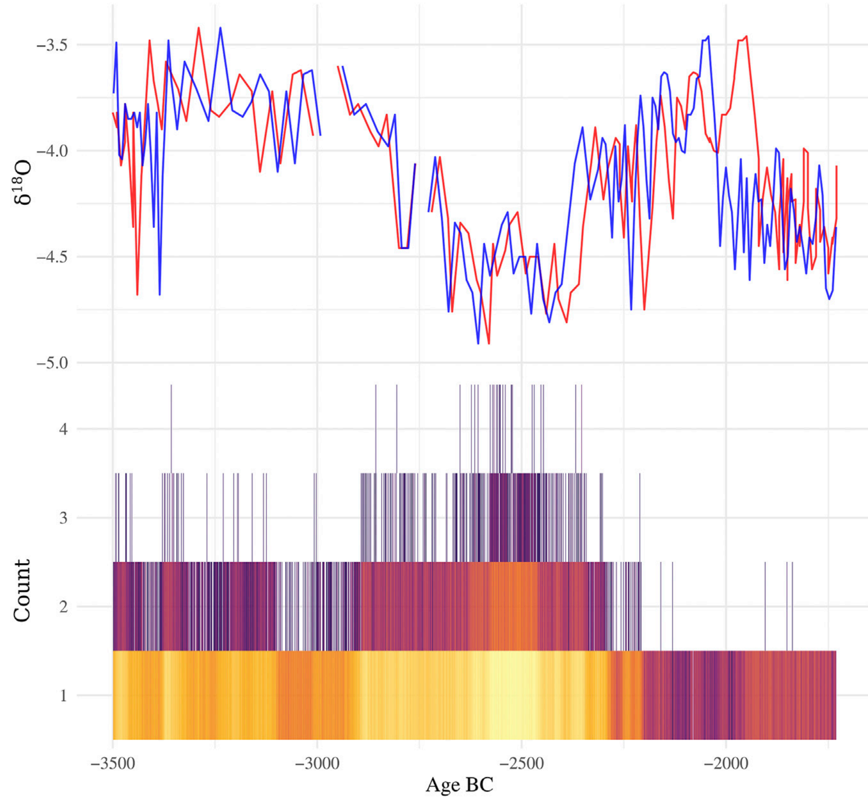

FIGURE 9 | The $\delta^{18}O$ record from Renella Cave, with blue line showing published age-depth model (Zanchetta et al., 2016 and red line our age-depth model from OxCal. More negative values indicate more rainfall, and less negative values indicate more arid conditions. Radiocarbon dated event count (REC) ensembles at bottom summarises multiple sequences of events which are compatible with the data, i.e., years in which archaeological activity is present. Brighter colours and higher *y*-axis values indicate a greater chance of archaeological activity at that time. See Carleton (2020) and Stewart et al. (2020) for more information on the REC model approach.

central Mediterranean archive is the best that can currently be done, and general regional paleoclimate data suggests similar patterns in Italy and Sicily, and by analogy, Malta (**Supplementary Material 1**).

Using the REC model approach, we created two Negative Binomial REC models. For one model, we compared event-count sequences based on all of the dates in the Maltese archaeological radiocarbon date database to the $\delta^{18}O$ record (**Figure 9**). In the other model, we compared only the dates from the Xagħra Circle (**Figure 10**). The event-count sequences were created by sampling the relevant calibrated radiocarbon date densities with replacement many times. Each random draw was then collated into a single count series by counting the number of events dated to a given time, where the times are determined by a temporal grid. This grid was defined by the temporal resolution and span of interest, i.e., 3500–2730 BC. Along similar lines, the $\delta^{18}O$ record samples were produced by first creating ensembles of the relevant age-depth model in OxCal and then assigning time-stamps to the palaeoclimatic observations with those sampled age-depth models. A fully reproducible explanation of this data preparation is available in **Supplementary Material 3**.

Our results overall indicated a negative relationship between the $\delta^{18}O$ proxy and radiocarbon-dated event counts (see **Figure 11**). In the first analysis, involving all dates, the posterior distribution of the key regression parameter had a mean close to −1 and roughly 93% of the density was negative. In the second, where we only included dates from Xagħra, the posterior distribution of the regression coefficient for the $\delta^{18}O$ covariate had a mean of around −2.5 and nearly 100% of the density was negative. So, while in the first case zero could not be excluded at one of the usual levels of confidence (i.e., 95 or 99%) it could be excluded even at the 99.99% level in the second analysis, and overall both posterior densities imply that negative values are the most likely. The negative relationship implies that reduced rainfall levels in the central Mediterranean corresponded to lower levels of human activity in the Maltese Islands.

Establishing this correlation between regional precipitation and human activity in Malta casts a new light on the end of the Temple Period. The results suggest that the Tarxien phase at the end of the Temple Period saw intense activity, corresponding with higher regional rainfall. From around 4.5 ka there is a decline in both regional precipitation and archaeological activity in Malta. The following centuries saw a decline in both. There is little evidence for archaeological activity in Malta in the 4.2 to 4 ka period. It may be that Malta was abandoned, or nearly so, during

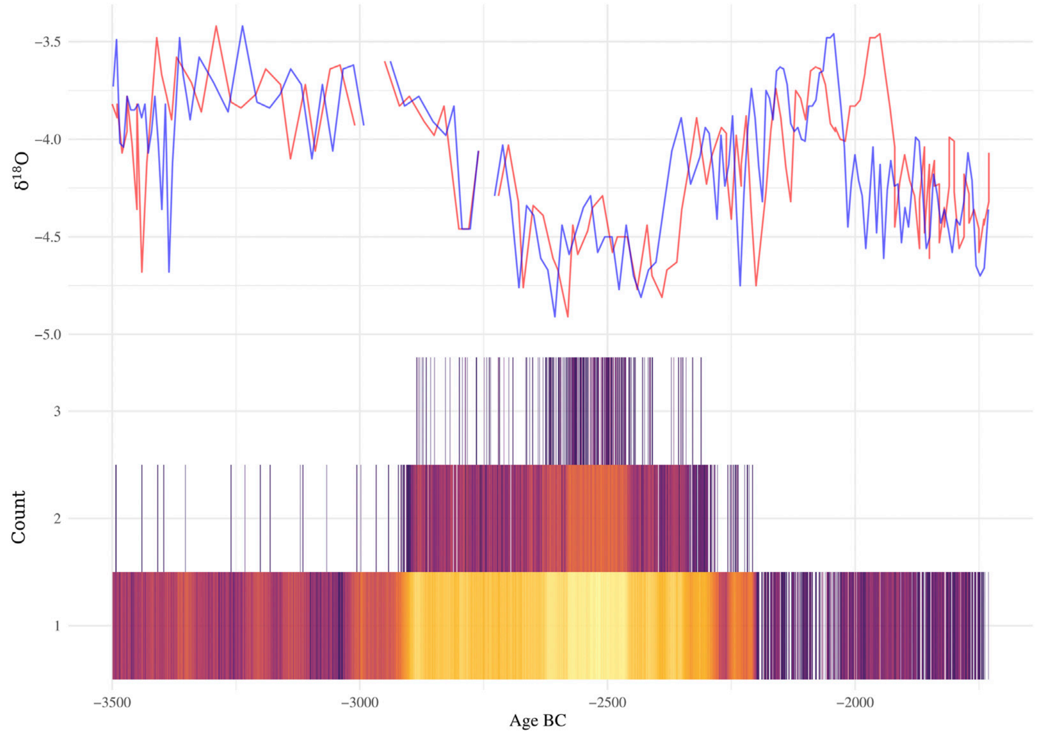

FIGURE 10 | As for **Figure 9**, but only including radiocarbon age estimates from the Xagħra Circle.

this time period. Crucially though, our results suggest that this occurred against a backdrop of centuries of decline. This is most clearly expressed with the Xagħra Circle data, while including all available dates from the islands produces weaker results. This is not surprising given the patchy nature of available samples for sites other than the Xagħra Circle. The varying frequencies of archaeological activity can be taken as indicating population decline and/or reduced ritual activity (such as burials). We hypothesise that it indicates both. This can be tested by future research, particularly as more data from non-ritual contexts is accumulated.

Agriculture and Water Management

By understanding how Temple Period society operated in terms of factors such as agriculture and water management, we will be in a better position to evaluate how it ended. It is also important to consider the several important aspects which are currently poorly understood. Even if climate change was key, there are diverse pathways from this to human societal changes.

Key Temple Period crops were wheat, barley, lentils, and peas, while for animals, sheep and goat were the most abundant, with cattle and pigs also relatively common (e.g., Trump, 1966; Bonanno, 1986; McLaughlin et al., 2020b; Malone et al., 2020c). This is both a classic Neolithic package, and one in many ways well suited to the conditions of the Maltese islands. The consistency of the taxa used for food production in the Temple Period, and preceding Neolithic, is noteworthy, and suggests an early and repeated recognition of the best ways to use the landscape of the islands (McLaughlin et al., 2020b).

The weakness of the Temple Period agricultural system was its reliance on presumably rainfall-fed annual crops which would have been vulnerable to drought. By storage and using livestock, a dry year need not have been catastrophic. It seems less likely, however, that extended periods of drought could be tolerated, as suggested by examples from the recent past. In the 1460s AD, for instance, there were three successive dry years when it is reported that all the livestock animals in Gozo died, the wheat crop failed, and there was widespread suffering (Wettinger 1982, 1985). Likewise, more recent examples from the Mediterranean highlight the frequency of crop failures (e.g., Garnsey, 1988). The Xagħra Circle human bones suggest a picture of generally good health in the Temple Period, yet there are indications of increasing stress from around 4.5 ka, with declining numbers of dental caries perhaps indicating reduction in cariogenic cereal consumption and increased enamel hypoplasia indicating childhood dietary stress (McLaughlin et al., 2020b). This may well indicate an agricultural system which generally still worked well, but was under stress.

Several sites have produced evidence for Temple Period water storage. The Ħal Saflieni hypogeum features a "vast cistern" (Trump, 2002, p. 131; see also Evans, 1971). This site also features basins positioned to catch water appearing from fissures, suggesting it may have acquired ritual significance (Grima, 2016). At temples such as Tas-Silġ and Tarxien,

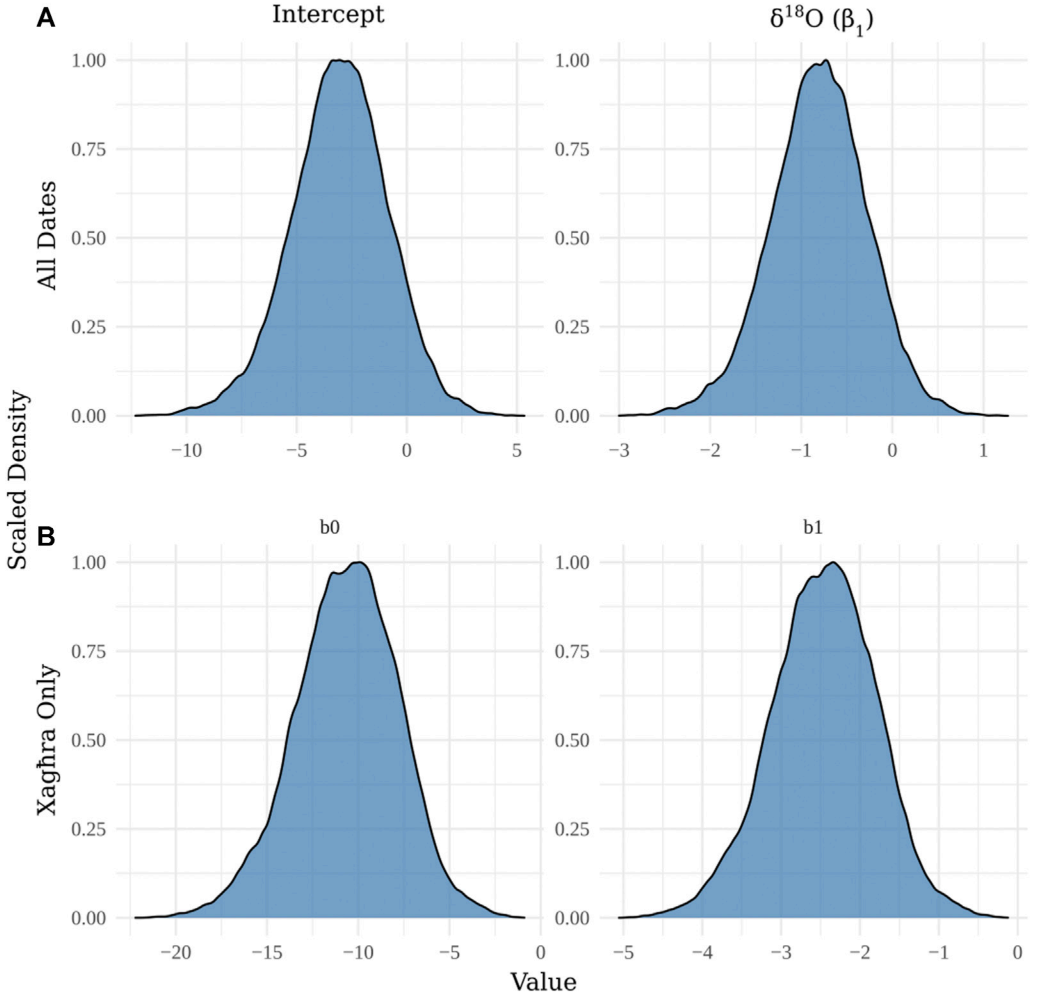

FIGURE 11 | Regression results for the REC models for all Maltese radiocarbon dates and climate **(A)**, and for only the Xagħra circle **(B)**. The left columns indicate the model intercept (i.e., the mean event counts, holding the $\delta^{18}O$ covariates constant at their study-period means) the columns on the right indicate the effects of climate (variation in $\delta^{18}O$) on the frequency of radiocarbon dated samples. The negative values indicate that drier conditions correlate with reduced numbers of radiocarbon dates.

multiple water storage facilities have been identified. However, given the multi-phase use of these sites, it is often hard to know how old these are. At Tarxien, however, a cistern was found by Ashby (1924) securely stratified beneath a *torba* (pounded rock powder) floor. This was located to catch water emerging from a fissure, again suggesting a ritual interest in this water (Grima, 2016). A much-discussed example is the Misqa Tanks (**Figure 12**). These are located very close to the Mnajdra and Ħaġar Qim temples, and a series of channels and cisterns have been cut in an outcrop of relatively impermeable rock. These are much larger than typical Bronze Age cisterns, and differently shaped to those built by Romans (Trump, 2002) and therefore quite possibly date from the Temple Period. Such water storage is important in thinking about Temple Period survival, yet it is also unlikely that water stored in such ways was sufficient for large-scale irrigation, and so crops and vegetation would have relied on precipitation and its vagaries.

A GIS-based study of variables that may have influenced temple location showed that proximity to springs was a very strong determining factor (Grima, 2004). More recently, further evidence of this relationship was found by a remote-sensing study of the immediate environs of Ġgantija, which identified the presence of a fault and springline running just east of the site (Ruffell et al., 2018).

After that brief summary of evidence for subsistence and water storage in the Temple Period, we now turn to consider the multiple areas of uncertainty which currently exist. Firstly, while multiple sites have produced evidence for wheat, barley, and legumes, were other kinds of crops absent? There are still relatively few Maltese sites at which extensive archaeobotanical studies have been conducted, and even fewer non-ritual sites where such evidence may be more abundant. Arboriculture, for

FIGURE 12 | Some of the channels and deep cisterns of the "Misqa Tanks." Located close to Mnajdra and Ħaġar Qim temples, they have been suggested to possibly represent Temple Period water storage.

instance, can offer a valuable way to manage annual variation in rainfall, as impacts will be less immediately devastating than with annual crops. A significant question then concerns whether Temple Period people in Malta made use of plants like olive trees and vines.

The earliest dates for olive domestication and cultivation come from the Levant, in the 7th millennium BC, while cultivation was occurring in the Aegean in the 6th millennium BC (Langutt et al., 2019). Yet it seems that by the third millennium BC, independent olive domestication occurred in areas including Iberia (Terral et al., 2004) and Italy (D'Auria et al., 2016) (for a summary see Besnard et al., 2018). In Sicily, olive oil residue dating to around 4 ka was recently identified (Tanasi et al., 2018). In the first millennium BC there was a Phoenician related spread of Levantine olives across the Mediterranean. Some analyses of olive genetic variation have found that Maltese olives occupy one side of the deepest split in the genetic tree (Di Rienzo et al., 2018), yet dating that split is currently challenging. Given these factors, the presence of domestic olive cultivation in Malta in the Temple Period seems possible. The limited number of systematic archaeobotanical studies in the islands should caution against the meaning of a current lack of on-site evidence for this. Pollen cores provide possible evidence for early cultivation in Malta. Olive pollen does not travel far (e.g., Florenzano et al., 2017), so high levels of olive pollen indicate extensive local cultivation. The complicating factor though is that wild non-domesticated olive is native to Malta, and it is not possible to separate this from the domesticated form by pollen (Farrell et al., 2020). The common approach to differentiate olive cultivation from wild olive changing in frequency due to natural climate change is to explore how olive changes in relation to other taxa in pollen records.

Different pollen records from Malta give different signals—for reasons discussed above, such as taphonomic biases, chronological uncertainty, and spatial variation within the islands. The record presented by Gambin et al., (2016) is particularly interesting, as it contains very high levels of olive pollen in the mid-third millennium BC, and this does not seem to be in sync with other Mediterranean arboreal taxa. Olive levels are higher than they were in the last two thousand years, when we know olive production was considerable in Malta. The interesting point though is that the high olive levels occur in the early to mid-third millennium BC, peaking ~4.6 ka at 19%. The proportion of olive pollen then declines so that it is low at ~4.2 ka (6%). A second peak occurs in the Roman era, but it reaches less than 10%. Different views have been expressed on whether available data suggests Temple Period olive cultivation (e.g., Fenech et al., 2020b) or not (Farrell et al., 2020). On face value, it could be argued that there was extensive olive cultivation in the peak of the Tarxien phase, but that this declined considerably, before 4.2 ka (Gambin et al., 2016).

With vine cultivation, the oldest known grape pips are from the Early Bronze Age at Tas Silġ (Fiontentio et al., 2012). Yet vine pollen has been identified in Malta as far back as ~6.7 ka (Djamali et al., 2012), and it may therefore have been a long-term part of the Neolithic and Temple Period diet. It was also identified in later setting, such as in the Wied Żembaq 1 core at ~4.7 to 4.3 ka (Farrell et al., 2020). Vines are also low producers of pollen, so its general paucity may be misleading. It has recently been argued that Sicily was a major centre for vine domestication, in the third or late fourth millennium BC (De Michele et al., 2019). There would therefore have been a long span of time for cultivation to spread to Malta.

A variety of other useful tree taxa such as fig (Trump, 2002) and carob (Trump, 1966; Farrell et al., 2020) are evident in the Temple Period. Some cores have high levels of *Pistacia* pollen, which may represent proximity to areas where these trees were being grown in a managed way, perhaps for food (for both people and animals) and firewood (McLaughlin et al., 2020b; Farrell et al., 2020). Likewise, French et al., (2020) suggested the coming and going of woodland indicators in different cores may indicate rotational land use. There are therefore fascinating hints at extensive arboriculture.

Another major area of uncertainty concerns the extent of landscape modification, which limits understanding on how climate changes would have manifested and impacted people. For instance, it remains unclear when the extensive artificial terracing which today characterises the Maltese landscape began. Some circumstantial evidence may come from the fact that Skorba and Ġgantija temples each have monumental artificial terracing, suggesting that the skills needed to create terracing for agricultural purposes were certainly available in theory. Likewise, the organisational and technological foundations were certainly in place for things like the artificial damming of steep sided valleys to create small reservoirs, yet there is currently no evidence that this was actually done.

Zammit (1928) argued that the numerous Maltese "cart ruts" were formed in the Temple Period, by people moving millions of cartloads of soil up slope to create terraces (see also McLaughlin et al., 2018). However, there remains a striking lack of consensus on the age and function of cart ruts, and most recent studies of cart ruts have suggested that they are much younger than the

Temple Period (e.g., Magro Conti and Saliba 2007; Trump and Cilia, 2008; Bonanno, 2017). Sagona (2004, 2015) argues that the cart ruts are actually “field furrows,” and represent marginal areas being brought into cultivation at the end of Temple Period. While an interesting idea, there is currently little evidence to support this model.

Another aspect concerns soil modification, and how this could improve agricultural yields. Brogan et al. (2020) discussed evidence from Ġgantija that soil manuring was being practiced in the Temple Period, which appears sensible given long-term soil quality decline (e.g., French and Taylor, 2020). A variety of other methods may have been used to improve soils. For instance, adding seaweed could have been a powerful strategy (as it was in other parts of the world, e.g., Sagona, 2004). Often large volumes of seaweed wash up in Malta, and following some kind of simple processing to remove excess salt, this could have been added to the fields to improve yield. In this regard the discovery of seaweed at Għar Dalam may be significant (Despott, 1923). Another possibility would be the addition of phosphoritic nodules which occur between the Globigerina Limestone members to fields in order to boost phosphate levels. Grima (2004) discussed dark pebbles from Tarxien which may be from this phosphoritic layer, and which may, conceivably, hint at such movements. The nearest source to Tarxien is around 5 km east.

Finally, while the small number of sites with relatively good zooarchaeological samples are dominated by domesticated taxa, there are nevertheless hints of an interesting role for wild foods. For instance, multiple Temple Period sites have produced deer remains (e.g., Tagliaferro, 1911; Evans, 1971). Several sites, such as Skorba (Trump, 1966) and Santa Verna (Evans, 1971), have produced relatively large numbers of shells. However, the number of marine molluscs from such sites is seemingly too small to suggest that they were used as a regular food source. It can also not be excluded that many of the shells from Temple Period sites were collected when already dead. Might it, however, have been that there were cultural taboos about the consumption of wild species, which helped to ensure their survival, and allowed them to be used during periodic agricultural crises? Such possibilities can be evaluated by future studies of non-ritual sites.

Two small-scale isotopic studies have been conducted on human remains from the Xagħra Circle (Richards et al., 2001; Stoddart et al., 2009) and the FRAGSUS project has recently expanded upon this by sampling 224 teeth from Xagħra and five teeth from the Xemxija tombs, although this data is not yet fully available (Thompson, 2019). Still, the isotopic data available provide some provisional insights into the environments and diets of people in Malta. According to **Figure 11** of Thompson (2019), the carbon ($\delta^{13}C$) isotope values range from around -18.5‰ to -20.3‰, while the nitrogen ($\delta^{15}N$) isotope values range from around 7.3–13.6‰ with all but one sample falling above 8.3‰. Taken together, these values suggest a mainly terrestrial diet. The $\delta^{13}C$ values indicate that C4 plants and marine protein did not form a substantial part of these people’s diets. The $\delta^{15}N$ values are consistent with high amounts of marine dietary protein, but given the $\delta^{13}C$ values this has instead been interpreted to reflect aridity. A decline in $\delta^{15}N$ values throughout the Tarxien phase may reflect a through-time decrease in meat and dairy consumption, given that the final centuries of this phase seem to have increasing rather than decreasing aridity, which could provide an alternative explanation for this observation. These interpretations are, however, currently hindered by a lack of faunal baseline data, although Malone et al. (2020a) suggest that yet-to-be-published isotope data from faunal remains supports a limited marine protein component in prehistoric Maltese diets. Interestingly, though, it has been shown that fish in the central Mediterranean have comparatively low $\delta^{13}C$ values (Craig et al., 2009). Another confounding factor relates to the possible use of marine biofertilisers (e.g., seaweed, fish), which have been shown to significantly enrich crop $\delta^{15}N$ and $\delta^{13}C$ values (Blanz et al., 2019; Gröcke et al., 2021). Key, then, for interpreting people’s diets will be a strong marine and terrestrial faunal baseline data from prehistoric Malta.

Trade and Connectivity

As well as the “internal” aspects discussed above, understanding the functioning and end of the Temple Period is of course related to the external relations of the Maltese Islands. While the isolation and distinctive cultural developments of Malta have often been emphasised (e.g., Stoddart et al., 1993), others have suggested much stronger connection with areas such as Sicily (Robb (2001), p. 187). While material including obsidian and non-local chert were imported, the extent and implications of this are not clear. To [Robb (2001), p. 187], interaction with groups in Sicily was “necessary and regular” for people in Malta. He suggested that resources such as timber, groundstone axes, and ochre were all imported in large amounts. Such a perspective is also pertinent in terms of thinking about whether there could have been a conscious abandonment of the Maltese Islands at the end of Temple Period (e.g., Bonanno, 1993). If Maltese groups were as integrated and familiar with Sicilian landscapes as Robb (2001) suggests, the possibility for emigration appears stronger.

While the strengths and weaknesses of Robb (2001) paper can be discussed, it is important to point out the several significant changes which have developed in our understanding of the Maltese archaeological record in recent years. In some regards, such as the possible import of wood from Sicily, it is simply impossible with available evidence to say either way. However, when it comes to ochre, Attard Montalto et al. (2012) carried out analyses of various geological materials in the Maltese Islands and showed that actually Temple Period ochre was consistent with local sources, and so we need not posit import. Likewise, Robb (2001) saw the long development of temples from simpler structures in the pre-Temple Period Neolithic, yet it now appears that there was a long hiatus between this and the subsequent Temple Period (e.g., McLaughlin et al., 2020a). Rather than the protracted cultural self-definition imaged by Robb (2001), the evidence arguably points to a rapid emergence of key distinguishing traits in the Żebbuġ phase at the start of the Temple Period (Malone et al., 2020a).

Discussions and research continue on lithic raw material sources in the Temple Period, and what these suggest about movement and exchange. In terms of knapped lithics, local Maltese chert was commonly used. Imported obsidian was present, but never in large amounts, and it often occurs as very small flakes and chips, suggesting intense reworking of a relatively small amount of imported material. Imported chert, including that from Sicilian sources, is certainly present in fairly large numbers, but again, often as very small pieces (e.g., Malone et al., 2009b; Malone et al., 2020e). Yet debates continue on assigning chert to particular sources. Knowledge on the variability of Maltese chert sources remains limited. In recent fieldwork, for instance Chatzimpaloglou and others (Chatzimpaloglou 2019; 2020; Chatzimpaloglou et al., 2020a,b) identified a currently unique and previously unknown chert source near Dwejra, Gozo, with radically different characteristics to "typical" Maltese chert (i.e., transparent colour and higher quartz content). Likewise, the most commonly identified in the recent excavations in Gozo, Malone et al. (2020e) "Group 1" is ambiguous in terms of origin. It did not match any of their Sicilian comparative samples. Chatzimpaloglou (2019, p. 250) suggests the dominance of this chert at sites such as Ġgantija and the Xagħra Circle provides strong evidence of "constant seafaring activity" that connected Malta to areas like Sicily. Given the character of lithics in this material – indicating complete reduction sequences, and not giving the impression of being a prized imported commodity, i.e., it was treated in a very similar way to other chert that Chatzimpaloglou does consider to be local—the possibility that it is in fact from a local source must be considered.

Groundstone "axes" provide another somewhat confusing category of material culture in Malta. Made of hard rock, particularly igneous rock, these are definitely imported, and have been linked to sources from Sicily to the Alps (Skeates, 2002). The interesting point here though is that seemingly functional axes are extremely rare—for instance, Trump (1966) found just two at Skorba—but miniature axe-shaped forms with a hole pierced at one end, commonly described as pendants, are relatively common. They mostly come from the Ħal Saflieni hypogeum, with Tarxien and the Xagħra Circle also producing reasonably large numbers. What are we to make of these "axe pendants"? Given the widespread use of groundstone axes for woodworking in the Neolithic, the paucity of seemingly functional forms in Malta is puzzling. An obvious possibility is that the axe pendants were originally functional axes, and that over long use these were worked down, reflecting limited supply, and became decorative/symbolic objects (Skeates, 2002). In some cases, it is clear that two pendants were being prepared from a single larger parent object, perhaps explaining the diminutive size of the pendants. To Skeates (2002), groundstone axes were increasingly ritualised through the Temple Period (see also Barrowclough, 2007).

The consistent presence of imported materials in Malta demonstrates connections to the wider world, yet the available data can be interpreted in different ways. In some cases, the extent of this import is seemingly fairly limited, and therefore Robb (2001) point that the distinctive Temple Period culture was because of a "symbolic boundary" remains a matter of debate; the long sea crossing to Sicily or other localities in the region may have presented a considerable challenge. A more isolationist view might suggest that rather than very regular contact and exchange, it is also possible that a boat from a neighbouring society may have been driven off course to the Maltese Islands in a storm every few years, perhaps bringing with it a few groundstone axes and a small supply of obsidian or chert. Mitigating against this view, however, is the point made above about typical location of temples being near good landing points. While it is possible that this reflects intra-Maltese movements by boat instead of by land, we think it more likely that the positioning of temples reflects positioning to meet boats arriving from other areas, mediating contact with the outside world. In a highly ritualised setting though, these landings need not have been frequent to provide the ideological underpinnings to temple construction.

A Plague Epidemic?

As we have discussed, various aspects of environmental change, societal change, and the arrival of new people and ideas can all, to varying extents of specificity, be correlated with the end of the Temple Period. A further factor which is potentially important concerns the role of disease. Recent research in mainland western Eurasia now suggests a possible disease which could be involved: plague.

Plague is caused by *Yersinia pestis* bacteria, and recent genetic sequencing of human remains from western Eurasia has identified *Y. pestis* genomes at multiple sites. The earliest are around 5 ka in Sweden and Latvia, with third millennium BC examples from areas including Estonia, Croatia, Poland, and Germany (Rasmussen et al., 2015; Valtueña et al., 2017; Spyrou et al., 2018; Rascovan et al., 2019; Susat et al., 2021). It has been suggested that the Neolithic strains were less of a health risk than the Bronze Age strains (Spyrou et al., 2018). However, this has been contested (Rascovan et al., 2019), and either way, a more virulent and flea-borne version of plague originated at least 4,000 years ago (Spyrou et al., 2018). Crucially for our narrative, by the end of the third millennium BC, people had plague around the Black Sea, the Balkans, and just north of the Alps.

The timing for the spread of plague in Europe and the Mediterranean seems to correlate with the westward spread of "steppe ancestry." Some see this as a "massive migration" around 4.5 ka (e.g., Haak et al., 2015), others see it as a long process of genetic change (e.g., Furtwängler et al., 2020; Racimo et al., 2020). Limited information is available for how steppe ancestry and plague may have spread through the Mediterranean. One exception is Sardinia, where 70 ancient genomes ranging from the Neolithic to the Medieval period were published by Marcus et al. (2020). Interestingly, they found evidence of genetic continuity from the Neolithic until the 1st millennium BC, with no evidence for major gene flow into Sardinia during this period. At least biologically, Sardinia was isolated and cut off from the dominant processes in Europe and the Mediterranean.

In the Aegean, genomic studies suggest that the Minoan and Mycenaean civilizations were both the product of people primarily (at least 3/4) descending from local Neolithic people (Lazzaridis et al., 2017). However, there was a smaller scale input of ancestry from other areas, including steppe ancestry, which may have played a role in cultural change in the area. A recent study suggests a large input (~50%) of steppe ancestry in northern Greece at around 4.5 ka (Clemente et al., 2021).

FIGURE 13 | Unusual clay figurine from Tarxien temple, which has had small pieces of shell pushed into it before firing. The location of these in places associated with key points of the lymphatic system may suggest a link to diseases such as the plague (Image provided by Heritage Malta. Copyright image not to be reused without permission of Heritage Malta).

Fernandes et al. (2020) report genome wide data from Sicily and the Balearic Islands. They report that the oldest known skeleton from the Balearic Islands (~4.4 ka) has significant (more than 1/3) steppe ancestry. In Sicily, steppe ancestry was present by ~4.2 ka, possibly arriving from a westward direction due to the particular Y-chromosomes in the Sicilian samples otherwise only being known in Iberia.

So, did Malta follow the Sardinia path of biological isolation, or did it, like some other Mediterranean islands see the arrival of people with steppe ancestry at the end of the third millennium? As discussed earlier, the Thermi Ware phenomenon suggests the movement of people from the Adriatic/Aegean to Malta at this time, coming from an area where both steppe ancestry and plague existed. Evaluating such possibilities will require the screening of ancient genomes. There are, however, interesting grounds for speculation. Malone et al. (2020f) suggest that currently unpublished DNA evidence and skeletal anatomy demonstrate the existence of different ethnic groups, including "Africans." So along with the Thermi evidence, there may have been multidirectional migrations to and from Malta in the later Temple Period. A conference poster recently compared three genomes from the Xagħra Circle with other samples from Europe, and found that they showed high levels of inbreeding (Ariano et al., 2021). As well as supporting the isolation of Maltese people in the Temple Period, it is possible to imagine that this isolation and inbreeding increased vulnerability to plague.

As well as biological aspects, it is interesting to consider whether there is any cultural evidence which could relate to plague. A clay figurine from Tarxien (**Figure 13**) has been widely discussed in the literature. It shows a large-proportioned woman, with prominent vulva, stomach, and breasts as well as protruding spine and ribs on the back. Multiple small pieces of shell have been pushed into the figurine. To Zammit and Singer (1924) the figurine suggested a pathological condition; they suggested filariasis. Another common interpretation has been that the figurine depicts pregnancy (e.g., Vella Gregory, 2005, Vella Gregory, 2016; Rich, 2008). Trump (2002, p. 103) suggested that the figurine gave a "sinister impression of witchcraft." Monsarrat (2004) discusses the figurine, and suggests it could relate to either disease or pregnancy.

While acknowledging the possibility that the Tarxien figurine does relate to pregnancy and childbirth, we propose revisiting the alternative possibility that it may relate to disease. The suggestion of filariasis by Zammit and Singer (1924) is interesting. This is a group of conditions relating to roundworm infection, which commonly manifests through the lymphatic system.

The locations of the shell pierced into the Tarxien figurine—in the groin, armpits, shoulder, neck, back, etc.—are similar to the locations of prominent parts of the lymph system. Today, lymphatic filariasis, spread by mosquitos, affects some 120 million people (Fenwick, 2012). However, bubonic plague is also a lymphatic infection, with buboes appearing in places such as the groin and armpits a few days after infection (Prentice and Rahalison, 2007). Other symptoms of plague, such as headaches and joint pain, may relate to the other positions in which the Tarxien figurine shell fragments were placed.

While we emphasise that it remains a hypothesis to be tested, we consider the possibility of a plague epidemic at the end of the Temple Period as being plausible. In such a view, temples may have become nexuses for infection, perhaps explaining changes in how they were treated. If plague arrived after several centuries of deteriorating climate and social unrest, it may have provided a final blow to a vulnerable society.

DISCUSSION

In the later third millennium BC there were a variety of trajectories of climatic and societal change in and around the Mediterranean. Some of these involved arid phases and seemingly correlated societal crises. Yet this was by no means a universal response; some areas got wetter, and some societies prospered around 4.2 ka. Even within a small area, such as central Italy, records located close to each other disagree on the timing of aridity by several centuries (**Supplementary Material 1**). The meaning of this variation is currently unclear, and the ambiguity is further amplified by the dearth of high-resolution climate records in the Maltese Archipelago itself.

What can we say about the Maltese Islands? There seems to be a period of increased aridity broadly dating to ~4.5 to 3.8 ka (e.g., Gambin et al., 2016; Farrell et al., 2020). At this point we re-iterate the challenges of constructing accurate age-depth models, and the need for caution when extrapolating from a few dates to long sequences. With that caveat in mind, there appears to be a significant decline in cereal pollen ~4.3 ka (Carroll et al., 2012). Molluscs present a similar story, with signs of aridification from the mid third millennium BC, perhaps coming to a head ~4.3 to 4.2 ka (e.g., Fenech et al., 2020). Future work on sediment cores can continue to seek to improve chronology by using tephras (e.g., Zanchetta et al., 2019), and studies of more diverse types of climate archives can be conducted.

Significantly, major social changes are evident and occurred at the same time as these climatic changes. The Thermi phase, ~4.4–4.2 ka, suggests the arrival of new communities in the islands. There are hints of damage at several sites in the late Temple Period and Thermi phases. We have explored an example of this from the Xagħra Circle, where our chronological modelling suggests the deliberate smashing of the statue occurred before 4.4 ka, and our REC model approach found a negative correlation between archaeological indications of human activity and regional precipitation. It appears that from around 4.5 ka there was a decline in both rainfall and archaeological activity. The Thermi phase and 4.2 ka event, when the islands may have been abandoned between 4.2 and 4 ka (Carroll et al., 2012; McLaughlin et al., 2020a), therefore seemingly occurred after centuries of decline. The 4.2 ka event may therefore have provided the coup de grâce on an already declining and stressed population, but it did not strike a stable society out of the blue. The possibility of a plague epidemic may also crosscut these debates and suggest an alternative narrative, yet, once again, if there was a plague outbreak, it seemingly occurred in the context of a society in decline.

After a remarkably long period of apparent societal stability on a small and climatically unstable archipelago, the unique local phenomenon of the Temple Period expired by the end of the third millennium BC. It was followed by a Bronze Age reflecting the re-integration of the islands into the more dominant trends of the Mediterranean and increasing connectivity and trade. As [Broodbank, (2015), p. 343] discusses, in some regards Malta parallels developments in Cyprus, another remote Mediterranean island which developed distinctive and localised trajectories before being "normalised" relative to neighbouring areas in the late third millennium BC. This "victory for connectivity" in the emerging Bronze Age world saw the end of the fascinating local experiment that was the Temple Period. Despite now being one of the most intensely chronometrically dated areas in the Mediterranean, the causes of the end of the Temple Period in Malta remain unclear. As we have discussed, certain correlations are suggested by the evidence, but establishing causal pathways remains challenging.

DATA AVAILABILITY STATEMENT

The data analysed for this study can be found in the paper, **Supplementary Material**, and at (https://github.com/wccarleton/malta42) for R code and base data, and doi: 10.5281/zenodo.5354992 for additional large data files.

AUTHOR CONTRIBUTIONS

HG conceived of the paper and led the writing. WCC carried out the chronological modelling, and all authors wrote and edited the paper.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feart.2021.771683/full#supplementary-material

REFERENCES

Adams, M. J. (2017). "Egypt and the Levant in the Early to Middle Bronze Age Transition," in *The Late Third Millennium in the Ancient Near East: Chronology, C14, and Climate Change*. Editor F. Höflmayer (Chicago: The Oriental Institute, University of Chicago), 493–515.

Alberti, G., Grima, R., and Vella, N. C. (2018). The Use of Geographic Information System and 1860s Cadastral Data to Model Agricultural Suitability before Heavy Mechanization. A Case Study from Malta. *PLoS ONE* 13, E0192039. doi:10.1371/journal.pone.0192039

Ariano, B., Mattiangeli, V., Cassidy, L., McLaughlin, R., Power, R., Stock, J., et al. (2021). Inbreeding in Ancient Malta and Neolithic Europe. Poster at ISBA9: 9th International Symposium on Biomolecular Archaeology.

Ashby, T. (1924). Supplementary Excavations at Hal-Tarxien, Malta, in 1921. *Antiq. J.* 4, 93–100. doi:10.1017/s0003581500005539

Attard Montalto, N., Shortland, A., and Rogers, K. (2012). The Provenancing of Ochres from the Neolithic Temple Period in Malta. *J. Archaeological Sci.* 39, 1094–1102. doi:10.1016/j.jas.2011.12.010

Barrowclough, D. A. (2007). "Putting Cult in Context: Ritual, Religion and Cult in Temple Period Malta," in *Cult in Context: Reconsidering Ritual in Archaeology*. Editors D. A. Barrowclough and C. Malone (Oxford: Oxbow), 45–53.

Bell, B. (1971). The Dark Ages in Ancient History. I. The First Dark Age in Egypt. *Am. J. Archaeology* 75, 1–26. doi:10.2307/503678

Besnard, G., Terral, J.-F., and Cornille, A. (2018). On the Origins and Domestication of the Olive: a Review and Perspectives. *Ann. Bot.* 121, 385–403. doi:10.1093/aob/mcx145

Bini, M., Zanchetta, G., Perşoiu, A., Cartier, R., CatalàCacho, A., Cacho, I., et al. (2019). The 4.2 Ka BP Event in the Mediterranean Region: an Overview. *Clim. Past* 15, 555–577. doi:10.5194/cp-15-555-2019

Biolchi, S., Furlani, S., Antonioli, F., Baldassini, N., Causon Deguara, J., Devoto, S., et al. (2016). Boulder Accumulations Related to Extreme Wave Events on the Eastern Coast of Malta. *Nat. Hazards Earth Syst. Sci.* 16, 737–756. doi:10.5194/nhess-16-737-2016

Blanz, M., Ascough, P., Mainland, I., Martin, P., Taggart, M. A., Dieterich, B., et al. (2019). Seaweed Fertilisation Impacts the Chemical and Isotopic Composition of Barley: Implications for Analyses of Archaeological Skeletal Remains. *J. Archaeological Sci.* 104, 34–44. doi:10.1016/j.jas.2019.02.003

Bonanno, A. (1986). "A Socioeconomic Approach to Maltese Prehistory: The temple Builders," in *Malta: Studies of its Heritage and History*. Editor J. H. Newman. Valletta, Malta (Mid-Med Bank), 17–46.

Bonanno, A., Gouder, T., Malone, C., and Stoddart, S. (1990). Monuments in an Island Society: The Maltese Context. *World Archaeology* 22, 190–205. doi:10.1080/00438243.1990.9980140

Bonanno, A. (2004). "Rituals of Life, Rituals of Death," in *Malta before History*. Editors D. Cilia and M. Malta, 271–305.

Bonanno, A. (1993). Tarxien and Tarxien Cemetary: Break or Continuity between Temple Period and Bronze Age in Malta? *Mediterraneo. Revistade Estudos Pluridiscplinares Sobre Ad Sociedades Mediterranicas* 2, 35–47.

Bonanno, A. (2017). *The Archaeology of Malta and Gozo: 5000 BC-AD 1091*. Heritage Malta: Malta.

Bradley, R. S., and Bakke, J. (2019). Is There Evidence for a 4.2 Ka BP Event in the Northern North Atlantic Region? *Clim. Past* 15, 1665–1676. doi:10.5194/cp-15-1665-2019

Brogan, C., French, C., Taylor, S., Bennett, J., Parkinson, E. W., McLaughlin, R., et al. (2020). "Ġgantija," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 169–192.

Bronk Ramsey, C. (1995). Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program. *Radiocarbon* 37, 425–430. doi:10.1017/s0033822200030903

Bronk Ramsey, C. (2008). Deposition Models for Chronological Records. *Quat. Sci. Rev.* 27, 42–60. doi:10.1016/j.quascirev.2007.01.019

Broodbank, C. (2015). *The Making of the Middle Sea: A History of the Mediterranean from the Beginning to the Emergence of the Classical World*. London: Thames and Hudson.

Buhagiar, K. (2008). "Water Management in Medieval and Early Modern Malta," in *Malta in the Hybleans, the Hybleans in Malta: Malta Negli Iblei, Gli Iblei a Malta* (Palermo: Officina di Studi Medievali)), 259–267.

Carleton, W. C. (2020). Evaluating Bayesian Radiocarbon-dated Event Count (REC) Models for the Study of Long-term Human and Environmental Processes. *J. Quat. Sci* 36, 110–123. doi:10.1002/jqs.3256

Carleton, W. C., and Groucutt, H. S. (2020). Sum Things Are Not what They Seem: Problems with point-wise Interpretations and Quantitative Analyses of Proxies Based on Aggregated Radiocarbon Dates. *The Holocene* 31, 630–643. doi:10.1177/0959683620981700

Carolin, S. A., Walker, R. T., Day, C. C., Ersek, V., Sloan, R. A., Dee, M. W., et al. (2019). Precise Timing of Abrupt Increase in Dust Activity in the Middle East Coincident with 4.2 Ka Social Change. *Proc. Natl. Acad. Sci. USA* 116, 67–72. doi:10.1073/pnas.1808103115

Carroll, F. A., Hunt, C. O., Schembri, P. J., and Bonanno, A. (2012). Holocene Climate Change, Vegetation History and Human Impact in the Central Mediterranean: Evidence from the Maltese Islands. *Quat. Sci. Rev.* 52, 24–40. doi:10.1016/j.quascirev.2012.07.010

Carozza, L., Berger, J. F., Marcigny, C., and Burens, A. (2015). "Society and Environment in Southern France from the 3rd Millennium BC to the Beginning of the 2nd Millennium BC: 2200 BC as a Tipping point?" in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch Halle, Germany: (Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte), 335–364.

Caruana, J., and Stroud, K. (2020). "Megalithic Site Intervisibility: a Novel Phenomenological Approach," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 447–456.

Causon Deguara, J., and Gauci, R. (2017). Evidence of Extreme Wave Events from Boulder Deposits on the South-East Coast of Malta (Central Mediterranean). *Nat. Hazards* 86, 543–568. doi:10.1007/s11069-016-2525-4

Cazzella, A., and Recchia, G. (2015). "The Early Bronze Age in the Maltese Islands," in *The Late Prehistory of Malta: Essays on Borg In-Nadur and Other Sites*. Editors D. Tanasi and N. Vella (Oxford, Archaeopress, 139–160. doi:10.2307/j.ctvr43j55.12

Cazzella, A., and Recchia, G. (2012). Tas-Silġ: The Late Neolithic Megalithic Sanctuary and its Re-use during the Bronze Age and Early Iron Age. *Scienze dell'antichità* 18, 15–38.

Chase, B., Meiggs, D., and Ajithprasad, P. (2020). Pastoralism, Climate Change, and the Transformation of the Indus Civilization in Gujarat: Faunal Analyses and Biogenic Isotopes. *J. Anthropological Archaeology* 59, 101173. doi:10.1016/j.jaa.2020.101173

Chatzimpaloglou, P. (2020). A Geoarchaeological Methodology for Sourcing Chert Artefacts in the Mediterranean Region: A Case Study from Neolithic Skorba on Malta. *Geoarchaeology* 35, 897–920. doi:10.1002/gea.21813

Chatzimpaloglou, P., French, C., Pedley, M., and Stoddart, S. (2020b). Connecting Chert Sources of Sicily with the Neolithic Chert Artefacts of Malta. *J. Arch. Sci. Rep.* 29, 102–111. doi:10.1016/10.1016/j.jasrep.2019.102111

Chatzimpaloglou, P. (2019). *Geological Reconnaissance and Provenancing of Potential Neolithic Lithic Sources in the Maltese Islands. PhD Thesis* Cambridge, Germany: University of Cambridge.

Chatzimpaloglou, P., Schembri, P. J., French, C., Ruffell, A., and Stoddart, S. (2020a). "The Geology, Soils and Present-Day Environment of Gozo and Malta," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 19–34.

Cilia, D. (Editor) (2004). *Malta before History* (Miranda: Malta).

Clemente, F., Unterländer, M., Dolgova, O., Amorim, C. E. G., Coroado-Santos, F., Neuenschwander, S., et al. (2021). The Genomic History of the Aegean Palatial Civilizations. *Cell* 184, 2565–2586. doi:10.1016/j.cell.2021.03.039

Copat, V., Danesi, M., and Ruggini, C. (2013). Late Neolithic and Bronze Age Pottery from Tas-Silġ Sanctuary: New Research Perspectives for the Maltese Prehistoric Sequence. *Scienze dell'Antichità* 18, 39–63.

Craig, O. E., Biazzo, M., O'Connell, T. C., Garnsey, P., Martinez-Labarga, C., Lelli, R., et al. (2009). Stable Isotopic Evidence for Diet at the Imperial Roman Coastal Site of Velia (1st and 2nd Centuries AD) in Southern Italy. *Am. J. Phys. Anthropol.* 139, 572–583. doi:10.1002/ajpa.21021

D'Auria, A., Buonincontri, P., Allevato, E., Saracino, A., Jung, R., Pacciarelli, M., et al. (2016). Evidence of a Short-Lived Episode of Olive (*Olea Europea* L.) Cultivation during the Early Bronze Age in Western Mediterranean (Southern Italy). *The Holocene* 27, 605–612. doi:10.1177/0959683616670218

deMenocal, P. B. (2001). Cultural Responses to Climate Change during the Late Holocene. *Science* 292, 667–673. doi:10.1126/science.1059287

De Michele, R., La Bella, F., Gristina, A. S., Fontana, I., Pacifico, D., Garfi, G., et al. (2019). Phylogenetic Relationship Among Wild and Cultivated grapevine in Sicily: A Hotspot in the Middle of the Mediterranean basin. *Front. Plant Sci.* 10, 1506. doi:10.3389/fpls.2019.01506

Despott, G. (1923). Excavations at Ghar Dalam (Dalam Cave), Malta. *The J. R. Anthropological Inst. Great Britain Ireland* 53, 18–35. doi:10.2307/2843749

Di Rienzo, V., Sion, S., Taranto, F., D'Agostino, N., Montemurro, C., Fanelli, V., et al. (2018). Genetic Flow Among Olive Populations within the Mediterranean basin. *PeerJ* 6, e5260. doi:10.7717/peerj.5260

Di Rita, F., Fletcher, W. J., Aranbarri, J., Margaritelli, G., Lirer, F., and Magri, D. (2018). Holocene forest Dynamics in central and Western Mediterranean: Periodicity, Spatio-Temporal Patterns and Climate Influence. *Sci. Rep.* 8, 8929. doi:10.1038/s41598-018-27056-2

Djamali, M., Gambin, B., Marriner, N., Andrieu-Ponel, V., Gambin, T., Gandouin, E., et al. (2012). Vegetation Dynamics during the Early to Mid-holocene Transition in NW Malta, Human Impact versus Climatic Forcing. *Veget Hist. Archaeobot* 22, 367–380. doi:10.1007/s00334-012-0380-0

Drysdale, R., Zanchetta, G., Hellstrom, J., Maas, R., Fallick, A., Pickett, M., et al. (2006). Late Holocene Drought Responsible for the Collapse of Old World

Civilizations Is Recorded in an Italian Cave Flowstone. *Geol* 34, 101–104. doi:10.1130/G22103.1

Evans, J. D. (1977). Island Archaeology in the Mediterranean: Problems and Opportunities. *World Archaeology* 9, 12–26. doi:10.1080/00438243.1977.9979682

Evans, J. D. (1973). "Islands as Laboratories for the Study of Culture Processes," in *The Explanation of Culture Change. Models in Prehistory*. Editors A. C. Renfrew. London, United Kingdom: (Duckworth), 517–520.

Evans, J. D. (1971). *The Prehistoric Antiquities of the Maltese Islands, A Survey*. London: Athlone Press.

Evans, J. D. (1953). The Prehistoric Sequence of the Maltese Archipelago. *Proc. Prehist. Soc.* 19, 41–94.

Farrell, M., Hunt, C. O., and McLung, L. C. (2020). "Holocene Vegetation History of the Maltese Islands," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 73–114.

Fenech, K. (2007). *Human Induced Changes in the Environment and Landscape of the Maltese Islands from the Neolithic to the 15th century AD as Inferred from a Scientific Study of Sediments from Marsa*. Oxford: BAR International Series 1692, Archaeopress.

Fenech, K., Hunt, C. O., Vella, N. C., and Schembri, P. J. (2020). "Molluscan Remains from the Valley Cores," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 115–159.

Fenwick, A. (2012). The Global burden of Neglected Tropical Diseases. *Public Health* 126, 233–236. doi:10.1016/j.puhe.2011.11.015

Fenwick, V. (2017). Robert Newall's Primary Record of the Prehistoric Ship Graffiti at Hal Tarxien, Malta: New Thoughts on Their Significance. *Int. J. Nautical Archaeology* 46, 415–426. doi:10.1111/1095-9270.12239

Fernandes, D., Mittnik, A., Olade, I., Lazaridis, I., Cheronet, O., Rohland, N., et al. (2020). The Spread of Steppe Ancestry and Iranian-Related Ancestry in the Islands of the Western Mediterranean. *Nat. Ecol. Evol.* 4, 334–345. doi:10.1038/s41559-020-1102-0

Finné, M., Woodbridge, J., and Roberts, C. N. (2019). Holocene Hydro-Climatic Variability in the Mediterranean: A Synthetic Multi-Proxy Reconstruction. *The Holocene* 29, 847–863. doi:10.1177/0959683619826634

Fiontentio, G., Oronzo, C., and Colainni, C. (2012). Human-Environment Interaction, in Malta from the Neolithic to the Roman Period: Archaeobotanical Analyses at Tas-Silġ. *Scienze dell'Antichità* 18, 169–184.

Florenzano, A., Mercuri, A. M., Rinaldi, R., Rattighieri, E., Fornaciari, R., Messora, R., et al. (2017). The Representativeness of *Olea* Pollen from Olive groves and the Late Holocene Landscape Reconstruction in central Mediterranean. *Front. Earth Sci* 5, 1–11. doi:10.3389/feart.2017.00085

French, C., Hunt, C. O., Farrell, M., Fenech, K., McLaughlin, R., Grima, R., et al. (2002b). "Conclusions," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 303–324.

French, C., and Taylor, S. (2020). "The Geoarchaeology of Past Landscape Sequences on Gozo and Malta," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 161–222.

French, C., Hunt, C. O., Grima, R., McLaughlin, R., Stoddart, S., and Malone, C. (2020a). *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. (Cambridge: McDonald Institute for Archaeological Research).

Furtwängler, A., Rohrlach, A. B., Lamnidis, T. C., Papac, L., Neumann, G. U., Siebke, I., et al. (2020). Ancient Genomes Reveal Social and Genetic Structure of Late Neolithic Switzerland. *Nat. Commun.* 11, 1915. doi:10.1038/s41467-020-15560-x

Gambin, B., Andrieu-Ponel, V., Médail, F., Marriner, N., Peyron, O., Montade, V., et al. (2016). 7300 Years of Vegetation History and Climate for NW Malta: a Holocene Perspective. *Clim. Past* 12, 273–297. doi:10.5194/cp-12-273-2016

Garnsey, P. (1988). *Famine and Food Supply in the Graeco-Roman World.* Cambridge: Cambridge University Press.

Gauci, R., and Schembri, J. A. (2019). *Landscapes and Landforms of the Maltese Islands*. Cham: Springer.

Genz, H. (2015). "Beware of Environmental Determinism: The Transition from the Early to Middle Bronze Age on the Lebanese Coast and the 4.2 Ka BP Event," in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch . Halle, Germany: (Halle, Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte), 97–112.

Greenberg, R. (2017). "No Collapse: Transmutations of Early Bronze Age Urbanism in the Southern Levant," in *The Late Third Millennium in the Ancient Near East: Chronology, C14, and Climate Change*. Editor F. Höflmayer (Chicago: The Oriental Institute, University of Chicago), 31–58.

Grima, R. (2001). An Iconography of Insularity: A Cosmological Interpretation of Some Images and Spaces in the Late Neolithic Temples of Malta. *Pap. Inst. Archaeology* 12, 48–65.

Grima, R. (2003). "Image, Order and Place in Late Neolithic Malta," in *Inhabiting Symbols. Symbol and Image in the Ancient Mediterranean*. Editors J. B. Wilkins and E. HerringLondon. London, United Kingdom: Accordia, 29–41.

Grima, R. (2008). Landscape, Territories, and the Life-Histories of Monuments in Temple Period Malta. *Jma* 21, 35–56. doi:10.1558/jmea.v21i1.35

Grima, R., Stoddart, S., Hunt, C. O., French, C., McLaughlin, R., and Malone, C. (2020). "Cultural Landscapes in the Changing Environments from 6000 to 2000 BC," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 223–238.

Grima, R. (2004). "The Landscape of Megalithic Architecture," in *Malta before History*. Editors D. Cilia and Miranda. Malta, 327–345.

Grima, R. (2016). Water, Geomythology and Cosmology in Late Neolithic Malta. *Accordia Res. Pap.* 14, 27–48.

Gröcke, D. R., Treasure, E. R., Lester, J. L., Gron, K. J., and Church, M. J. (2021). Effects of marine Biofertilisation on Celtic Bean Carbon, Nitrogen, and sulphur Isotopes: Implications for Reconstructing Past Diet and Farming Practices. *Rapid Com. Mass. Spec.* 15, e8985. doi:10.1002/rcm.8985

Haak, W., Lazaridis, I., Patterson, N., Rohland, N., Mallick, S., Llamas, B., et al. (2015). Massive Migration from the Steppe Was a Source for Indo-European Languages in Europe. *Nature* 522, 207–211. doi:10.1038/nature14317

Höflmayer, F. (2017). "The Late Third Millenium B.C. In the Ancient Near East and Eastern Mediterranean: A Time of Collapses and Transformation," in *The Late Third Millenium in the Ancient Near East: Chronology, C14, and Climate Change*. Editor F. Höflmayer (Chicago: The Oriental Institute, University of Chicago), 1–28.

Hunt, C. O., Farrell, M., Fenech, K., French, C., McLaughlin, R., Blaauw, M., et al. (2020). "Chronology and Stratigraphy of the valley Systems," in *Temple Landscapes: Fragility, Change and Resilience of Holocene Environments in the Maltese Islands*. Editors C. French, C. O Hunt, R. Grima, R. McLaughlin, S. Stoddart, and C. Malone (Cambridge: McDonald Institute for Archaeological Research), 35–72.

Hunt, C. O. (1997). Quaternary Deposits in Maltese Islands: A Microcosm of Environmental Change in Mediterranean Lands. *Geo-Journal* 41, 101–109. doi:10.1023/a:1006824605544

Jung, R., and Wenninger, B. (2015). "Archaeological and Environmental Impact of the 4.2 Ka Cal BP Event in the central and Eastern Mediterranean," in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch. Halle, Germany: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 205–234.

Kanawti, N. (2003). *Conspiracies in the Egyptian Palace Unis to Pepy I*. New York: Routeledge.

Kaniewski, D., Marriner, N., Cheddadi, R., Guiot, J., and Van Campo, E. (2018). The 4.2 Ka BP Event in the Levant. *Clim. Past* 14, 1529–1542. doi:10.5194/cp-14-1529-2018

Langutt, D., Cheddadi, R., Carrión, J. S., Cavanagh, M., Colombaroli, D., Eastwood, W. J., et al. (2019). The Origin and Spread of Olive Cultivation in the Mediterranean Basin: The Fossil Pollen Evidence. *The Holocene* 29, 902–922.

Lawrence, D., Palmisano, A., and de Gruchy, M. W. (2021). Collapse and Continuity: A Multi-Proxy Reconstruction of Settlement Organization and Population Trajectories in the Northern Fertile Crescent during the 4.2kya Rapid Climate Change Event. *PLoS ONE* 16, e0244871. doi:10.1371/journal.pone.0244871

Lazaridis, I., Mittnik, A., Patterson, N., Mallick, S., Rohland, N., Pfrengle, S., et al. (2017). Genetic Origins of the Minoans and Mycenaeans. *Nature* 548, 214–218. doi:10.1038/nature233110.1038/nature23310

Leonardi, G., Cupitò, M., Baioni, M., Longhi, C., and Martinelli, N. (2015). "Northern Italy Around 2200 Cal BC. From Copper to Early Bronze Age: Continuity And/or Discontinuity?" in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch. Halle, Germany: (Halle, Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 283–304.

Magro Conti, J., and Saliba, P. C. (Editors) (2007). *The Significance of Cart-Ruts in Ancient Landscapes* (Midsea: Malta).

Magro Conti, J. (1999). "Aggression and Defence in Prehistoric Malta," in *Facets of Maltese Prehistory*. Editors A. Mifsud and C. Savona Ventura (Malta. Halle, Germany: Prehistoric Society of Malta, 191–208.

Malone, C., Stoddart, S., Trump, D., Bonanno, A., and Pace, A. (Editors) (2009a). *Mortuary Ritual in Prehistoric Malta. The Brochtorff Circle Excavations (1987-1994* (Cambridge: McDonald Institute for Archaeological Research).

Malone, C., Bonanno, A., Trump, D., Dixon, J., Leighon, R., Pedley, M., et al. (2009b). "Material Culture," in *Mortuary Customs in Prehistoric Malta*. Editors C. Malone, S. Stoddart, A. Bonanno, and D. Trump (Cambridge: McDonald Institute for Archaeological Research), 219–314.

Malone, C., and Stoddart, S. (2013). "Ritual Failure and the temple Collapse of Prehistoric Malta," in *Ritual Failure: Archaeological Perspectives*. Editors V. G. Koufratouri and J. Sanders (Leiden, Sidestone, 63–84.

Malone, C., and Stoddart, S. (2016). "Figurines of Malta," in *The Oxford Handbook of Prehistoric Figurines*. Editor T. Insoll (Oxford: Oxford University Press), 729–753.

Malone, C., Cutajar, N., McLaughlin, T. R., Mercieca-Spiteri, B., Pace, A., Power, R. K., et al. (2019). Island Questions: the Chronology of the Brochtorff Circle at Xagħra, Gozo, and its Significance for the Neolithic Sequence on Malta. *Archaeol Anthropol. Sci.* 11, 4251–4306. doi:10.1007/s12520-019-00790-y

Malone, C., Grima, R., McLaughlin, R., Parkinson, E. W., Stoddart, S., and Vella, N. (Editors) (2020a). *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta* (Cambridge: McDonald Institute for Archaeological Research).

Malone, C., Stoddart, S., McLaughlin, R., and Vella, N. (2020b). "Archaeological Studies of Maltese Prehistory for the *FRAGSUS Project* 2013-19," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 1–26.

Malone, C., McLaughlin, R., Armstrong, S., Bennett, J., McAdams, C., French, C., et al. (2020c). "Excavations at Taċ-Ċawla, Rabat, Gozo, 2014," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 39–122.

Malone, C., Brogan, C., and McLaughlin, R. (2020d). "The Pottery of Prehistoric Malta," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 309–398.

Malone, C., Chatzimpaloglou, P., and Brogan, C. (2020e). "Small Finds and Lithics: Reassessing the Excavated Artefacts and Their Sources in Prehistoric Malta," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 399–446.

Malone, C., Brogan, C., Grima, R., Parkinson, E. W., McLaughlin, R., et al. (2020f). "Conclusions," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 457–482.

Manning, S. W. (2017). "Comments on Climate, Intra-regional Variations, Chronology, the 2200 B.C. Horizon of Change in the East Mediterranean Region, and Socio-Political Change on Crete," in *The Late Third Millenium in the Ancient Near East: Chronology, C14, and Climate Change*. Editor F. Höflmayer (Chicago: The Oriental Institute, University of Chicago), 451–490.

Maran, J. (1998). *Kulturwandel auf dem griechischen Festland und den Kykladen im späten 3. Jahr tausand v. Chr. Studien zu den kulturellen Verhältnissen in Südosteuropa und dem zentralen sowie östlichen Mittelmeerraum in der späten Kupfer-und frühen Bronzezeit*, 53. Bonn: Univorsch. Prähist. Arch.Habelt.

Marcus, J. H., Posth, C., Ringbauer, H., Lai, L., Skeates, R., Sidore, C., et al. (2020). Genetic History from the Middle Neolithic to Present on the Mediterranean Island of Sardinia. *Nat. Commun.* 11, 939. doi:10.1038/s41467-020-14523-6

Marriner, N., Kaniewski, D., Morhange, C., Flaux, C., GiaimeVacchi, M., Vacchi, M., et al. (2017). Tsunamis in the Geological Record: Making Waves with a Cautionary Tale from the Mediterranean. *Sci. Adv.* 3, e1700485. doi:10.1126/sciadv.1700485

McLaughlin, R., McCormick, F., Hamilton-Dyer, S., Bates, J., Morales-Mateos, J., French, C., et al. (2020b). "Economy, Environment and Resources in Prehistoric Malta," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 281–308.

McLaughlin, R., Parkinson, E. W., Reimer, P. J., and Malone, C. (2020a). "Dating Maltese Prehistory," in *Temple Places: Excavating Cultural Sustainability in Prehistoric Malta*. Editors C. Malone, R. Grima, R. McLaughlin, E. W. Parkinson, S. Stoddart, and N. Vella (Cambridge: McDonald Institute for Archaeological Research), 27–38.

McLaughlin, T. R., Stoddart, S., and Malone, C. (2018). Island Risks and the Resilience of a Prehistoric Civilization. *World Archaeology* 50, 570–600. doi:10.1080/00438243.2018.1515656

Mead, M. (1957). Introduction to Polynesia as Laboratory for the Development of Models in the Study of Cultural Evolution. *J. Polynesian Arch.* 66, 145.

Micallef, P., Attard, G., and Mangion, J. (2000). Water Resource Management in Malta: Cultural Heritage and Legal Administrative Set-Up. *Options Méditerranéennes* 48, 199–207.

Monsarrat, A. (2004). "The Deity: God or Goddess?" in *Malta before History*. Editors D. Cilia and M. Malta, 288–305.

Moreno García, J. C. (2015). "Climatic Change or Sociopolitical Transformation? Reassessing Late 3rd Millennium BC in Egypt," in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch. Mosta, Malta: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 79–94.

Mottershead, D., Bray, M., Soar, P., and Farres, P. J. (2014). Extreme Wave Events in the central Mediterranean: Geomorphic Evidence of Tsunami on the Maltese Islands. *zfg* 58, 385–411. doi:10.1127/0372-8854/2014/0129

Mottershead, D., Pearson, A., Farres, P., and Schaefer, M. (2019). "Humans as Agents of Geomorphological Change: The Case of the Maltese Cart-Ruts at Misraħ Għar Il-Kbir, San Ġwann, San Pawl Tat-Tarġa and Imtaħleb," in *Landscapes and Landforms of the Maltese Islands*. Editors R. Gauci and J. A. Schembri (Cham: Springer), 103–116. doi:10.1007/978-3-030-15456-1_9

Mueller, C., Micallef, A., Spatola, D., and Wang, X. (2019). The Tsunami Inundation hazard of the Maltese Islands (Central Mediterranean Sea): A Submarine Landslide and Earthquake Tsunami Scenario Study. *Pure Appl. Geophys.* 177, 1617–1638. doi:10.1007/s00024-019-02388-w

Newbury, J. (1968). The Perched Water Table in the Upper Limestone Aquifer of Malta. *J. Inst. Eng. (India)* 22, 551–570.

Pacciarelli, M., Scarano, T., and Crispino, A. (2015). "The Transition between the Copper and Bronze Ages in Southern Italy and Sicily," in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt? Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte*. Editors H. Meller, H. W. Arz, R. Jung, and R. Risch, 253–282.

Pace, A. (2004). "The Sites," in *Malta before History*. Editors D. Cilia and M. Malta, 42–227.

Palmisano, A., Lawrence, D., de Gruchy, M. W., Bevan, A., and Shennan, S. (2021). Holocene Regional Population Dynamics and Climatic Trends in the Near East: A First Comparison Using Archaeo-Demographic Proxies. *Quat. Sci. Rev.* 252, 106739. doi:10.1016/j.quascirev.2020.106739

Pedley, H. M., Hughes-Clarke, M., and Galea, P. (2012). *Limestone Isles in a Crystal Sea: The Geology of the Maltese Islands*. San Gwann, Malta: PEG Ltd.

Perşoiu, A., Ionita, M., and Weiss, H. (2019). Atmospheric Blocking Induced by the Strengthened Siberian High Led to Drying in West Asia during the 4.2 Ka BP Event – a Hypothesis. *Clim. Past* 15, 781–793. doi:10.5194/cp-15-781-2019

Peyron, O., Combourieu-Nebout, N., Brayshaw, D., Goring, S., Andrieu-Ponel, V., Desprat, S., et al. (2019). Precipitation Changes in the Mediterranean basin during the Holocene from Terrestrial and marine Pollen Records: a Model-Data Comparison. *Clim. Past* 13, 249–265. doi:10.5194/cp-13-249-2017

Prentice, M. B., and Rahalison, L. (2007). Plague. *The Lancet* 369, 1196–1207. doi:10.1016/S0140-6736(07)60566-2

Racimo, F., Woodbridge, J., Fyfe, R. M., Sikora, M., Sjögren, K.-G., Kristiansen, K., et al. (2020). The Spatiotemporal Spread of Human Migrations during the European Holocene. *Proc. Natl. Acad. Sci. USA* 117, 8989–9000. doi:10.1073/pnas.1920051117

Rahmstorf, L. (2015). "The Aegean before and after C. 2200 BC between Europe and Asia: Trade as a Prime Mover of Cultural Change," in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch. Halle, Germany: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 149–180.

Railsback, L. B., Liang, F., Brook, G. A., Voarintsoa, N. R. G., Sletten, H. R., Marais, E., et al. (2018). The Timing, Two-Pulsed Nature, and Variable Climatic Expression of the 4.2 Ka Event: A Review and New High-Resolution Stalagmite Data from Namibia. *Quat. Sci. Rev.* 186, 78–90. doi:10.1016/j.quascirev.2018.02.015

Ran, M., and Chen, L. (2019). The 4.2 Ka BP Climatic Event and its Cultural Responses. *Quat. Int.* 521, 158–167. doi:10.1016/j.quaint.2019.05.030

Rascovan, N., Sjögren, K.-G., Kristiansen, K., Nielsen, R., Willerslev, E., Desnues, C., et al. (2019). Emergence and Spread of Basal Lineages of *Yersinia pestis* during the Neolithic Decline. *Cell* 176, 295–305. doi:10.1016/j.cell.2018.11.005

Rasmussen, S., Allentoft, M. E., Nielsen, K., Orlando, L., Sikora, M., Sjögren, K.-G., et al. (2015). Early Divergent Strains of *Yersinia pestis* in Eurasia 5,000 Years Ago. *Cell* 163, 571–582. doi:10.1016/j.cell.2015.10.009

Recchia, G., and Cazzella, A. (2011). "Maltese Prehistoric Ceramic Sequence and Chronology: On-Going Problems," in *Ceramics of the Phoenician-Punic World: Collected Essays*. Editors C. Sagona. Leuven, China: Peeters, 373–396.

Recchia, G., and Fiorentino, G. (2015). "Archipelagos Adjacent to Sicily Around 2200 BC: Attractive Environments or Suitable Geo-Economic Locations?" in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch. Halle, Germany Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 305–320.

Renfrew, C. (1973). *Before Civilization: The Radiocarbon Revolution and Prehistoric Europe*. London: Jonathan Cape.

Renfrew, C., and Level, E. V. (1979). "Exploring Dominance: Predicting Polities from Centers," in *Transformations: Mathematical Approaches to Culture*. Editors C. Renfrew and K. L. Cooke (New York: Academic Press), 145–167. doi:10.1016/b978-0-12-586050-5.50016-6

Rich, S. A. (2008). Midwifery and Neolithic Malta: Interpreting and Contextualising Two Terracotta Figurines. *Omertaa*, 260–268.

Richards, M. P., Hedges, R. E. M., Walton, I., Stoddart, S., and Malone, C. (2001). Neolithic Diet at the Brochtorff Circle, Malta. *Eur. J. Archaeol.* 4, 253–262. doi:10.1179/eja.2001.4.2.253

Robb, J. (2001). Island Identities: Ritual, Travel and the Creation of Difference in Neolithic Malta. *Eur. J. Archaeology* 4, 175–202. doi:10.1177/146195710100400202

Robinson, M. G. P., Porter, A., Figueira, W., and Fletcher, R. (2019). Neolithic Temples of Malta: 3D Analysis Points to Novel Roof Reconstruction. *Digital Appl. Archaeology Cult. Heritage* 13, e00095. doi:10.1016/j.daach.2019.e00095

Rohling, E. J., Marino, G., and Grant, K. M. (2015). Mediterranean Climate and Oceanography, and the Periodic Development of Anoxic Events (Sapropels). *Earth-Science Rev.* 143, 62–97. doi:10.1016/j.earscirev.2015.01.008

Ruffell, A., Hunt, C. O., Grima, R., McLaughlin, R., Malone, C., Schembri, P., et al. (2018). Water and Cosmology in the Prehistoric Maltese World: Fault Control on the Hydrogeology of Ġgantija, Gozo (Maltese Islands). *J. Archaeological Sci. Rep.* 20, 183–191. doi:10.1016/j.jasrep.2018.05.002

Sagona, C. (2004). Land Use in Prehistoric malta. A Re-examination of the Maltese 'cart Ruts'. *Oxford J. Archeol* 23, 45–60. doi:10.1111/j.1468-0092.2004.00201.x

Sagona, C. (2015). *The Archaeology of Malta: From the Neolithic through the Roman Period*. Cambridge: Cambridge University Press.

Sahlins, M. D. (1955). Esoteric Efflorescence in Easter Island. *Am. Anthropologist* 57, 1045–1052. doi:10.1525/aa.1955.57.5.02a00150

Scerri, S. (2019). "Sedimentary Evolution and Resultant Geological Landscapes," in *Landscapes and Landforms of the Maltese Islands*. Editors R. Gauci and J. A. Schembri (Cham: Springer), 31–47. doi:10.1007/978-3-030-15456-1_4

Schembri, P. J., Hunt, C., Pedley, M., Malone, C., and Stoddart, S. (2009). "The Environment of the Maltese Islands," in *Mortuary Customs in Prehistoric Malta*. Editors C. Malone, S. Stoddart, A. Bonanno, and D. Trump (Cambridge: McDonald Institute for Archaeological Research), 17–40.

Schembri, P. J. (1997). The Maltese Islands: Climate, Vegetation and Landscape. *GeoJournal* 41, 1–11. doi:10.1023/a:1006828706452

Schwarz, G. M. (2007). Taking the Long View on Collapse: A Syrian Perspective. *Pub. Inst. Franç. D'études Anatol.* 1, 45–67.

Singh, B. N. (1997). *Water Scarcity in the Maltese Islands: Geopolitic and Managemen Tissues*. Durham, United Kingdom: PhD thesis, University of Durham. Available online: http://etheses.dur.ac.uk/4721/.

Skeates, R. (2002). Axe Aesthetics: Stone Axes and Visual Culture in Prehistoric Malta. *Oxford J. Archeol* 21, 13–22. doi:10.1111/1468-0092.00147

Spyrou, M. A., Tukhbatova, R. I., Wang, C.-C., Valtueña, A. A., Lankapalli, A. K., Kondrashin, V. V., et al. (2018). Analysis of 3800-Year-Old *Yersinia pestis* Genomes Suggests Bronze Age Origin for Bubonic Plague. *Nat. Commun.* 9, 2234. doi:10.1038/s41467-018-04550-9

Stanley, J.-D. (2019). Egypt's Nile Delta in Late 4000 Years BP: Altered Flood Levels and Sedimentation, with Archaeological Implications. *J. Coastal Res.* 35, 1036–1050. doi:10.2112/jcoastres-d-19-00027.1

Stewart, M., Carleton, W. C., and Groucutt, H. S. (2021). Climate Change, Not Human Population Growth, Correlates with Late Quaternary Megafauna Declines in North America. *Nat. Commun.* 12, 965. doi:10.1038/s41467-021-21201-8

Stewart, M., Carleton, W. C., and Groucutt, H. S. (2020). Extreme Events in Biological, Societal, and Earth Sciences: a Systematic Review of the Literature. *Front. Earth Sci.*

Stoddart, S., Barber, G., Duhig, C., Mann, G., O'Connell, T., Lai, L., et al. (2009). "The Human and Animal Remains," in *Mortuary Customs in Prehistoric Malta*. Editors C. Malone, S. Stoddart, A. Bonanno, and D. Trump (Cambridge: McDonald Institute for Archaeological Research), 315–340.

Stoddart, S., Bonanno, A., Gouder, T., Malone, C., and Trump, D. (1993). Cult in an Island Society: Prehistoric Malta in the Tarxien Period. *Caj* 3, 3–19. doi:10.1017/s095977430000069x

Stoddart, S., Woodbridge, J., Palmisano, A., Mercuri, A. M., Mensing, S. A., Colombaroli, D., et al. (2019). Tyrrhenian central Italy: Holocene Population and Landscape Ecology. *The Holocene* 29, 761–775. doi:10.1177/0959683619826696

Stuart, M. E., Maurice, L., Heaton, T. H. E., Sapiano, M., Micallef Sultana, M., Gooddy, D. C., et al. (2010). Groundwater Residence Time and Movement in the Maltese Islands - A Geochemical Approach. *Appl. Geochem.* 25, 609–620. doi:10.1016/j.apgeochem.2009.12.010

Susat, J., Lübke, H., Immel, A., Brinker, U., Macāne, A., Meadows, J., et al. (2021). A 5,000-Year-Old hunter-gatherer Already Plagued by *Yersinia pestis*. *Cell ReportsCell* 35, 109278. doi:10.1016/j.celrep.2021.109278

Tagliaferro, N. (1911). 92. Prehistoric Burials in a Cave at Bur-Meghez, Near Mkabba, Malta. *Man* 11, 147–150. doi:10.2307/2840439

Tanasi, D., Greco, E., Noor, R. E., Feola, S., Kumar, V., CrispinoGelis, A., et al. (2018). 1H NMR, 1H-1H 2D TOCSY and GC-MS Analyses for the Identification of Olive Oil in Early Bronze Age Pottery from Castelluccio (Noto, Italy). *Anal. Methods* 10, 2756–2763. doi:10.1039/c8ay00420j

Terral, J.-F., Alonso, N., CapdevilaChatti, R. B. i. N., Chatti, N., Fabre, L., Fiorentino, G., et al. (2004). Historical Biogeography of Olive Domestication (*Olea Europaea* L.) as Revealed by Geometrical Morphometry Applied to Biological and Archaeological Material. *J. Biogeog.* 31, 63–77. doi:10.1046/j.0305-0270.2003.01019.x

Thompson, J. E. (2019). in *Heads, Shoulders, Knees and Toes: Exploring Bodies, Body Parts and Personhood in Late Neolithic Malta through Funerary Taphonomy*. Cambridge, United Kingdom: University of Cambridge. PhD thesis.

Thompson, J. E., Parkinson, E. W., McLaughlin, T. R., Barratt, R. P., Power, R. K., Mercieca-Spiteri, B., et al. (2020). Placing and Remembering the Dead in Late Neolithic Malta: Bioarchaeological and Spatial Analysis of the Xagħra Circle

Hypogeum, Gozo. *World Archaeology* 52, 71–89. doi:10.1080/00438243.2019.1745680
Tiboni, F. (2017). Of Ships and Deer: Early Western Mediterranean Ship Graffiti Reappraised. *Int. J. Nautical Archaeology* 46, 406–414. doi:10.1111/1095-9270.12265
Tinney, S. (1985). A New Look at Naram-Sin and the "Great Rebellion". *J. Cuneiform. Stud.* 47, 1–14.
Torpiano, A. (2004). "The Construction of the Prehistoric Megalithic Temples of Malta," in *Malta before History*. Editors D. Cilia and M. Malta, 327–345.
Trump, D. H., and Cilia, D. (2008). *Cart-ruts and Their Impact on the Maltese Landscape*. Santa Venera, Malta: Heritage Books.
Trump, D. (2002). *Malta: Prehistory and Temples*. Midsea: Malta.
Trump, D. (1966). *Skorba: Excavations Carried Out on Behalf of the National Museum of Malta*. London: Society of Antiquaries.
Trump, D. (1976). "The Collapse of the Maltese Temples," in *Problems in Economic and Social Archaeology*. Editors G. Sieveking, I. H. Longworth, and K. E. Wilson (London: Duckworth), 605–609.
Valtueña, A. V., Mittnik, A., Key, F. M., Haak, W., Allmäe, R., Belinskij, A., et al. (2017). The Stone Age Plague and its Persistence in Eurasia. *Curr. Biol.* 27, 3683–3691. doi:10.1016/j.cub.2017.10.025
Vella, N. C. (1999). in *"Trunkless Legs of Stone: Debating Ritual Continuity at Tas-Silġ, Malta", in: Facets Of Maltese Prehistory*. Editors A. Mifsud and C. Savona Ventura Mosta, Malta: Prehistoric Society of Malta, 226–232.
Vella-Gregory, I. (2005). *The Human Form in Neolithic Malta*. Midsea: Malta.
Vella-Gregory, I. (2016). Immensity and Miniaturism: The Interplay of Scale and Sensory Experience in the Late Neolithic of the Maltese Islands. *Oxford J. Archaeology* 35, 329–344. doi:10.1111/ojoa.12092
Weiss, H. (2016). Global Megadrought, Societal Collapse and Resilience at 4.2-3.9 Ka BP across the Mediterranean and West Asia. *PAGES Mag.* 24, 62–63. doi:10.22498/pages.24.2.62
Weiss, H. (2015). "Megadrought, Collapse and Resilience in Late 3rd Millennium B.C. Mesopotamia" in *Ein Klimasturz als Ursache für der Zerfall der Alten Welt?* Editors H. Meller, H. W. Arz, R. Jung, and R. Risch. Halle, Germany: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 35–52.
Weiss, H. (2017). "Seventeen Kings Who Lived in Tents," in *The Late Third Millennium in the Ancient Near East: Chronology, C14, and Climate Change*. Editor F. Höflmayer (Chicago: The Oriental Institute, University of Chicago), 131–162.
Wettinger, G. (1982). "Agriculture in Malta in the Late Middle Ages," in *Proceedings of History Week*. Editor M. Buhagiar Valletta, Malta: The Historical Society, 1–48.
Wettinger, G. (1985). *The Jews of Malta in the Late Middle Ages*. Midsea: Malta.
Wiener, M. H. (2014). The Interaction of Climate Change and agency in the Collapse of Civilizations Ca. 2300-2000 BC. *Radiocarbon* 56, S1–S16. doi:10.2458/azu_rc.56.18325
Williams, M. (2019). *The Nile Basin: Quaternary Geology, Geomorphology, and Prehistoric Environments*. Cambridge: Cambridge University Press.
Zammit, T. (1928). Prehistoric Cart-Tracks in Malta. *Antiquity* 2, 18–25. doi:10.1017/s0003598x00001289
Zammit, T. (1930). *Prehistoric Malta: The Tarxien Temples*. Oxford: Oxford University Press.
Zammit, T., and Singer, C. (1924). Neolithic Representations of the Human Form from the Islands of Malta and Gozo. *J. R. Anthropological Inst. Great Britain Ireland* 54, 67–100. doi:10.2307/2843662
Zanchetta, G., Bini, M., Di Vito, M. A., Sulpizio, R., and Sadori, L. (2019). Tephrostratigraphy of Paleoclimatic Archives in central Mediterranean during the Bronze Age. *Quat. Int.* 499, 186–194. doi:10.1016/j.quaint.2018.06.012
Zanchetta, G., Regattieri, E., Isola, I., Drysdale, R. N., Bini, M., Baneschi, I., et al. (2016). The So-Called "4.2 Event" in the central Mediterranean and its Climatic Teleconnections. *Alpine Quat.* 29, 5–17.
Zielhofer, C., Köhler, A., Mischke, S., Benkaddour, A., Mikdad, A., and Fletcher, W. J. (2019). Western Mediterranean Hydro-Climatic Consequences of Holocene Ice-Rafted Debris (Bond) Events. *Clim. Past* 15, 463–475. doi:10.5194/cp-15-463-2019

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