Quaternary International 449 (2017) 29–57

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Late Quaternary sea-level changes and early human societies in the central and eastern Mediterranean Basin: An interdisciplinary review

J. Benjamin [a], [*], A. Rovere [b], [c], A. Fontana [d], S. Furlani [e], M. Vacchi [f], R.H. Inglis [g], [h], E. Galili [i], F. Antonioli [j], D. Sivan [k], S. Miko [l], N. Mourtzas [m], I. Felja [n], M. Meredith-Williams [o], B. Goodman-Tchernov [p], E. Kolaiti [q], M. Anzidei [r], R. Gehrels [s]

[a] *Flinders University of South Australia, Department of Archaeology, GPO Box 2100, Adelaide, SA 5001, Australia*
[b] *MARUM, Center for Marine Environmental Sciences, University of Bremen, Germany*
[c] *ZMT, Leibniz Centre for Tropical Marine Research, Bremen, Germany*
[d] *University of Padova, Department of Geosciences, Italy, CoNISMa, Italy*
[e] *University of Trieste, Department of Mathematics and Geosciences, Italy*
[f] *Université P. Valéry Montpellier 3, CNRS ASM, UMR 5140, Montpellier, France*
[g] *University of York, Department of Archaeology, The King's Manor, YO1 7EP, United Kingdom*
[h] *Macquarie University, Department of Environmental Sciences, NSW 2109, Australia*
[i] *University of Haifa, Zinman Institute of Archaeology, Haifa 3498838, Israel*
[j] *ENEA, Laboratory Climate Modelling and Impacts, Roma, Italy*
[k] *University of Haifa, Department of Maritime Civilizations, L. H. Charney School of Marine Sciences, Leon Recanati Institute for Maritime Studies (RIMS), Haifa 3498838, Israel*
[l] *Croatian Geological Survey, Sachsova 2, Zagreb, Croatia*
[m] *Gaiaergon Ltd, Athens, Greece*
[n] *University of Zagreb, Department of Geology, Faculty of Science, Horvatovac 102a, 10000 Zagreb, Croatia*
[o] *La Trobe University, Department of Archaeology and History, Kingsbury Drive, Melbourne, VIC 3086, Australia*
[p] *University of Haifa, Department of Marine Geosciences, L. H. Charney School of Marine Sciences, Haifa 3498838, Israel*
[q] *University of the Peloponnese, Kalamata, Greece*
[r] *Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy*
[s] *University of York, Environment Department, Heslington, York YO10 5NG, United Kingdom*

ARTICLE INFO

Article history:
Received 1 September 2016
Received in revised form
9 May 2017
Accepted 14 June 2017
Available online 20 July 2017

Keywords:
Sea-level change
Pleistocene
Holocene
Mediterranean Archaeology

ABSTRACT

This article reviews key data and debates focused on relative sea-level changes since the Last Interglacial (approximately the last 132,000 years) in the Mediterranean Basin, and their implications for past human populations. Geological and geomorphological landscape studies are critical to archaeology. Coastal regions provide a wide range of resources to the populations that inhabit them. Coastal landscapes are increasingly the focus of scholarly discussions from the earliest exploitation of littoral resources and early hominin cognition, to the inundation of the earliest permanently settled fishing villages and eventually, formative centres of urbanisation. In the Mediterranean, these would become hubs of maritime transportation that gave rise to the roots of modern seaborne trade. As such, this article represents an original review of both the geo-scientific and archaeological data that specifically relate to sea-level changes and resulting impacts on both physical and cultural landscapes from the Palaeolithic until the emergence of the Classical periods. Our review highlights that the interdisciplinary links between coastal archaeology, geomorphology and sea-level changes are important to explain environmental impacts on coastal human societies and human migration. We review geological indicators of sea level and outline how archaeological features are commonly used as proxies for measuring past sea levels, both gradual changes and catastrophic events. We argue that coastal archaeologists should, as a part of their analyses, incorporate important sea-level concepts, such as indicative meaning. The interpretation of the indicative meaning of Roman fishtanks, for example, plays a critical role in reconstructions of late Holocene Mediterranean sea levels. We identify avenues for future work, which include the consideration of glacial isostatic adjustment (GIA) in addition to coastal tectonics to explain vertical movements of coastlines, more research on Palaeolithic island colonisation, broadening of Palaeolithic studies to include materials from the entire coastal landscape and not just coastal resources, a focus on rescue of archaeological sites under threat by

---

[*] Corresponding author.
E-mail address: jonathan.benjamin@flinders.edu.au (J. Benjamin).

http://dx.doi.org/10.1016/j.quaint.2017.06.025

coastal change, and expansion of underwater archaeological explorations in combination with submarine geomorphology. This article presents a collaborative synthesis of data, some of which have been collected and analysed by the authors, as the MEDFLOOD (MEDiterranean sea-level change and projection for future FLOODing) community, and highlights key sites, data, concepts and ongoing debates.

Contents

1. Introduction

The study of past sea-level changes in the Mediterranean Sea has been a focus of coastal scientists for almost two centuries. While interest in vertical land and sea movements is recorded at least as early as the Roman Period (e.g., Strabo, 1st century AD), the first modern sea-level studies may be attributed to Lyell (1833) and Négris (1903a,1903b; 1904). Gignoux (1913), Issel (1914) and Blanc (1920), were the first to define the 'Tyrrhenian' (the Last Interglacial) as a chronostratigraphic subunit along the Tyrrhenian coasts of Italy, especially in Sardinia, Tuscany and Lazio. Coastal and sea-level studies flourished especially post World War II, with the early studies of Bonifay and Mars (1959) and Stearns and Thurber (1965) in the western Mediterranean. In the late 1970s, and through the 1980s and 1990s, the investigations of Mediterranean Sea levels grew to become a stand-alone scientific discipline championed by geologists, archeologists, biologists, geophysicists and geochemists. Scientists increasingly acknowledged the connection between past sea-level changes and human migrations along the coasts. Changes in coastal conditions impacted upon landscapes, waterways, ecological zones and people as the coastlines migrated as a result of sedimentation, erosion and relative land-sea-level changes.

In parallel, archaeologists throughout the 20th century documented coastal sites, which demonstrated intensive maritime activity around the Mediterranean basin, though much of the focus remained on the relatively recent periods since the adoption of metal and written language, while less attention was given to earlier periods and the archaeological significance of coastal changes over longer periods of time. In many respects, the eastern Mediterranean, where Africa and Eurasia meet, is an ideal study area, and important for the integrated studies of landscape evolution and archaeology; it has contributed significantly to our understanding of human dispersals and migrations, as well as terrestrial and maritime trade routes.

The overarching aim of this article is to define the state of the art of Mediterranean sea-level studies, a century after its inception, and to consider the impacts of past sea-level and coastal changes on human-environment interaction. We identify and highlight the major on-going discussions and gaps in knowledge which we expect to, at least partially, define the next decade of integrated sea-level research into past coastal environments and archaeology (Fig. 1). In doing so, we aim to bring together the research of the geomorphological and archaeological communities and promote interdisciplinary work specifically related to sea-level change.

This article stems from the efforts of the "MEDiterranean sea-level change and projection for future FLOODing" (MEDFLOOD, Rovere et al., 2012) community, and is focused primarily on the central and eastern Mediterranean basin. This review is not designed to be geographically all-inclusive and there are some references to specific data or sites from further afield, for example the western Mediterreanean, where they are representative,

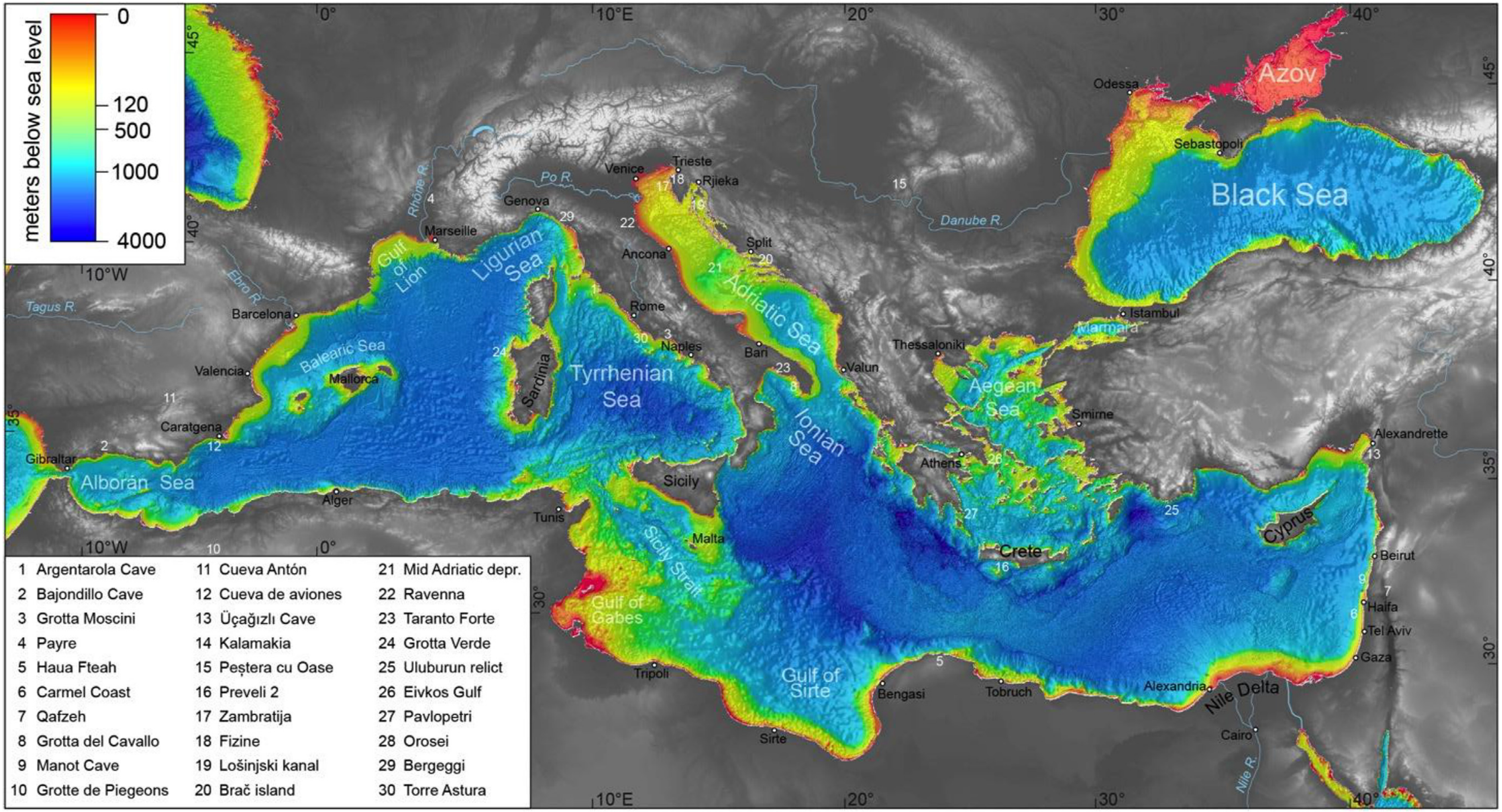

Fig. 1. A topographic map of the Mediterranean Sea region with bathymetric data derived from the European Marine Observation and Data Network (http://www.emodnet.eu/). Topographic data derived from Shuttle RADAR Topographic Mission (SRTM, srtm.csi.cgiar.org). Key sites as mentioned in text. (credit: A. Fontana).

Table 1
Indicators and proxies used to reconstruct past Mediterranean sea levels.

Type of RSL marker	Chronology	Typology	Elements improving RSL estimate	References and examples
Tidal notches	Late Quaternary	Geomorphological	Fixed biological indicators	Antonioli et al., 2015; Rovere et al., 2016a; Goodman-Tchernov and Katz, 2016
Abrasion notch and sea caves	Late Quaternary	Geomorphological	Fixed biological indicators (may be difficult to find due to erosion).	Rovere et al., 2016a; Ferranti et al., 2006
Shore/Abrasion platforms	Late Quaternary	Geomorphological	Biological indicators	Rovere et al., 2016a; Ferranti et al., 2006
Marine terraces	Late Quaternary	Geomorphological/ sedimentary	Fixed biological indicators or sedimentary features	Rovere et al., 2016a; Ferranti et al., 2006; Lambeck et al., 2004a
Speleothems	Late Quaternary	Geomorphological/ sedimentary	Fixed biological indicators	Antonioli et al., 2004; Dutton et al., 2009
Beach deposits	Late Quaternary	Sedimentary	Biofacies, orientation and integrity of shells, sedimentary structures.	Rovere et al., 2016a; Galili et al., 2007, 2015; Goodman et al., 2008
Beachrocks	Late Quaternary	Sedimentary	Sedimentary structures, types of cement	Vousdoukas et al., 2007; Mauz et al., 2015b
Salt-marsh deposits	Holocene	Sedimentary	Faunal assemblages (foraminifera, ostracods, molluscs) and plant remains	Vacchi et al., 2016b; Lambeck et al., 2004a; Nixon et al., 2009
Lagoonal deposits	Holocene	Sedimentary	Faunal assemblages (foraminifera, ostracods, molluscs)	Vacchi et al., 2016a, b; Lambeck et al., 2004a
River deltas	Holocene	Sedimentary	Sedimentary structures	Stanley 1995; Anthony et al., 2014
Fossil fixed bioconstructions	Holocene	Sedimentary	Midlittoral species	Laborel and Laborel-Deguen, 1994; Rovere et al., 2015
Harbour structure (quay, pier, breakwater)	Late Holocene	Archaeological	Fixed biological indicators	Auriemma and Solinas, 2009; Morhange and Marriner, 2015
Fishtanks	Late Holocene	Archaeological	Preservation of all structural parts, presence of fixed biological indicators	Lambeck et al., 2004b; Mourtzas, 2012a
Coastal quarries	Late Holocene	Archaeological	Preservation of the lowest quarry level	Lambeck et al., 2004b Auriemma and Solinas, 2009; Galili and Sharvit 1998
Slipways	Late Holocene	Archaeological	Fixed biological indicators	Lambeck et al., 2010; Anzidei et al., 2014a,b; Morhange and Marriner, 2015
Coastal Water Wells	Holocene	Archaeological	Definition of the ancient water table	Galili and Nir, 1993; Sivan et al., 2004; Rovere et al., 2011

especially significant, or where the resolution of data (in the principle study area) is too low to discuss important concepts in a meaningful way. We base discussions on our own expertise and use examples from selected regions from the early Prehistoric, Protohistoric (or 'Later Prehistoric' Bronze and Iron Age periods) and early Classical periods. Through these lenses, we review the existing evidence in the geomorphological and archaeological records that document or contextualise early human-environment interactions.

The review is sub-divided chronologically from the Last Interglacial to the Holocene using Marine Isotopic Stages (MIS, Imbrie et al., 1984). Defining the chronological boundaries from $\delta^{18}O$ benthic stacks as applied to coastal and terrestrial records is not straightforward; therefore at the beginning of each subsection we provide an overview of the timing for each MIS. We base the age attribution of each MIS mainly on the Lisiecki and Stern (2016) $\delta^{18}O$ stack, making reference, where available, to specific data. For a more detailed discussion on the duration of past interglacials and their boundaries see Berger et al. (2015).

In each section, we first describe the sea-level changes that occurred, followed by sub-sections on human coastal occupation, contemporary with, and influenced by, relative sea-level change. We begin with a review of geological sea-level indicators. Towards the end of the article we include a section on the use of archaeological sea-level indicators, of interest to both archaeologists and geoscientists.

All the elevations in the text are referred to mean sea level, with a '+' prefix if they are above it or a '-' prefix if they are below modern sea level. Throughout the text we maintain the distinction between relative sea level (RSL) whenever we refer to local coastal sea level, uncorrected for tectonic, isostatic and other post-depositional processes. We use eustatic sea level (ESL) when we refer to global mean sea level or ice-equivalent sea-level changes. For a more detailed description of RSL and ESL, we refer the reader to Milne et al. (2009) and Rovere et al. (2016b).

2. Indicators of past sea-level changes

RSL variations have left imprints on the modern coastlines and continental shelves worldwide. Past human cultures have also built infrastructure in close connection with RSL throughout the Mediterranean dating to at least the Neolithic, and with increasing intensity through Classical and later periods. A landscape feature, a fossil, or a sedimentary deposit whereby its elevation can be linked to a former sea level is considered a RSL indicator. Note that the term 'relative' implies that an indicator measures both the local sea surface change and the sum of all vertical land movements (e.g. due to tectonics, and/or different forms of isostasy) that affected the indicator since its formation (for a summary of these, see Rovere et al., 2016b and references therein). Once a RSL indicator is identified and measured in the field, it is necessary to establish its indicative meaning (Van de Plassche, 1986; Shennan et al., 2015). The indicative meaning defines the elevation where the RSL indicator was formed or was built with respect to the palaeo sea level and includes a measure of uncertainty. The main RSL indicators that have been used to reconstruct past sea-level changes in the Mediterranean are listed in Table 1. In the following subsections we describe these, and eventually we detail the on-going discussions on the interpretation of their indicative meaning. For a more in depth description of each marker and examples of their use to reconstruct paleo RSL, the reader is referred to the works cited in Table 1. In the following paragraphs we describe natural, non anthropogenic RSL indicators. Anthropogenic (archaeological) RSL indicators are described in a later section as they are only relevant to the Holocene.

2.1. Depositional, bio-constructional and erosional RSL indicators

Natural, non-anthropogenic RSL indicators can be divided roughly into three categories: depositional (e.g. estuarine or deltaic brackish sediments, salt marshes, coastal lagoons, beachrocks, etc.), biological (e.g encrustations by marine organisms, such as vermetids, algae, etc.) and erosional (e.g. abrasion platforms and marine notches). These sea-level indicators require stabilization of sea level, for at least a short period, for their formation and preservation (Table 1).

2.1.1. *Depositional sea-level indicators*

Some of the most useful and precise depositional indicators are salt-marsh foraminifera and testate amoebae (Scott and Medioli, 1978; Gehrels, 1994; Edwards and Horton, 2000; Barnett et al., 2017). Salt marshes are abundant in northeastern Italy, Croatia and Greece, for example, and host a limited number of cosmopolitan foraminiferal taxa. Some have very restricted depth and salinity constraints, which allow for decimetre-scale sea-level reconstructions (e.g., Serandrei-Barbero et al., 2006; Shaw et al., 2016). Similarly, vertical distributions of ostracods and malacofauna of Mediterranean coastal lagoons and estuarine or deltaic brackish areas, has proved to be useful for sea-level reconstructions (e.g., Mazzini et al., 1999; Marco-Barba et al., 2013; Vacchi et al., 2016a). Typically, studies incorporating these methods apply coring campaigns along shore-perpendicular transects to identify the salt-marsh, lagoonal or other brackish facies and determine their age by radiocarbon dating.

Another widely used depositional Holocene sea-level indicator are beach deposits and beachrocks. A beachrock is a form of calcarenite that is present within the littoral zone and often is characterised by significant amounts of marine-associated inclusions such as shell or broken coral remains, and depending on its age and composition can be crumbly and pliable. Beachrocks represent the hard fossilised section of a former sandy/gravel coast, of both clastic and biogenic origin, rapidly cemented by the precipitation of carbonate cements (e.g., Mauz et al., 2015b).

Beachrock formation is traditionally associated with an interface between stable seawater and fresh groundwater, but may also form in the absence of groundwater (Kelletat, 2006) by river floods, storms, or tsunamis (Vött et al., 2010; May et al., 2012). Regardless of its genesis, beachrock forms within a limited distance of the coastline and is therefore regarded as a proxy for sea level (Mauz et al., 2015b). The presence of soda bottles and modern trash incorporated into some beachrock today reinforce arguments that diagenesis can be rapid. In best cases, beachrock can provide one-metre vertical accuracy (Hopley, 1986). Cementation occurs either in the intertidal or in the swash/backwash and spray zone under complex physicochemical and biological conditions, under low wave energy conditions and possibly in the presence of meteoric water. Intertidal sediments may be difficult to interpret on the basis of the cement alone (Hopley, 1986). However, analysis of sedimentary structures and cement microstratigraphy of Mediterranean beachrocks can result in very detailed RSL reconstructions (e.g., Desruelles et al., 2009; Vacchi et al., 2012; Mauz et al., 2015a; Ozturk et al., 2016).

The Mediterranean shelf contains multiple depressions that flooded during high stands but which are isolated from the sea during lowstands, and therefore can preserve records of marine flooding during the Quaternary. Examples of such places include the Sea of Marmara (Taviani et al., 2014), the Maltese shelf (Micallef et al., 2012) or the Evoikos Gulf (Drinia et al., 2014). The flooded karst depressions along the eastern Adriatic Coast, such as at the Lošinjski Canal Bay, contain records of multiple marine incursions, which are controlled by the relative mean sea-level position and the elevation of a sill (Fig. 2). Sediment cores from such basins hold valuable information on sedimentary architecture, chronology, geochemical and biological proxies related to Quaternary sea-level changes.

2.1.2. *Biological sea-level indicators*

Some examples of biological RSL indicators include the bioconstructions created by coral reefs or vermetids. Some shallow water coral reefs can yield sea-level reconstructions that are accurate to within ±1 m (Lighty et al., 1982). Other bioconstructions, such as large reefs formed by vermitids, for example *Dendropoma petraeum*, are formed within a vertical range of ±0.10 m and are excellent sea-level indicators (Laborel, 1986; Antonioli et al., 1999; Sivan et al., 2010). Fossil remains fixed to former sea cliffs, such as *L. lithophaga*, *Cerastoderma glaucum*, limpets and barnacles, particularly in conjunction with other sea-level indicators, have also been used as past sea-level indicators (Van de Plassche, 1986; Rovere et al., 2015 and references therein). Biological indicators can also be erosive in nature, in which case the former sea level can be reconstructed from bioeroded surfaces (see next section). The most common features produced by bioerosion are borings left on rocky carbonate coasts by molluscs (such as *L. lithophaga*) or by sponges (such as Clionadae).

2.1.3. *Erosional sea-level indicators*

Marine notches and abrasion platforms are commonly used as erosional sea-level indicators in the Mediterranean. Tidal notches have been classically divided into: i) tidal notches, formed in sheltered rocky areas in the intertidal zone; ii) infra-littoral notches, formed in the sub-tidal zone under exposed conditions and high surf; iii) surf notches, formed under exposed conditions in the supra-littoral zone (Pirazzoli, 1986). Abrasion platforms (shore platforms) are the product of marine erosion in exposed rocky coasts under periods of stable sea level (Trenhaile, 1987; Kennedy, 2015).

Tidal notches can be very precise sea-level indicators, as their width is related to the tidal range of the locality where they form and the deeper point of the notch is closely correlated to mean sea level (Antonioli et al., 2015 and references therein). The rate of notch formation is faster in seaward, less sheltered, sites, as well as in softer or more porous matrixes (e.g. Goodman-Tchernov and Katz, 2016). Measurements of tidal notches at 73 sites in the Central Mediterranean Sea suggested that several processes contribute, at varying rates, to the formation of tidal notches (Furlani et al., 2014a). These processes include bioerosion, weathering, hyperkarst and mechanical erosion; the relative dominance of each process can produce a slightly different notch morphology (Trenhaile 2016). One of the main factors favouring the development of a tidal notch is the existence of submarine fresh-water springs which enhance rock dissolution (Furlani et al., 2014b). We note the current, on-going debate regarding whether tidal notches are disappearing due to the recent increasing rates of sea-level rise. While this view is supported by studies in Greece (Evelpidou et al., 2012a; Pirazzoli and Evelpidou, 2013; Evelpidou and Pirazzoli, 2015), other studies elsewhere in the Mediterranean reject this hypothesis (Boulton and Stewart, 2013; Antonioli et al., 2015, 2016, 2017b; Goodman-Tchernov and Katz, 2016).

3. MIS 5

3.1. *Sea level*

ESL in the last 2 million years reached positions as low as 130 m below the present mean sea level during glacial periods, and highstands up to ~ +6 m and possibly +13–15 m during interglacial periods (Rohling et al., 1998; Dutton et al., 2015; Lisiecki and Raymo, 2005; Grant et al., 2012, 2014; Raymo and Mitrovica, 2012; Spratt and Lisiecki, 2016; see also Fig. 4 herein). MIS 5 includes several sub-stages that were characterised by both higher and lower-than-modern sea levels: MIS 5.5, MIS 5.3 and MIS 5.1.

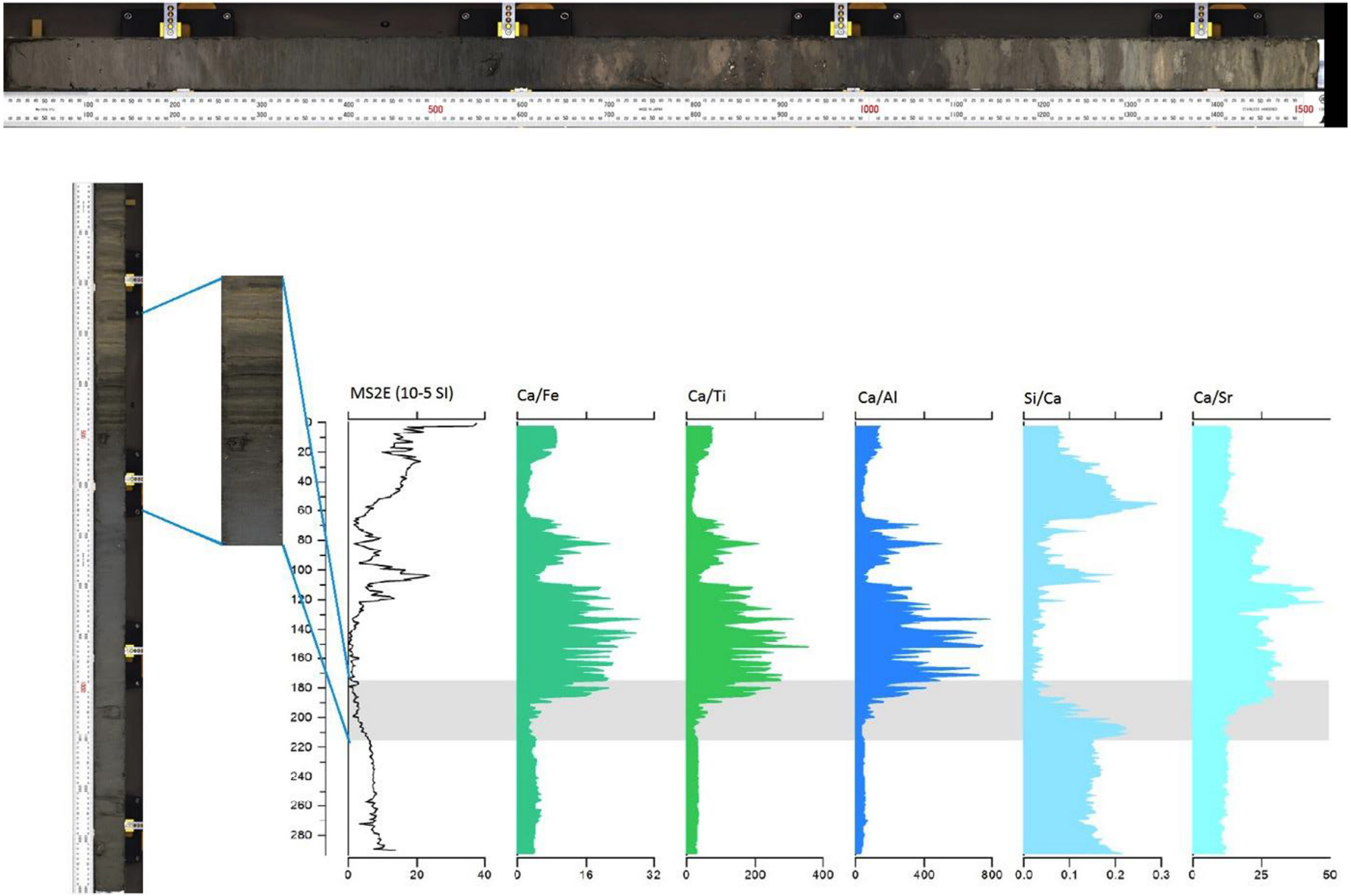

Fig. 2. A split core form the karst depression in the Lošinjski Kanal Bay (−72 m), isolated from the Northern Adriatic Sea by a sill at −50 m. The core displays multiple marine flooding (grey homogeneous sediment, low Ca/Sr ratio, top and bottom parts of the Core) and a lake sediment sequence (laminated sediments-high Ca/Sr ratio). (Photo: S. Miko).

Fig. 3. Measurement of a fossil tidal notch (Orosei Gulf, Sardinia Italy) using a metered rod. The measured height of the notch is 8.7 m. (Photo: F. Antonioli).

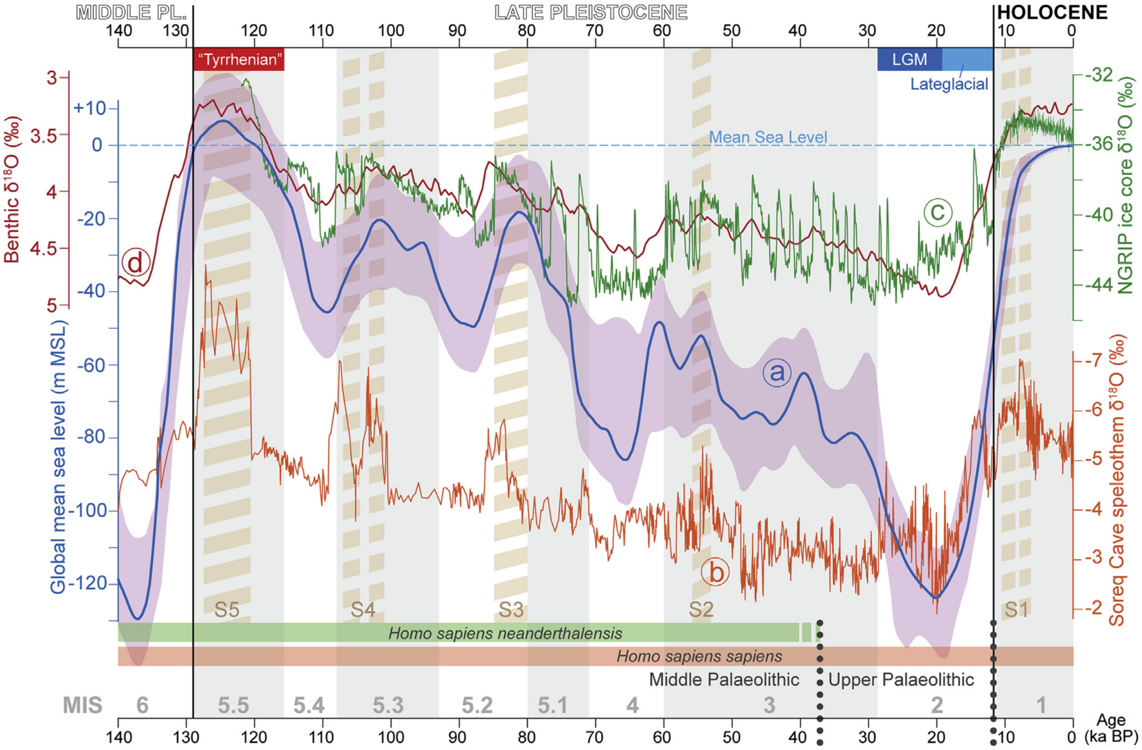

Fig. 4. Comparison between the reconstruction of the past global mean sea level and palaeoclimatic, palaeoenvironmental and archaeological data for the Mediterranean Sea since 140 ka. a) Global mean sea-level curve with uncertainty indicated in light blue (Waelbroeck et al., 2002). As a palaeoclimatic proxy for the SE Mediterranean region the $\delta^{18}O$ composition of the Soreq Cave speleothem (b) is plotted, while for the palaeoclimate of the Northern Hemisphere, the $\delta^{18}O$ composition of NGRIP ice core (c) is represented (NGRIP members, 2004; Kindler et al., 2014). Grey and white rectangles indicate the MIS according to the LS16 $\delta^{18}O$ stacked benthic composition (d) (Lisiecki and Stern, 2016). Brown dashed shading indicates periods of sapropel deposition (Rohling et al., 2015). (For interpretation of the colours in this figure, the reader is referred to the web version of this article.)

These three substages are described separately in the following sections.

3.1.1. MIS 5.5

In a global sense, the Last Interglacial (MIS 5.5) in the $\delta^{18}O$ benthic record begins chronologically at 127.5 ka, approximately in sync with the ESL highstand. The end of the interglacial shows

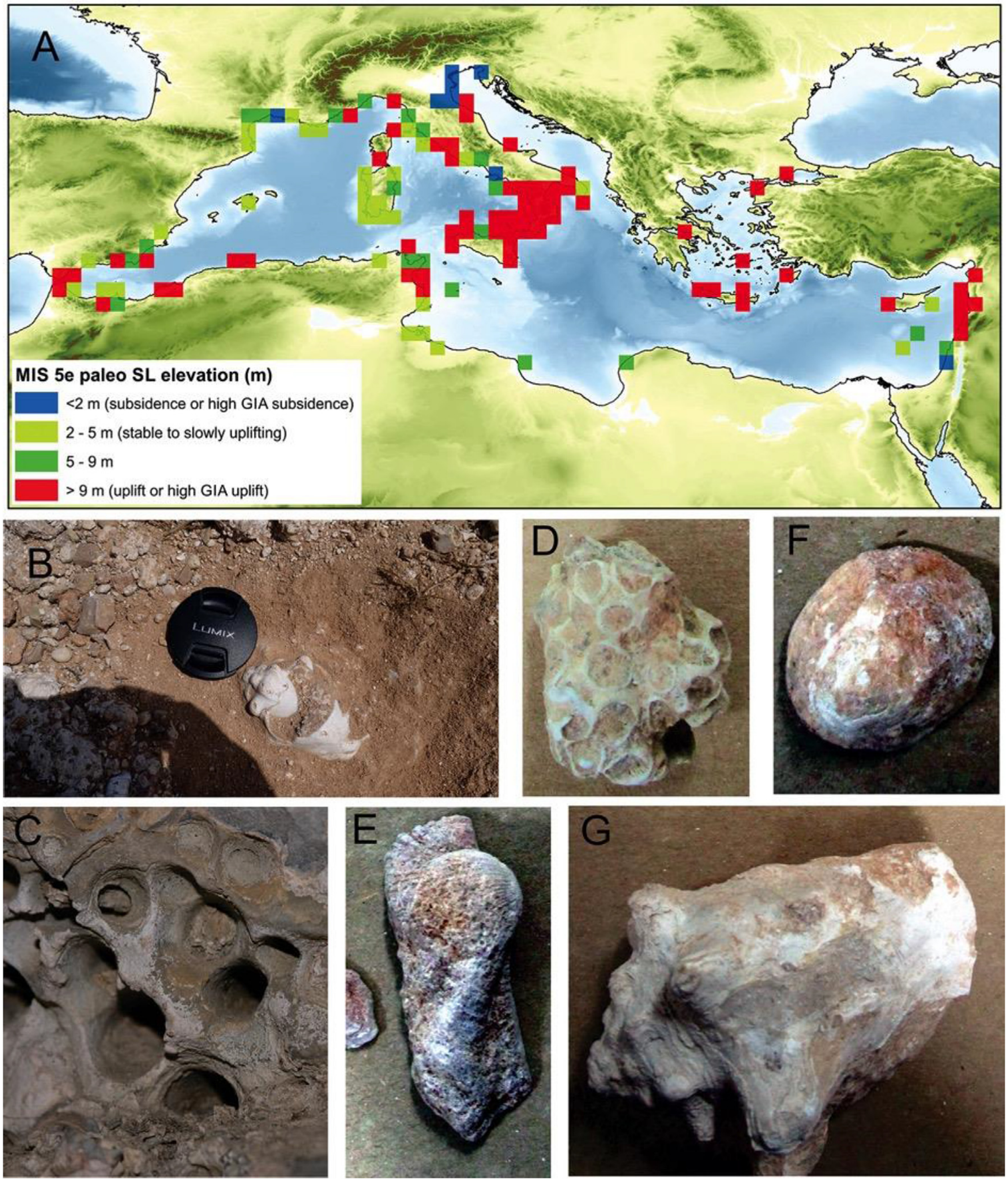

Fig. 5. A) Average elevation per area of the MIS 5.5 shoreline (data from Ferranti et al., 2006; Pedoja et al., 2014); B) MIS 5.5 deposit containing *Strombus latus* (ex bubonius); C) *Lithophaga lithophaga* in the marine cave of Bergeggi (Italy, Liguria, Western Mediterranean). Each borehole has a diameter of ~2–3 cm; D-G) typical senegalese fauna, from deposits in Mallorca (Spain, Catalunya, Western Mediterranean, collection J. Cuerda Barceló): D) *Cladocora caespitosa*, one of the few corals in the Mediterranean that can be used to obtain reliable U-series ages (the fossil length is ~5 cm); E) *Arca noae* (the fossil length is ~7 cm); F) *Patella lusitanica* (the fossil length is ~4 cm); G) *Persistrombus latus* (ex *Strombus bubonius*) (the fossil length is ~10 cm). (Photos: A. Rovere).

significant regional variability (Lisiecki and Stern, 2016). Atlantic benthic δ^{18}O increases gradually from 122 to 111 ka, whereas Pacific benthic δ^{18}O increases rapidly from 119 to 116 ka (Lisiecki and Stern, 2016). Dutton et al. (2015) and Kopp et al. (2009) set the beginning of the interglacial to ~129 ka, while Hibbert et al. (2016) report that, globally, corals above present sea level attributed to MIS 5.5 date from 139 to 111 ka.

Sea-level deposits associated with MIS 5.5 in the Mediterranean Sea have been referred to as ‘Tyrrhenian’, despite the fact that, in the formal terminology, the Tyrrhenian Stage encompasses a time period longer than MIS 5.5 (260–11 ka), while MIS 5.5 corresponds to the Eutyrrhenian subunit (e.g. Gignoux, 1913; Asioli et al., 2005). Global estimates based on the analysis of RSL indicators corrected for GIA and tectonics constrain the maximum MIS 5.5 ESL between +5.5 and +9 m (Dutton and Lambeck, 2012; Kopp et al., 2009).

A large database focussed on MIS 5.5 RSL indicators in Italy was published by Ferranti et al. (2006) and was later used by Pedoja et al. (2011, 2014) in the framework of a global synthesis (Fig. 5a). From the spread of elevations of MIS5.5 RSL indicators in the

Mediterranean, it is evident that some areas are tectonically highly active, producing rapid rates of subsidence or uplift, with shorelines now found at elevations between −105 and +210 m (Anzidei et al., 2014b). In other areas, the elevation of MIS 5.5 RSL indicators is constrained between +2 and +3 m (e.g. Mallorca, Balearic Islands; Vesica et al., 2000) and +7 to +8 m (e.g. western Italy; Antonioli et al., 2006a) or up to +7 m for the end of MI5.5 in the east Mediterranean (Sivan et al., 2016). These areas are generally considered as tectonically 'stable', despite slight variations in the elevation of the MIS 5.5 RSL indicators.

Commonly used MIS 5.5 sea-level indicators in the Mediterranean include marine terraces, tidal notches (e.g. well dated notches of the Galilee coast, Israel; Sisma-Ventura et al., 2017), beachrocks, coastal conglomerates and sediments containing diagnostic fauna (e.g. Hearty, 1986). In the Mediterranean, the key fossil indicator for MIS 5.5 found in palaeo beach deposits is the gastropod currently named as *Persististrombus latus* (Taviani, 2014), but generally described in the literature with its former name, *Strombus bubonius* (e.g., Gignoux, 1913; Sivan et al., 1999, 2016; Zazo et al., 2003, 2013, Fig. 5b). This gastropod is the most conspicuous specimen of the "Senegalese fauna" (Fig. 5b–g), which indicates a relatively warm coastal and littoral environment. *Strombus*-bearing terraces are mainly attributed to MIS 5.5, although they also occur in terraces assigned to MIS7 in the western Mediterranean (Zazo et al., 2013).

Another important element found in fossil MIS 5.5 deposits is *Cladocora caespitosa* (Fig. 5c), a stony coral of the subclass Hexacorallia. This coral can still be found living in the Mediterranean today (Peirano et al., 1998) and has been used to infer MIS 5.5 temperatures (Peirano et al., 2004). In Mediterranean deposits, this is one of the few fossils that can be dated by U-series (e.g. Jedoui et al., 2003; Muhs et al., 2015).

Despite studies on MIS 5.5 RSL indicators dating back at least to the beginning of the last century (Gignoux, 1913; Issel, 1914; Blanc, 1920), several geological research questions remain unanswered. These are briefly outlined below.

It is uncertain if the Mediterranean RSL indicators point to the stability of ESL during MIS 5.5 or to a sea level characterised by significant variations and pulses of meltwater. The ongoing debate over the sea-level behaviour during MIS 5.5 is global in scope (as summarised in Long et al., 2015). Whether eustatic sea level during MIS 5.5 was stable around a certain value (typically +5.5 to +9 m, Dutton and Lambeck, 2012), fluctuating with peaks (Rohling et al., 2008b; Kopp et al., 2009), or around +2 to +3 m for most of the interglacial with drastic rising peaks towards the end (Hearty et al., 2007; O'Leary et al., 2013) is still under debate. While some of the classic MIS 5.5 sites in the Mediterranean preserve the evidence of two sea-level highstands during this period (e.g., deposits of Cala Mosca, Sardinia, Italy, see Ulzega and Hearty, 1986 for a detailed description), other sites preserve only a single RSL highstand (e.g., Capo San Vito Sicily, Italy; see Antonioli et al., 2006b). More detailed studies, elevation measurements and GIA models are needed, particularly for those Mediterranean MIS 5.5 indicators that point to a stepped MIS 5.5 relative sea-level history (e.g. Sivan et al., 2016).

Another important issue is that, while low tidal ranges and relatively low wave energy favor the development of precise RSL indicators (i.e. with relatively small indicative meaning), there is in the Mediterranean a scarcity of deposits bearing corals for which relative chronologies within MIS 5.5 can be obtained through U-series dating and that fulfil the criteria of reliable U-series ages (Brocas et al., 2016).

A large portion of Mediterranean MIS 5.5 sea-level evidence is represented by erosional RSL indicators, in particular fossil tidal notches (Ferranti et al., 2006) (Fig. 3). While one of the main advantages of tidal notches is that they can be tightly related to palaeo mean sea level (see section 2.1.3), their main disadvantage is that, being erosional in nature, they cannot be dated directly. This difficulty is overcome when it is possible to correlate the tidal notch with deposits for which the MIS 5.5 age can be either inferred (e.g. deposits containing *Persististrombus* fossils) as in the case of the Galilee notch in Israel where MIS5.5 sediments infill the notch (Sisma-Ventura et al., 2017), or calculated with analytical tools (e.g. U-series ages on deposits containing the coral *Cladocora caespitosa*). At present, there is no known methodology to directly date fossil tidal notches and other erosional RSL indicators, although advancements in the application of cosmogenic dating (e.g. ^{36}Cl cosmogenic dating, Mitchell et al., 2001) to limestone surfaces might open, in the future, new possibilities to give more precise age constraints to these important landforms.

Another important application of MIS 5.5 RSL indicators in the Mediterranean is their use to assess neotectonic uplift rates. The general procedure used is the subtraction of a global eustatic sea-level estimate (usually 6–9 m) from the elevation of the RSL indicator. The result is then divided by the age of the indicator (e.g. Antonioli et al., 2006b). This process does not take into account the effect of the solid earth response to melting ice (Lambeck and Purcell, 2005; Creveling et al., 2015), a process that in the Mediterranean has been occasionally considered qualitatively (Antonioli et al., 2006a; Mauz et al., 2012), but has been quantified only in some MIS 5.5 studies (e.g. Rovere et al., 2016a; Sivan et al., 2016). Predictions of GIA for MIS 5.5 can have, however, large variations and efforts are still ongoing to obtain reliable GIA predictions for this period (e.g. see Lambeck and Purcell, 2005). Such modelling studies will need to consider varying mantle viscosities and varying ice-sheet configurations to obtain reliable uncertainties on the predicted GIA contribution to the departure from eustasy in MIS 5.5 Mediterranean records. The extrapolation of tectonic rates since MIS 5.5 to calculate modern vertical movements of coastal areas (e.g. Antonioli et al., 2017a) should be considered within this context. When the elevation of a MIS 5.5 RSL indicator is not corrected for GIA (for a discussion on MIS 5.5 GIA corrections, see Creveling et al., 2015), both the comparison with global eustatic sea levels and the calculation of tectonics from the elevation of MIS 5.5 RSL indicators should be treated with a degree of caution.

3.1.2. MIS 5.1 – MIS 5.3

Temporally, the peak of MIS 5.3 and MIS 5.1 in the δO^{18} benthic record correlates with Northern Hemisphere summer insolation maxima at, respectively, ca. 93–108 ka and ca. 80–85 ka (Lisiecki and Raymo, 2005; Spratt and Lisiecky, 2016). The dating of RSL indicators for these two periods is less constrained than for MIS 5.5, as there are very few reliable U-series ages for RSL indicators attributed to this period (see Creveling et al., 2017).

Regarding sea levels, and in terms of oxygen isotope records, Waelbroeck et al. (2002) place global ESL during MIS 5.1 at −21 m. A recent global compilation of field data (with related GIA calculations) placed ESL during MIS 5.1 in a range between −22 and +1 m, and MIS 5.3 sea level between −24 and +2 m, using the best dated field records available globally (Creveling et al., 2017).

The lack of available GIA corrections for the Mediterranean Sea for MIS 5.1 makes it difficult to compare regional measurements with global data. Gzam et al. (2016) associated alignments of submerged fossil dunes in the Gulf of Gabes, Tunisia, where palaeoshorelines formed during the MIS 5.1 are found at about −8 m (with MIS 5.3 at −19 m and MIS 5.5 at +3 m). Rovere et al. (2011, Table 1) reported on submerged RSL indicators across the Italian peninsula, and discussed their possible attribution to MIS 5.1 and 5.3 or older periods (e.g. MIS 7). On the Island of Krk (Croatia) two stalagmites, collected from −14.5 m and −18.8 m, have been interpreted to infer two RSL peaks at ~84 ka and ~77 ka based on the absence of tectonic deformation (Surić et al., 2009). Further evidence comes from Mallorca, where a phreatic speleothem sampled in a partially submerged cave was dated to MIS 5.1 (Dorale et al., 2010) and supports RSL reconstruction at ca. +1 m. Also on Mallorca, other deposits containing fossils of *Cladocora caespitosa* were recently dated to MIS 5.5 at an elevation between +1 and 2 m RSL, having previously been attributed to MIS 5.1 (Muhs et al., 2015).

3.2. Human populations during MIS 5

Coastal regions provide a wide range of resources to the populations that inhabit them, and may have been particularly important to hunter-gatherers and mobile groups of foragers during prehistory (Erlandson, 2001; Bailey and Milner, 2002). The exploitation of coastal landscapes and resources has been the subject of major discussion in recent years. Debates include the identification of the earliest systematic exploitation of littoral resources and its significance for hominin cognition (e.g. Marean, 2014), the role of coastal regions in facilitating dispersals of *Homo sapiens* populations out of Africa (Stringer, 2000; Mellars et al., 2013), and the ability of coastal regions to act as refuges during environmental downturns (e.g. Finlayson, 2008; Jennings et al., 2011; Garcea, 2012; Shtienberg et al., 2016; Jones et al., 2016). Understanding the spatial relationship between populations and coastlines in the Mediterranean during MIS 5 is therefore crucial to understand interactions of early human populations with the landscape, and also human migrations and extinctions.

The MIS 5 archaeological record in the Mediterranean, and in particular MIS 5.5, is the most promising period for examining the role of coastal resources during the Middle Palaeolithic (a period defined by lithic technology which broadly corresponds to 300ka – 40 ka). The fact that, in most areas, MIS 5.5 RSL proxies are found above present sea level means that coastlines from this period should be largely accessible for research today, except in areas of subsidence. In tectonically active sites, it is possible that MIS 5.3 and 5.1 coastal records may too be preserved above present sea level, unlike the period from MIS 4 to the early Holocene (Bailey and Flemming, 2008). The archaeological record of occupation in the period 129–71 ka around the Mediterranean is relatively rich and is characterised by Middle Palaeolithic/Middle Stone Age (MP/MSA) industries, manufactured by two populations of *Homo* species: *H. neanderthalensis* (or *H. sapiens neanderthanlensis*) in Europe and *H. sapiens* (or *H. sapiens sapiens*/Anatomically Modern Humans, [AMH]) in North Africa. Archaeological deposits of Middle Paleolothic coastal dwellers embedded in beach deposits, however, are relatively rare.

The MP/MSA archaeological record in the Levant contains the first evidence for *H. sapiens* dispersals into Eurasia during MIS 5.5–3, with their remains preserved in terrestrial contexts at Skhul and Qafzeh caves dated to 100–130 ka (#7 in Fig. 1, Grün and Stringer, 1991; Grün et al., 2005). Both Neanderthals and *H. sapiens* populations utilised MP/MSA technology in the Levant during this period (Shea, 2003). The extent to which these populations exploited the coastal regions and the resources they contained is becoming clearer with targeted research into the origins of marine exploitation. Outside of the Mediterranean, evidence for exploitation of marine resources (molluscs, mammals etc.) by *H. sapiens* is known from MIS 6 contexts in southern Africa, with populations there developing a full 'coastal adaptation' by ~110,000 ka (Marean, 2014). Possible occupation of coastal environments during MIS 5.5, presumably by *H. sapiens*, are also suggested from the Red Sea region (Walter et al., 2000; Bailey et al., 2015).

Exploitation of marine molluscs and fauna preserved in cave sites can be observed in the archaeological record around the Mediterranean. Such evidence exists from ~150 ka at Bajondillo Cave, southern Spain (Cortés-Sánchez et al., 2011) and evidence for freshwater fish processing by Neanderthals in Payre, France 250–125 ka (Hardy and Moncel, 2011). Neanderthal subsistence strategies included exploitation of marine molluscs during early MIS 5 at sites such as Vanguard Cave, Gibraltar (Stringer et al., 2008) and Grotta dei Moscini, Italy (Stiner, 1993). Similar levels of sporadic marine mollusc exploitation are shown in North Africa by *H. sapiens* at the Haua Fteah, Libya (Klein and Scott, 1986; Barker

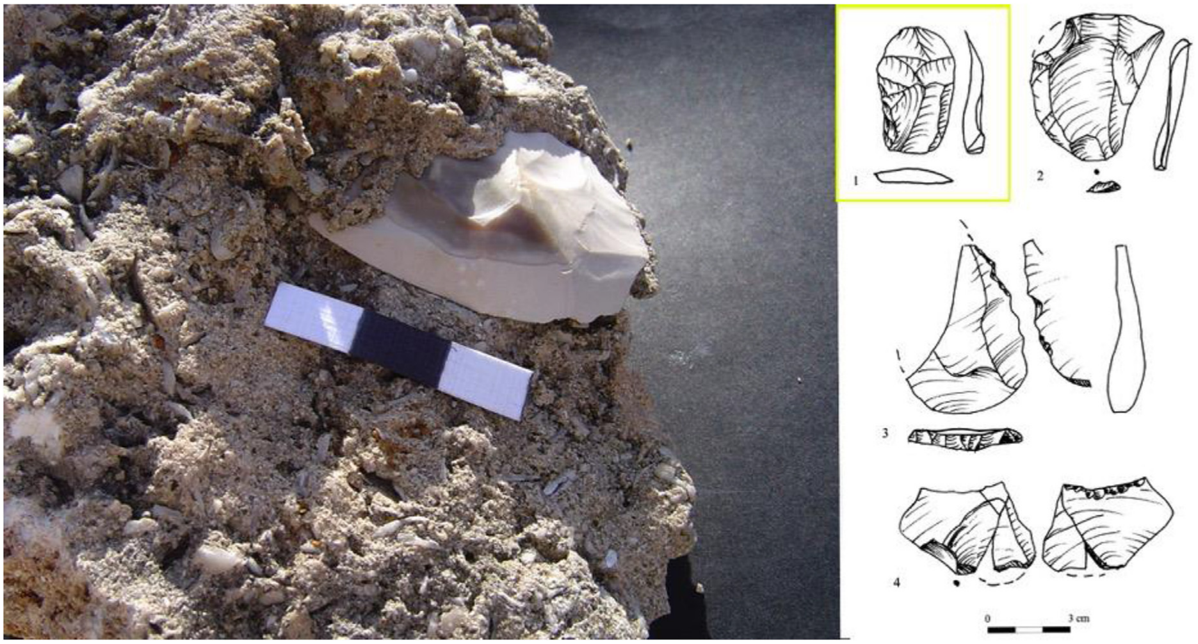

Fig. 6. Middle Palaeolithic stone tools from the coastal Levant (Carmel Coast, Israel, #6 in Fig. 1) contemporary with the highstand at MIS 5.5 (after Galili et al., 2007).

et al., 2010, 2012), although caves in the Maghreb do not contain much evidence for the collection of molluscs for subsistence purposes until after MIS 5 (Marean, 2014).

Tracing the importance and use of marine resources in open air sites remains difficult. In the Levant, activity in coastal environments during early MIS 5 is shown in the form of MP stone industries in several MIS 5.5 beach deposits on the Israeli coast (Galili et al., 2007, 2017; Ronen et al., 2008), where assemblages containing molluscs, animal bones and Middle Palaeolithic flint implements were recovered from such deposits on the Carmel coast at Nahal Bir Ibdawiya and Nahal Me'arot (Fig. 6; #6 in Fig. 1) and on the Galilee coast. Whilst the molluscs in these beach deposits may be naturally occurring, the deposition of stone tools and animal bones within them highlights an occupation and use of the wider coastal landscape. It appears that whilst marine resources were exploited by both *H. sapiens* and Neanderthal populations, these economies likely used marine molluscs as part of a range of resources available during this period of relative environmental stability and high sea levels around the Mediterranean.

There is also evidence that interactions with coastlines during MIS 5 were not limited to consumption of resources. Shell tools were manufactured by Neanderthals during MIS 5.1 in Mediterranean cave sites such as Grotta del Cavallo (#8 in Fig. 1, Romagnoli et al., 2015). That technology persisted until ~50 ka (Douka and Spinapolice, 2012). Perforated shell beads from early MIS 5 cave contexts associated with *H. sapiens* dated to 100–135 ka (MIS 5.5–5.3) are known from Skhul (e.g. Vanhaeren et al., 2006) as well as Qafzeh where, dated to ~90–100 ka (MIS 5.3), they were stained with pigment (Bar-Yosef Mayer et al., 2009). Both cave sites were ca. 35 km from the coastline, indicating specific transport of personal ornaments away from the coast (Bar-Yosef Mayer et al., 2009). Similar beads have also been found in cave sites in the Maghreb around 82 ka, again linked to *H. sapiens* populations (Bouzouggar et al., 2007; D'Errico et al., 2009). There are no known symbolic uses of marine shells by Neanderthals until MIS 4 (see below). In North Africa these ornaments seem to disappear from the archaeological record after 70 ka, remaining absent until around 50–40 ka, indicating that they may have been part of specific symbolic adaptations, the disappearance of which may have marked a cultural discontinuity (D'Errico et al., 2009).

Only a few marine fish bones have been recovered in coastal Middle Palaeolithic sites of the Levant, while at inland sites of that period there is evidence for fresh water fishing (Van Neer et al., 2005). However, recent studies by Zohar (2017) show that exploitation of marine resources during the Middle Palaeolithic did occur; marine material has been identified in Kebara cave, Mount Carmel, some five kilometres inland.

The Palaeolithic colonisation and occupation of Mediterranean islands remain a matter of debate. Lower and Middle Palaeolithic finds from Preveli 2 on Crete have been assigned to at least MIS 5.3 and 5.1 based on geomorphological context (Strasser et al., 2011). That interpretation is contested, however, as it would indicate sea crossings during these periods. Mousterian Palaeolithic artefacts are also known from the Ionian islands (e.g. Ferentinos, 2012), closer to the mainland, but their age is not assessed by securely dated finds (Phoca-Cosmetatou and Rabett, 2014b). Palaeolithic island colonisation is therefore a research theme where further interdisciplinary study is needed.

To further our understanding of the relationships between populations and coastlines during MIS 5, we must continue to trace marine mammal and mollusc exploitation through the recovery of shells and faunal remains from deep cave stratigraphies that dominate the Mediterranean archaeological record. It is also important to consider the occupation of wider littoral environments and the opportunities they produce including, but not limited to, marine mollusc exploitation (Bailey et al., 2008). This will require further survey of coastal deposits and areas linked to the MIS5.5 high sea stands and palaeoshoreline features (Bailey and Flemming, 2008; Bailey et al., 2015) to locate evidence of activity within the coastal zone, as at Nahal Bir Ibdawiya, Nahal Me'arot and on the Galilee coast (Galili et al., 2007, 2017), as well as areas where deposits created by the later high stands are preserved above present day sea level. In broadening the focus to the whole of the coastal biome, not simply to one strand of coastal resources, and by combining material from surface and landscape contexts, we can begin to reconcile how Middle Palaeolithic populations interacted with their coastlines. In that way we can assess how these populations responded to the impacts of coastal change.

4. MIS 4, MIS 3 and MIS 2

4.1. Sea level

Throughout most of the last glacial-interglacial cycle, ESL was tens of metres lower than its present position (Waelbroeck et al., 2002; Grant et al., 2014). The extended periods when sea level was low (MIS 4 and MIS 3) and reached its maximum lowstand (MIS 2) (see Fig. 4a) were crucially important in shaping the present Mediterranean Basin, as large portions of the seabed were exposed and coastlines were further seaward than at present. The cold peak in the MIS 4 δ^{18}O benthic records occurs between 67 ka and 63 ka (Spratt and Lisiecki, 2016), while MIS 3 can be generally constrained between 60 ka and 29 ka (Clark et al., 2009; Hughes et al., 2013). MIS 2 follows MIS 3 and ends chronologically with the beginning of the Holocene, 11.7 ka.

Several factors make investigations of coastal and marine processes (and sea level) during these periods difficult: i) the areas where suitable coastal geomorphic features or coastal sediments formed are currently submerged, often at depths of few tens of meters below present sea level, and their accessibility is therefore difficult; ii) the preservation of geomorphic features and sedimentary records is limited; iii) the dating of most deposits has been considered to be prone to methodological problems; iv) in places there is a lack of high resolution bathymetry and subsurface survey at the scale required to assess seabed conditions. This final point highlights the need for more submarine surveys and exploration.

In many areas, the ESL rise after the Last Glacial Maximum (LGM) eroded and reworked older stratigraphic and morphologic evidence, especially through the development of ravinement surfaces. Moreover, long periods of subaerial exposure altered and/or eroded pre-existing deposits and fluvial and aeolian processes, as well as weathering, soil-forming activity and karstification affected large sectors of the Mediterranean coastal areas. Recent work by Shtienberg et al. (2016, 2017) demonstrate how the study of the seabed, through marine seismic interpretation, paired with terrestrial geotechnical analysis, can be used to investigate the shelves that are now (partially) submerged, but which were previously uninterrupted landscapes, exploited by humans as a result of sea-level fall.

Because of the incomplete sea-level record in the Mediterranean Sea, data from other regions (e.g. the Red Sea, Tahiti) or a ‘global eustatic’ curve are commonly applied to the Mediterranean for the period 116–20 ka (e.g. Imbrie et al., 1984; Bard et al., 1996; Waelbroeck et al., 2002; Rohling et al., 2008a). Moreover, a detailed history of ice-volume changes in the Mediterranean has been proposed only as far back as 35 ka (Lambeck et al., 2014), while geophysical models describing the sea-level evolution before 20 ka are not usually available for the Mediterranean Sea (Lambeck et al., 2011).

Isotopic analyses of speleothems in coastal caves in karstic areas can produce records of submergence and emergence. Along the eastern Adriatic, where the rocky coast consists of limestone (Pikelj and Juračić, 2013; Furlani et al., 2014b), more than 140 submarine caves with speleothems are known to exist, some of which have been studied for sea-level reconstructions (Surić et al., 2005, 2009, 2010). The deepest speleothems along the Croatian coast reach depths of −71 m near the island of Brač in southern Dalmatia (Garašić, 2006). In some other caves, speleothems formed during MIS 3 show evidence of subaerial formation and confirm that sea level was at an elevation lower than −40 m (Surić et al., 2005). Despite the potential of the eastern Adriatic, reliable constraints of RSL during MIS 4 and 3 remain lacking. Nevertheless, this and other karstic coasts of the Mediterranean are key areas for future research into Quaternary coastal evolution, early human populations, migration routes and coastal settlement and resource exploitation. Submerged caves have also been identified as a major opportunity for future archaeological prospection and submerged karstic regions throughout the Mediterranean are likely to yield well preserved organic material (Benjamin et al., 2011; Campbell, 2017).

In ESL curves, a relative short-lived highstand occurred c. 52 ka at about ~−60 m (Shackleton et al., 2000). Three other sea-level fluctuations are shown for MIS 3, with amplitudes of 20–30 m and their peaks centred at about 55 ka, 45 ka and 38 ka respectively. At the transition to MIS 2, ESL fell at a relatively sharp rate to nearly −80 m, subsequently culminating in a lowstand between 29 ka and 21 ka, when ESL is usually estimated to be between −120 m and −140 m (Lambeck et al., 2014).

In the Po Plain, south of the present Po Delta, between −75 m and −25 m, cores containing deposits dated to MIS 4 and MIS 3 indicate alluvial environments in this long period (Amorosi et al., 2004). In the central Adriatic, geophysical surveys have found clear sedimentary traces of forced regressions occurring during the sea-level fall following MIS 5.5 (Ridente et al., 2009; Maselli et al., 2010; Pellegrini et al., 2017).

The formation and growth of the Alpine ice sheet during the LGM only minimally affected the eustatic curve because of its limited volume as compared to polar ice sheets (e.g. Lambeck et al., 2004a). Notwithstanding their limited effect on ESL, the glacial advances in the Alps and partly in the Dinarides and Pyrenees, strongly affected the general environmental conditions of the northern side of Mediterranean basin. In particular, the Po river dramatically enlarged its catchment basin during the marine lowstand (De Marchi, 1922; Maselli et al., 2010). Moreover, the fluvial systems of the southern Alps received enhanced sedimentary input supplied by glacial activity, allowing the widespread aggradation and progradation of alluvial fans and megafans, that prograded for tens of kilometres over the exposed shelf in the Adriatic (Fontana et al., 2014) and in the Gulf of Lion (Jouet et al., 2006).

The lowstand deposits produced by the Po River mainly consist of a sequence of prodeltaic deposits that prograded for 40 km in the foredeep basin and reached a maximum thickness of about 350 m in the Middle Adriatic Depression and of 70 m on the shelf (Trincardi et al., 2004; Pellegrini et al., 2017). Topset beds of the LGM delta can be recognised through geophysical soundings from a depth of −100 m and below, and this elevation is a constraint for the LGM sea-level position (Ridente et al., 2008; Trincardi et al., 2011a, 2011b; Amorosi et al., 2014; Pellegrini et al., 2017). In the Tyrrhenian Sea, submerged depositional terraces are documented at variable depths between −50 m and −200 m. Between −90 m and −150 m they are interpreted as the evidence of the LGM shoreline (Chiocci et al., 1997; Milli et al., 2016). Direct evidence of the LGM lowstand is known from offshore near Termini Imerese in northern Sicily, where a piston core collected a sample dated to 21.8 ka at a depth of −127 m (Caruso et al., 2011). Another location with LGM shoreline deposits has been found near the Asinara Island, in northern Sardinia, through grab sampling at a depth of −129 m; this yielded an age of 19.2 ka (Palombo et al., 2017).

4.2. Human populations from MIS 4 to MIS 2

The period from the onset of MIS 4 to the MIS 2 was characterised globally by major and sometimes relatively rapid oscillations in temperature and ESL, changes that are documented around the Mediterranean (e.g. Almogi-Labin et al., 2009; Moreno et al., 2002, 2005; Shtienberg et al., 2016, 2017). The onset of MIS 4 brought hyperaridity in the Sahara, leaving potential refuges along the North African Mediterranean coast, such as Cyrenaica and the Maghreb (Garcea, 2012). The advance of the ice sheets in northern Europe forced the contraction of human populations into southern European refuges (Van Andel et al., 2003). Many of these refuges were in coastal regions such as southern Iberia, Gibraltar (Jennings et al., 2011) and the Levant (Belmaker and Hovers, 2011; Bailey et al., 2008; Finlayson, 2008; Stewart and Stringer, 2012). Understanding the relationship between populations and coastlines is therefore a key to understanding the ways in which populations adapted to these shifting environments and the cultural changes we see in the archaeological record during this period.

This period of climatic instability documents significant biological and cultural changes around the Mediterranean Basin. *H. sapiens* populations carrying late Middle Palaeolithic to early Upper Palaeolithic technology dispersed out of Africa into the Levant. By 54.7 ± 5.5 ka they had reached Manot Cave, Israel (Hershkovitz et al., 2015), spreading across Europe as early as ~45–43 ka (Benazzi et al., 2011) and, further afield (e.g. into Australia as early as *c.*55 ka; Hiscock, 2008). It is possible that these *H. sapiens* populations interbred with Neanderthals in the Levant between 65 and 47 ka (Sankararaman et al., 2012). Neanderthal populations had almost disappeared by 41–39 ka (Higham et al., 2014). However, a population of Neanderthals in Iberia/Gibraltar persisted to at least 28 ka (Finlayson et al., 2006). In North Africa, the spread of Upper Palaeolithic (UP)/Later Stone Age (LSA) technology was not accompanied by the spread of a new species as the region was already occupied by *H. sapiens* populations and our understanding of the mechanisms of this spread remains poorly understood. Genetic evidence may suggest a migration of *H. sapiens* populations from southwest Asia between 40 and 45 ka, utilising the southern Mediterranean coast to move into North Africa from the Levant (Olivieri et al., 2006). The current available data for the region, however, remain insufficient to confirm this hypothesis. It is, however, clear that UP/LSA industries are present after 43 ka in Cyrenaica at the Haua Fteah, Libya (Douka et al., 2014), and 30–29 ka onwards in the Maghreb at the Grotte de Pigeons, Taforalt, Morocco (Barton et al., 2007).

These population movements and cultural changes took place when sea level was far below that of the present day in areas with low-lying shelves. In areas where narrow continental shelves existed, sea-level change would have had little impact on travel times to the coastline and coastal resources were still exploited as they had been during MIS 5 (Colonese et al., 2011). In Gibraltar, at Gorham's and Vanguard caves, Neanderthals exploited marine mammals and molluscs during MIS 3. The quantity of marine shells and other marine indicators in these caves is limited, but there is no evidence that it was any greater in the Upper Palaeolithic levels, indicating a consistent level of exploitation through the Late Pleistocene (Brown et al., 2011; Stringer et al., 2008). Exploitation of marine molluscs at the Haua Fteah, Libya is low during the late MSA/Early LSA levels (Klein and Scott, 1986), but this may be due to a more ephemeral occupation at the site during these periods.

Shell beads were manufactured in large numbers in the Upper Palaeolithic layers at Üçağızlı Cave II in southern Turkey (#13 in Fig. 1) between 40 and 23 ka (Stiner et al., 2013) and became a feature of Upper Palaeolithic contexts across Europe (Bar-Yosef, 2002). At Cueva de los Aviones and Cueva Antón, Spain, perforated shells and pigments have also been found dating from c.50 ka (Zilhão et al., 2010) in MP Neanderthal contexts. Evidence for Neanderthal shell tool manufacture in MP contexts, focussed on *Callista chione* and *Glycymeris* sp. shells, continued until around ~50 ka (Douka and Spinapolice, 2012). Examples of retouched shell tools, produced by Neanderthals before 40 ka were found in Kalamakia Cave, Greece (#14 in Fig. 1; Darlas, 2007; Douka and Spinapolice, 2012).

Isotopic analysis suggests that *H. sapiens* from across Europe exploited marine and freshwater resources between 40 and 24 ka, with freshwater fishing at Peştera cu Oase (#15 in Fig. 1), Romania, potentially accounting for high nitrogen values in the Oase 1 individual (Richards and Trinkaus, 2009). Whilst there is some evidence for pelagic fish exploitation on a global scale (i.e. from 42 ka in Jerimalai, East Timor; O'Connor et al., 2011), there is little direct evidence that marine fishing was carried out in the Mediterranean until the late Palaeolithic and Late Glacial (Stiner and Munro, 2011) (see section 6.2). In cave sites such as the Haua Fteah, northern Libya (Barker et al., 2010, #5 in Fig. 1), and the Gibraltar caves (Rodriguez Vidal et al. 2004) important coastal archeological records for this period were preserved above modern sea level due to their geographic setting. The now submerged landscapes and coastlines accessible during MIS 4 and the LGM are one of the main areas where future research must focus.

Underwater archaeological prospection for Palaeolithic sites and artefacts may be more difficult than that for later periods given the nature of the record left by hunter-gatherer populations, prior to sedentism. The archaeological signature is mostly void of recognisable architectural remains and the sites themselves are ephemeral in nature. However, recent discoveries by archaeologists working in the Atlantic at La Mondrée off the coast of Normandy illustrate that artefacts from these periods can be preserved (Cliquet et al., 2011), and that the records of human movement and occupation in coastal areas during this period were not necessarily destroyed by late glacial and Holocene sea-level rise (Flemming et al., 2012; Stanford et al., 2015). In deeper water the probability of recovering significant submerged traces of prehistoric activity is limited by the fact that those environments were above sea level and habitable for shorter durations. Thus, there is higher probability of tracing submerged remains of later human occupations in shallower waters, than those from earlier periods in deeper waters. This should not be confused, however, with any notion that such deeper, older sites would be less significant archaeologically. In fact, future interdisciplinary research undertaken by archaeologists and marine scientists may further demonstrate the value of submerged Pleistocene sites.

As well as presenting a taphonomic challenge to archaeologists wishing to trace past coastal occupation, lower sea levels during MIS 4 and MIS 3 would have exposed landscapes that may have been crucial to the movement and occupation of areas of the Mediterranean. Although seafaring probably did not develop until after the LGM (Broodbank, 2006), lower sea levels would have connected many present-day islands, and reduced the distance between others, making them accessible via short crossings (Phoca-Cosmetatou and Rabett, 2014a). Large areas of exposed land also provided new opportunities for populations to migrate, for example into the northern Adriatic, where a large plain was exposed during periods of low sea level (Correggiari et al., 1996; Spry-Marqués, 2012).

New investigations of the landscape submerged since the LGM, alongside further research in areas where sea-level change had little impact on the position of the coastline, are therefore needed in order to better understand human-coastal interactions around the Mediterranean rim, as well as their implications for global histories. In particular, rescue surveys and research operations should be considered as a priority by heritage managers in places where coastal and underwater erosion and development activities may adversely impact submerged prehistoric remains. The European Marine Board has published a position paper (Flemming et al., 2014) which highlights the strategic need to better understand and manage submerged landscape archaeology, from the Palaeolithic through later periods and has identified the concern of preservation and modern threats to underwater archaeology.

5. Significant palaeoenvironmental phases of the Upper Pleistocene

In this short section, we digress to provide a short overview of the main environmental events or phases which occurred in the Upper Pleistocene, discussing their main characteristics and chronology. It is important that archaeologists are aware of the major environmental changes that occurred during the Late Pleistocene, even if they are not directly linked to changes in sea level. The period between MIS 5 and MIS 2 has been characterised by the occurrence of some climatic and environmental variations with a relatively short duration (i.e. from decades to few millennia). Parts of these fluctuations are clearly recorded in the Mediterranean and, even if some of them are not directly related to coastal change, they affected the evolution of the basin and its environmental and oceanographic settings. Thus, part of these short-lived variations could have impacted on past human populations. Some of the palaeoenvironmental fluctuations generated marker layers in the stratigraphy or left their signature in other proxy records, allowing the cross correlations between different archives and regions, with potential applications in coastal and maritime archaeology.

In the eastern Mediterranean, the depositional sequences of deep waters are characterised by the quasi-cyclical occurrence of dark layers, rich in organic carbon, called ‘sapropels’ (Negri et al., 2012; Rohling et al., 2015; Grant et al., 2016 and reference therein). They correspond to hypoxic or anoxic episodes that are recorded east of the Sicily Strait (Fig. 1) and during which oxygen starvation occurred in deep basins and caused the collapse of the deep ecosystems, but affected the entire water column (e.g. Cramp and O'Sullivan, 1999). The most recent sapropel has a Holocene age (Fig. 7), while another 4 sapropels are documented during the Late Pleistocene (Fig. 4). In different parts of the Mediterranean they can display some noticible differences in their age limits and duration (De Lang et al., 2008; Grant et al., 2016). The causes that led to the sapropel formations are still a question of debate, but their deposition was influenced by astronomical forces and generally correspond to periods of enhanced monsoon rainfall (e.g. Rossignol-Strick et al., 1982; Grant et al., 2016). In the late Quaternary, the sapropels generally caused notable sedimentation during periods of major fresh-water input, probably in connection with enhanced discharge of the Nile River linked with monsoon activity (e.g. Rohling et al., 2015).

During MIS 4 and especially MIS 3, several rapid climatic variations occurred. Among these fluctuations, the so-called Heinrich Events (HEs) are of particular importance, because they represent global climatic episodes that are widely recognised in many archives of the Upper Pleistocene (e.g. Hemming, 2004; Lisiecki and Stern, 2016). The HEs correspond to periods of important collapse of the ice shelves of the northern hemisphere, which caused the release of massive cold fresh-water inputs in the North Atlantic and

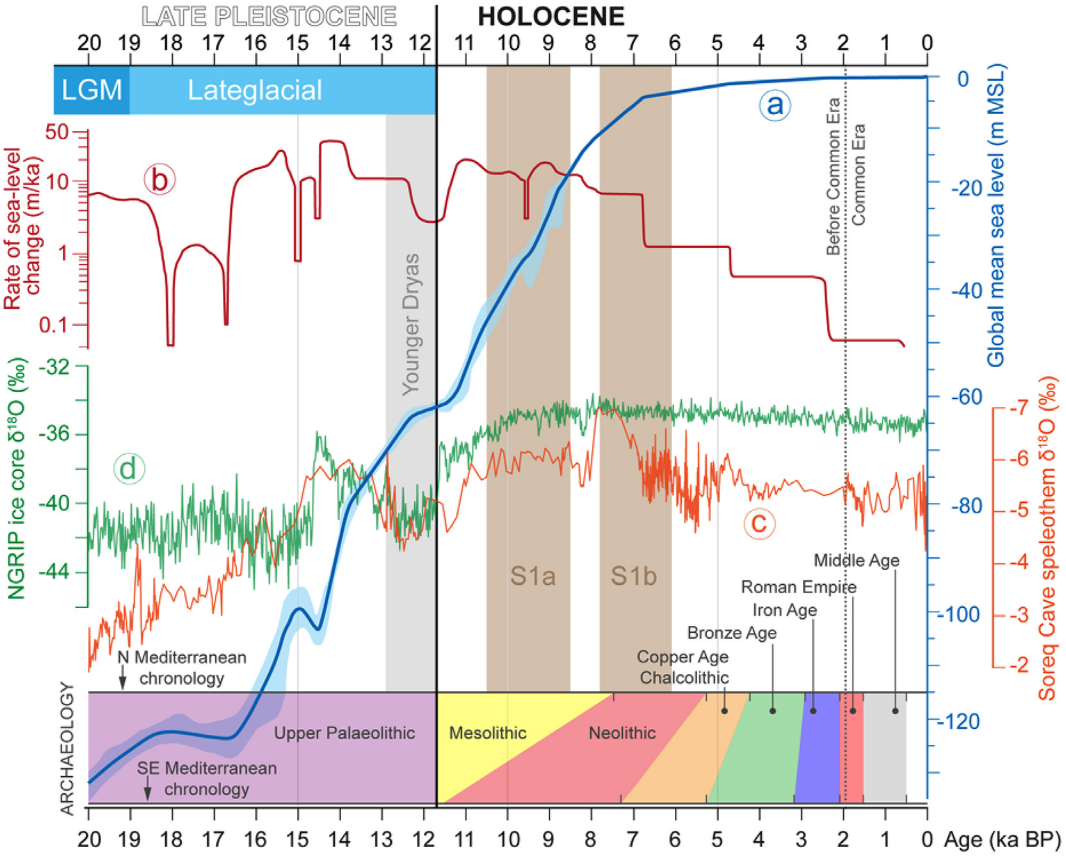

Fig. 7. Comparison between the reconstructed curve of global mean sea level and palaeoclimate, palaeoenvironmental and archaeological data for the Mediterranean Sea in the last 20 ka. a) Global mean sea level curve with indication of the uncertainty shown in pale light blue (Lambeck et al., 2014); b) Rate of sea-level change (Lambeck et al., 2014); c) δ18O composition of the Soreq Cave speleothem; d) δ18O composition of NGRIP ice core (NGRIP members, 2004). Brown shading indicates the period of deposition of sapropel1 (Rohling et al., 2015). The durations of the main archaeological phases appear in the lower portion of the plot, according to the general chronology of south-eastern and northern Mediterranean (cf. Broodbank, 2013). (For interpretation of the colours in this figure, the reader is referred to the web version of this article.)

induced a sensitive drop in the sea surface temperature (Hemming, 2004; Naughton et al., 2009). HEs have been noticeably recorded in the Alboran Sea (Cacho et al., 1999), while their footprint is not clearly evident in the central and eastern Mediterranean (though for further discussion see Wulf et al., 2004). In the eastern and central sectors of the Mediterranean Basin a peculiar role is played by HE4, which occurred ca. 39 ka. It overlaps with the Laschamp geomagnetic excursion (Tric et al., 1992) and is contemporaneous with the eruption that generated the Campanian Ignimbrite ca. 39.3 ka (De Vivo et al., 2001). This volcanic event, which originated in the Campi Flegrei area in southern Italy, represents one of the largest late Quaternary eruptions in Europe and the related tephra has been recognised in many marine cores and continental sequences (Fedele et al., 2008). Another well-recorded volcanic episode produced by the same volcanic area is represented by Neapolitan Yellow Tuff (ca. 14.5 ka), but also some tephra layers related to the explosive activity of the Hellenic Arc are important in the eastern Mediterranean, such as the Cape Riva tephra from Santorini Island (ca. 22 ka, Wulf et al., 2002).

Apart from the catastrophic events themselves, layers of non-visible ash (cryptotephra) are relatively diffuse in the marine cores and their occurrence provides a correlation between marine and terrestrial archives at a Mediterranean and European scale (e.g. Lowe et al., 2007; Bourne et al., 2010; Davies et al., 2012). Moreover, tephra layers are a major tool in the chronostratigraphy of MIS 3 and previous periods, because they can be independently dated through isotopic geochemistry (e.g. $^{40}Ar/^{39}Ar$; K/Ar). This is of particularly value for the deposits older than 40 ka, which can be difficult to date because they are at the boundary or radiocarbon dating, compounded with the marine reservoir effect of the biogenic fossils (i.e. shells, foraminifers), which is generally unknown for this period. Tephra stratigraphy may also have applications to coastal and maritime archaeology, especially for correlating in time human occupation sites across the Mediterranean and beyond.

6. LGM through the early Holocene

While we respect a need for consistency in general, for the Holocene (starting at ca. 11,700 BP) we intentionally change the dating conventions, from thousand years ago (ka) to calibrated years before present (BP), which facilitates the discussion of the links between archaeology and coastal geomorphology in the Holocene.

6.1. Sea level

Since the end of the Last Glacial Maximum (LGM), significant volumes of meltwater have been released into the global oceans as a consequence of ice sheets melting, resulting in a global sea-level rise of about 120 m (Fairbanks, 1989; Edwards, 2006; Clark et al., 2009). Sea level rose during the period between 19 ka – 7000 BP by a mean rate of 10 mm/yr. Although the rise is measured generally to have been consistent and sustained, at least two major punctuated episodes of ice melting are known. The first significant addition of meltwater may have started about 19 ka when ocean levels rose 10–15 m in less than 500 years (Clark et al., 2004). An even more significant phase of accelerated sea-level rise, known as Meltwater Pulse (MWP) 1A. The exact timing of this event and the magnitude of the pulse have been subject to debate. Weaver et al. (2003) reported that MWP-1A occurred between 14.6 and 13.5 ka when global sea level may have increased by as much as 16–24 m. Other studies have suggested sea-level rise during MWP 1A of 20 m during the period between 14.3 and 13.8 ka, sourced from both the Laurentide and Antarctic ice sheets (Bard et al., 1996; Clark et al., 2002; Rohling et al., 2004; Siddall et al., 2010). Deschamps et al. (2012) dated MWP-1A to 14.65–14.31 ka with sea levels rising 14–18 m, coincident with the Bølling warming in the Northern Hemisphere. They suggested that the rate of eustatic sea-level rise exceeded 40 mm/yr during MWP-1A (Deschamps et al., 2012). That rate of change would be noticeable by humans living in coastal areas during a single generation, particularly in low-lying areas and especially where coastal resources were a significant source of dietary protein, fuel and other aspects of economy.

The last deglaciation was interrupted by the Younger Dryas event, which began approximately 12.8 ka. In this short interval, until 11.7 ka, the rate of sea-level rise slowed, as documented in Tahiti (Bard et al., 1996, 2010), the Huon Peninsula, New Guinea (Edwards et al., 1993; Cutler et al., 2003), Vanuatu (Cabioch et al., 2003), and Barbados (Peltier and Fairbanks, 2006), consistent with the overall cooling in the Northern Hemisphere.

In the Northern Adriatic, the slowdown led to the formation of the well developed deltaic complex of the Po River. This sedimentary body is partly preserved at a depth around −40 m between 40 and 60 km offshore of the city of Ravenna (Correggiari et al., 1996; Cattaneo and Trincardi, 1999). Slightly north of this area, lagoon-barrier systems were formed under transgressive conditions during the early Holocene. RSL indicators dating to the interval 11,000–10,000 BP are found between −38 m and −35 m (Moscon et al., 2015). Some lagoonal deposits dating to 10,000–9500 BP are found near the coastline of the present Po River mouth (Amorosi et al., 2008), and in other sites, at −30 m (Correggiari et al., 1996; Trincardi et al., 2011b). The transgression of the Adriatic reached the area of Trieste by approximately 9000 BP (Antonioli et al., 2009; Trincardi et al., 2011b).

The early Holocene sea-level rise was probably punctuated by smaller meltwater peaks due to the episodic deglaciation of the Laurentide Ice Sheet (Carlson et al., 2008). For example, a multi-millennial interval of enhanced rates of sea-level rise between 11,000 and 8800 BP included a probable peak rate of rise of 13–15 mm/yr (67% confidence) at around 9500 BP (Stanford et al., 2011). The 8.2 ka cold event may have been preceded by a sea-level jump of one or two metres (Törnqvist and Hijma, 2012) that also affected the Mediterranean Sea. Some have argued that this flood led to the sudden loss of farming land and the abrupt migration of some Neolithic groups (Turney and Brown, 2007).

6.2. *Human populations during the early Holocene*

The transition from the LGM to early Holocene saw major changes to both coastal landscape evolution and human populations. The Neolithic transition, or ‘Neolithisation’ process, can be described as a cultural shift beginning with the emergence of agriculture and animal husbandry; it is one of the pivotal developments in human evolution, comparable in scale with language, tool use and bipedalism (Zeder, 2006). This is particularly relevant to the Mediterranean Basin, which is thought to have played a significant role in these cultural and technological changes which also coincided with a period of rapid sea-level change.

The scope and span of the area in question and the inevitable research bias resulting from the much greater studied northern coastlines of the Basin makes a survey of this period feel naturally incomplete. Nevertheless, sufficient historical interest and data have been generated to enable some overview synopses across the region's coastal zones, though mainly through European material. The Neolithic emerges from the Epipalaeolithic (as it is referred to in the Levant) and the Mesolithic (as it is known in European archaeology).

Summarising the coastal Mediterranean populations of the European Mesolithic, Pluciennik (2008) points out that the Mesolithic begins and ends in a somewhat arbitrary way; it is a transitional period that generally describes the last hunter-gatherer groups, or the pre-farming/agricultural communities of the early Holocene approximately 13ka–9000 BP in the Mediterranean region (and progressively later in an east-west direction as well as a north-south direction from its origin in the middle east). This period saw dramatic change in both the cultural and environmental records, with much debate centred around cause-and-effect of this human-environment interaction and, possibly what is described as environmental determinism (see Wright, 1993). Avoiding the intricacies of such debates here, it will suffice to say that during a time when postglacial sea-level rise was relentlessly redrawing the coastlines of the Mediterranean map, dramatic changes taking place amongst the cultural practices of the people who occupied the region.

Sea-level rise changed the physical landscape, inundated coastal sites, displaced fishing and shellfishing grounds and created isolated environments in the form of new islands, bays and straits, which would have been culturally occupied throughout these processes of evolution and occasionally punctuated events of both eustatic and tectonic origin. Questions surrounding the apparently low population of the late Mesolithic, which has left little archaeological signature across entire regions of the coastal Mediterranean landscape (e.g. Forenbaher and Miracle, 2005) may be answered, in part by underwater archaeology (Fitzpatrick et al., 2015: 3), though this has only begun to scratch the surface of potential in the Mediterranean (cf. Galili et al., 1993; Galili and Rosen, 2011; Galili, 2017; Bailey and Flemming, 2008; Ammerman et al., 2011; Benjamin et al., 2011; Flemming et al., 2014).

The classic debates by archaeologists in the 20th century centred on the Mesolithic-Neolithic transition and often focused around the questions of demic diffusion (e.g. Ammerman and Cavalli-Sforza, 1971), or modified versions of demic diffusion (e.g. Van Andel and Runnels, 1995), which described the migration of people in the form of a ‘wave of advance’ model hypothesis (for clarification see Ammerman, 1989). This was in contrast with the transmission of cultural practices, including indigenous adoption of new ‘technology’ and substance by existing populations. Theories generally posit that incoming populations replaced or advanced from the southeast and east, or via a ‘leapfrog’ process by maritime pioneers, an idea popularised by Zilhão (1997, 2001). Much focus has been placed on domesticated flora and fauna, however other indicators have also played a key role in establishing cultural typology, particularly pottery. Budja (2009) provides a historical overview on this topic and compares results with genetic data as this technique was becoming popularised in the last decade. Population expansion is often at the center of these debates, with many discussions related to a decline in late Mesolithic population (e.g. Van Andel and Runnels, 1995; Forenbaher and Miracle, 2005). The archaeological discussion has sometimes centred on whether late Mesolithic populations were reduced significantly in numbers prior to the arrival of Neolithic people or the Neolithic cultural ‘package’ (or marker components of the package), or whether the archaeological signatures for those cultures pre-dating the Neolithic have largely not

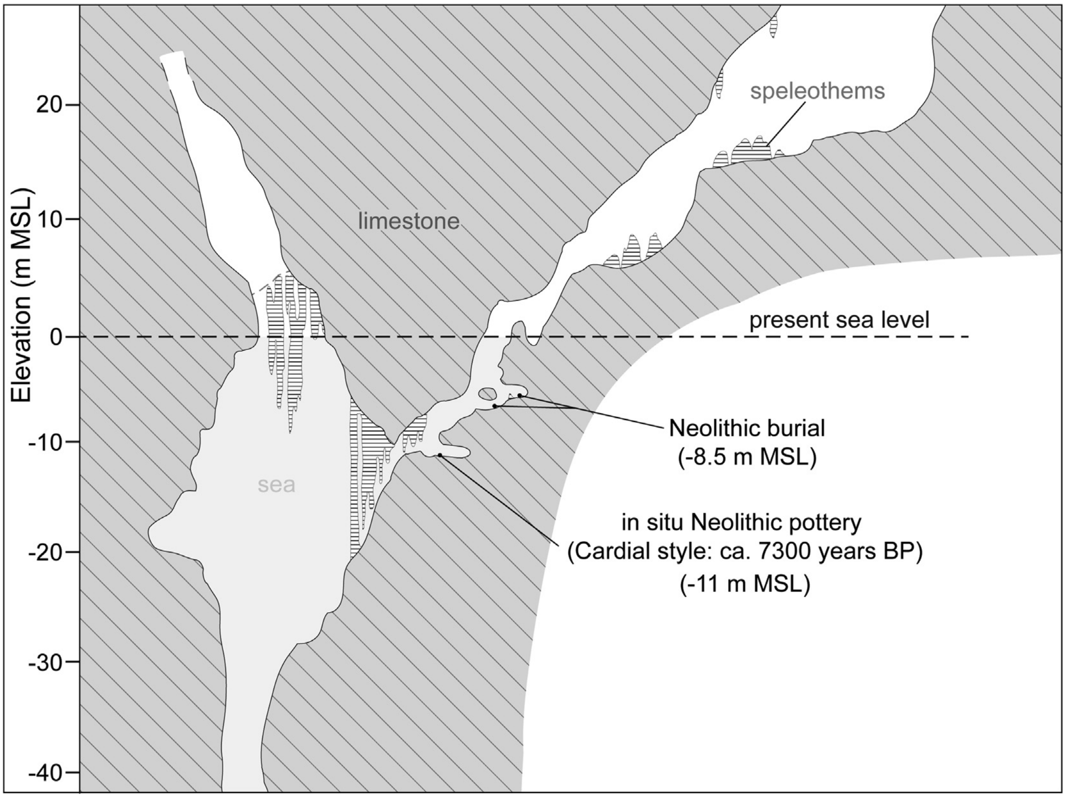

Fig. 8. The Grotta Verde (Green Cave), Sardinia, Italy. Submerged Neolithic material was located associated with associated human remains in what appears to have been a ritualised burial in the cave prior to innundation (after Antonioli et al., 1996; Palombo et al., 2017).

survived. Some have argued that the notion of a single migration is in itself incorrect and that repeated dispersals, each replacing the previous, would have been a more likely scenario (eg. Zvelebil and Zvelebil, 1988).

It is now generally accepted that the extended process, which saw the human inhabitants of the Mediterranean Basin during the early Holocene shift from a subsistence model of hunter-gatherer to herder-farmer, can be considered a complex and dynamic process which took some three millennia to complete its course along Mediterranean coasts (Zeder, 2008, Fig. 2) and which has even been characterised as a ‘mixed migrationist/diffusionists model’ (Richards, 2003). Recent focus has shifted away from early models of a steady ‘wave of advance’ popularised by Ammerman and Cavalli-Sforza (1971), which predicted an annual rate of the westward spread of the Neolithic package, mainly domesticated plants and animals. Studies of demography (e.g. Bocquet-Appel, 2011), burial practices (e.g. Hershkovitz and Galili, 1990) as well as those focused on early herding (e.g. Mlekuz, 2003), have continued to make a significant contribution to the key debates. Such discussions also have been impacted by recent studies in ancient DNA (e.g. Richards, 2003; Haak et al., 2010; Skoglund et al., 2012).

Early maritime voyages have also been suggested to have played a key role in pre-Neolithic life in the eastern Mediterranean (Simmons, 2007). Other island colonisation debates remain unresolved. Antonioli et al. (2014) suggested that the earliest presence of *H. sapiens* on Sicily coincided with the land-bridge connection during the LGM. Palombo et al. (2017), on the other hand, found that the oldest *H. Sapiens* from Sardinia is dated to 8500 BP. Colonisation of uninhabited islands aside, it can be difficult to establish the extent of impact the rising sea levels had on past societies when much of the archaeological record has been lost, or remains under water, undiscovered. For example, Van Andel and Runnels (1995) reject that a large coastal Mesolithic population could have existed along the Black Sea coast. They regard the “complete wipe-out” of coastal Mesolithic cultures as “implausible” (Van Andel and Runnels, 1995, 481). While well known specialists are eager to point out the likelihood of Mesolithic marine resource exploitation leading to increased coastal and riverine populations, including potentially sedentary communities (e.g. Zvelebil and Zvelebil, 1988; Richards, 2003), they have often stopped short of considering the true impact of Mediterranean sea-level rise which may have preserved material of this nature, as it has done in the Baltic Sea (e.g. Fischer, 1995). Indeed, materials have been preserved of Bronze Age (e.g. Henderson et al., 2011), Copper Age (i.e. Chalcolithic/Eneolithic; Benjamin et al., 2011), and early Neolithic period (Galili and Nir, 1993).

The Zambratija Bay site, in northern Croatia, (#17 in Fig. 1), which remains to be explored in detail, represents a submerged settlement in the northern Adriatic (Benjamin et al., 2011, Fig 16.4). It is still unclear as to why the site was abandoned, though early indications do not exclude sea-level rise as a direct cause. The site represents an important opportunity in this respect, and further, detailed study will be required to resolve the abandonment question (Benjamin and Bonsall, 2009; Benjamin, 2010). The Grotta Verde in Sardinia (Italy, #24 in Fig. 1) has yielded submerged archaeological material in the form of cardial ceramics at −10 m depth and human remains at −8 m (Antonioli et al., 1996) in what appears to be a submerged grave, dated to approximately 7300 BP (Fig. 8).

The oldest submerged Neolithic site known in the Mediterranean, Atlit Yam in Israel, dates to 9000 BP and is contemporaneous with much of the Mesolithic hunter-gather societies occupying central, western and northern Europe at that time (Wreschner 1973; Raban 1983; Galili et al., 1993; Galili and Rosen, 2011). The

Fig. 9. Archaeologist (E. Galili) records a Pottery Neolithic water well at the Kfar Samir site (dated to ca. 7000 BP), now submerged at a depth of −5 m. Such archaeological sites are useful indicators of sea-level change and provide limiting dates for transgression. (Photo: J. Benjamin).

Pre Pottery Neolithic C (PPNC) site is located in an area 200–400 m offshore, at −8 to −12 m in the North Bay of Atlit (Galili and Nir, 1993) and radiocarbon determinations range from 9250 to 7970 BP. Excavations have revealed human burials, rectilinear structures and rich assemblages of implements made on flint, stone, bone and wood, as well as faunal and floral remains (Galili and Rosen, 2011). The village economy was based on hunting, herding, fishing and agriculture.

A further six settlement sites from the later Pottery Neolithic belonging to the Wadi Rabah culture were also discovered on the Israeli Carmel coast. These sites, dated to the 8th millennium BP, are located close to the present coastline at a depth of 0 to −5 m (Galili and Weinstein-Evron, 1985; Galili and Nir, 1993; Galili and Rosen, 2011). The Kfar Samir well indicates that during the Pottery Neolithic, some 7000–8000 years ago, sea level on the Carmel coast was at -9 to −10 m (Fig. 9). The archaeological studies of the Carmel Coast indicate that sea level rose from −35 m to −7 m between 9000 and 6500 BP, at an average rate of 11–13 mm/yr. This demonstrates how the coastal Neolithic population was responding to the rising sea level as the older settlements were abandoned and new sites were established landward.

The early Neolithic village at Atlit Yam and the Neolithic and Chalcolithic material from Grotta Verde and Zambratija further demonstrate the potential of submerged archaeology to contribute significantly to prehistory and sea-level studies as foreseen by Masters and Flemming (1983) in their benchmark interdisciplinary volume *Quaternary Coastlines and Marine Archaeology*. Increased research into coastal and submarine geomorphology and archaeology will continue to increase knowledge of the significant environmental and cultural transitions which took place throughout the early and middle Holocene.

7. Middle and late Holocene

7.1. Sea level

Reconstructions of middle and late Holocene sea-level changes in the Mediterranean are based on geomorphological evidence (such as tidal notches and beachrocks), fixed biological indicators (such as coralline algae, boring molluscs, oyster beds and the fixed vermetidae *Dendropoma petraeum*) and archaeological indicators. The most precise sea-level indicators are specific types of fixed biological indicators (Laborel, 1996; Laborel and Laborel-Deguen, 1994; Morhange et al., 2001; Sivan et al., 2010; Rovere et al., 2015).

Holocene sea-level curves have been constructed in Italy (e.g., Lambeck et al., 2004a, 2011), Croatia and Slovenia (e.g., Antonioli et al., 2007; Faivre et al., 2013), southern France and Corsica (e.g., Laborel and Laborel-Deguen, 1994; Vacchi et al., 2016a); Turkey (Anzidei et al., 2011a), Greece (e.g., Pirazzoli, 2005; Vött, 2007; Pavlopoulos et al., 2011; Vacchi et al., 2014; Mourtzas et al., 2016; Kolaiti and Mourtzas, 2016; Mourtzas and Kolaiti, 2016), Tunisia and Libya (Anzidei et al., 2011b), the Aeolian Islands (Anzidei et al., 2014a, 2016a, b), Israel (Sivan et al., 2001, 2004; Toker et al., 2012; Galili et al., 1988, 2005) and Lebanon (Morhange et al., 2006; Sivan et al., 2010). Data collected from tectonically stable regions, some characterised by negligible isostatic effects (Sivan et al., 2001, 2004; Toker et al., 2012) for the last 4000 years, indicate that sea level was close to present levels by 4000–3600 BP (Galili et al., 2005; Galili and Sharvit, 1998; Porat et al., 2008). Depending on the location in the Mediterranean, RSL fluctuated either below or slightly above the present since that time (Sivan et al., 2004; Toker et al., 2012; Vacchi et al., 2016a, b). As an example, RSL along the coastlines of Israel rose from −7 m to the present level at a rate of 2.5–3.5 mm/yr between 6800 and 4000 BP. At the same location, RSL was approximately between −2.5 m and −5 m during the Chalcolithic period (6000–5700 BP). By the Middle Bronze Age (~4000 BP) the sea had reached its present level and the coastline reached its current form. Since then, RSL has been relatively stable with possible fluctuations of no more than 0.5 m vertically (Galili et al., 2005; Sivan et al., 2001, 2004; Anzidei et al., 2011a). A recent notch study by Goodman-Tchernov and Katz (2015) does however question this stability and theorises that a more punctuated rise may have occurred during the Holocene.

Although the Mediterranean basin lies beyond the direct influence of ice sheets, ice-sheet loading had a pronounced effect on the shape of Mediterranean sea-level curves. This is seen in the output of GIA models, which produce lower sea levels when ice loading is increased (e.g. Lambeck and Purcell, 2005; Stocchi and Spada, 2009). In the eastern and southern regions of the Mediterranean, the ice-loading effect is least significant and along coasts where tectonics can be discarded (e.g. Lybia) the regional sea level approximates the global eustatic value (Milne and Mitrovica, 2008). In most of the Mediterranean, water loading (hydro-isostasy) is an important contributor to middle and late Holocene relative sea-level change, but because the glacio-isostatic signal is of the opposite sign, middle Holocene sea-level highstands are not found across most of the Mediterranean basin (Lambeck and Purcell, 2005; Stocchi and Spada, 2007). An exception is the coast of the Gulf of Gabes (Tunisia), where it has been proposed that relative sea level between 6000 and 5000 BP was close to +1.5 m (Mauz et al., 2015a, 2015b; Vacchi et al., 2016b; Morhange and Pirazzoli, 2005). This highstand is correctly predicted by the GIA model of Lambeck and Purcell (2005), but their predicted highstand in the northern Adriatic, supposedly due to the Alpine glacial load, is not supported by sea-level field data (e.g. Antonioli et al., 2007, 2009).

7.2. Human populations: protohistory and urbanisation

The end of prehistory and the beginnings of urbanisation in the eastern Mediterranean have yielded an extensive record of archaeological sites and material. For a recent and comprehensive overview, Broodbank (2013) has devoted multiple chapters of the *Making of the Middle Sea* to these periods of intense development, innovation and technological and cultural changes. Broodbank's recent work is also significant to this discussion because it is a mainstream archaeological text that focuses heavily on maritime peoples, their way of life and relationship with the sea, past and present. It also draws upon evidence from the submerged sites discussed in sections above and serves to highlight that submarine geoarchaeology has become indispensably linked to the terrestrial record. This current section, therefore avoids an impossible attempt at a comprehensive review of all Mediterranean coastal archaeology. Here we focus on human-sea-level interaction, and highlight representative sites from across our geographical and temporal remit.

The Protohistoric coastal structures of the Mediterranean Basin and their archaeological signatures, have suffered from the development of later societies: many sites were destroyed, incorporated or generally transformed the pre-existing archaeological evidence. In particular, widespread diffusion and large stone construction (especially during the Classical periods) have resulted in the loss of the protohistoric features, through human reuse and recycling of materials. Thus, information on sea levels in the Bronze and Iron Age based on coastal settlements' remains is not as well documented as in later periods and is often related to a few selected sites, as in the case of the harbour of Marseille (Morhange et al., 1996, 2001), the Northern Cyclades, the central and eastern Crete (Mourtzas and Kolaiti, 2016; Mourtzas et al., 2016), or along the coast of modern day Israel (Sivan et al., 2001). The rare finding of a protohistoric vessel that would have entered a harbour might offer an extraordinary window on maritime life and seafarers ways (e.g. Uluburun in Turkey, #25 in Fig. 1; Bass et al., 1984), however shipwrecks of the open seas do not provide good indication of past sea levels. Conversely, relicts of beached or abandoned vessels (particularly vernacular vessels used for every day short-range activity), which can be confidently determined to have been left at or near sea level at the time, may contribute information related to sea level and environment.

Once the Holocene sea-level rise had slowed down, various areas throughout the eastern Mediterranean continued to undergo significant regional and micro landscape changes owing to adjustment in land level caused by tectonic activity. The Bronze Age site at Pavlopetri (Greece, #27 in Fig. 1), was first investigated in the 1960s for its archaeological implications and for its contribution to sea-level studies in the Peloponnese (Flemming, 1978) and later revisited and systematically mapped by Henderson et al. (2011). The changes in landscape around similar coastlines would certainly not have gone unnoticed by local populations and oral traditions are likely to persist in the region's modern collective memory.

During the Middle and Late Bronze Ages (ca. 3600–3100 BP) of northwestern Adriatic, society flourished along the rims of the lagoons of Venice, Carole and Grado-Marano. Villages developed on slightly elevated fluvial ridges entering in the lagoon, and also on salt marshes. Several archaeological structures constrain sea level to −3.0 ± 0.6 m around 4000 BP and −2.0 ± 0.6 m at 3000 BP (Fontana et al., 2017). This symbiotic relationship between lagoon and dwelling sites existed in the area also in the Iron Age, as clearly depicted in the 1st century BC by the geographer Strabo in his description of the cities of the Venetian people, that “stand in the midst of water like islands, others are only partially surrounded. Such as lie above the marshes in the interior are situated on rivers navigable for a surprising distance” (Strabo, Geografia, V, 1, 5). Thus, it seems that the settlement system of the Bronze Age represents the early evidence of an Adriatic culture strongly related to the brackish environments. This was later developed in the same area during the Iron Age and the Roman period with the harbour cities of Aquileia, Concordia Sagittaria, Altinum, Adria, Spina and Ravenna (#22 in Fig. 1), and later, during the early Middle Age, by Venice and its Republic.

While submergence occurred in some parts of the world due to tectonics or loading of the underlying deltaic sediments, other coastal cities from the same periods are now positioned several kilometres inland as a result of river sedimentation. Sites such as Troy (Kraft et al., 2003), Miletus (Brückner et al., 2006), Liman tepe (Goodman-Tchernov et al., 2009b), and Acco (Morhange et al., 2016) provide such examples. There, the slowing of sea-level rise allowed the build-up of alluvial sediment that ultimately closed these anchorages and proto-harbors, leaving the settlements some distance from the sea. Liman Tepe, located in the Bay of Izmir, Turkey, for example, has indications for a large bay that closed just before the construction of an archaic harbour on the new shoreline. Today, the presence of those features and settlements are useful markers for reconstructing the process of coastal progradation and its relation to sea-level change.

Sites lost to the sea due to subsidence and tectonic activity are not unique to prehistory and as noted by Broodbank (2013) ‘the end of the beginning’ or the emergence of classical periods, saw entire cities submerged. The now well known ‘sunken cities’ of Egypt (Robinson and Goddio, 2015; see also Stanley and Bernasconi, 2012) are also in contrast to the earlier site at Pavlopetri (Late Bronze

Age), because they appear to have been submerged during a period of their flourishment, and not after their abandonment. The cognitive impacts on lost habitat would have differed from that of earlier periods, particularly pre-Neolithic settled societies; the scale of these proto-urban and fully urban submerged sites would have resulted in a much greater cumulative impact than during the Neolithic or earlier periods, due to population size and overall settlement scale. Imprints on the collective histories, both oral and written, relating to sea levels, land loss, and their practical and spiritual impacts require increased consideration by the archaeological community for both fully sedentary and mobile societies.

8. Archaeological RSL indicators

Archaeological indicators of RSL are most precise when they can be associated with the biological remains of organisms living in close connection with tidal ranges. A classic example of such remains used by geoscientists and archaeologists alike, is that of barnacles (*balanidae*) which once clung to the inside harbour walls and other fixed structures (e.g. in Marseille, France, Morhange et al., 2001). Classical and historic archaeological features can be useful palaeo-sea-level indicators, however those from earlier prehistory tend to be less precise and less common, particularly those from hunter gatherer contexts (e.g. shell middens, cave deposits). But sea level and geomorphic impacts upon these earlier societies (and the human responses they resulted in) are no less important – and can inform on debates such as dispersals, migrations, and even the development of capabilities such as sea faring.

8.1. Early, middle and late Holocene archaeological sea-level indicators

Archaeological evidence for early and middle Holocene sea-level rise is found throughout Europe (e.g. Benjamin et al., 2011), but excellent examples are found in the Mediterranean Sea, especially the Neolithic sites of the Carmel Coast of Israel. Though the submerged Neolithic (described above) is relatively sparse compared with later periods, it is very informative for sea-level studies. Its settlements and burial sites provide evidence of ancient populations, and in some instances, how people coped with environmental changes and their response and resilience to coastline shifts and sea-level rise (Galili and Rosen, 2011).

In the later Holocene, direct evidence of submerged terrestrial land surfaces and many types of archaeological features associated with the coastal and marine environment can be used as highly accurate sea-level indicators (e.g. Morhange and Marriner, 2015). Keys to the successful application of any archaeological element to reconstructing past sea levels are: (i) careful measuring of the site elevation relative to the present sea level; (ii) the definition of the site function, and (iii) determining its association with the sea level in the past (e.g. Blackman, 1973; Flemming, 1969; Galili et al., 1988, 2005, 2015; Galili and Sharvit, 1998; Sivan et al., 2001, 2004; Toker et al., 2012; Antonioli et al., 2006a; Goodman et al., 2008; Lambeck et al., 2004b; Vacchi et al., 2016b).

Coastal structures may be found today in situations that prevent them from functioning for one or several reasons: i) RSL change resulting from vertical land movements (e.g. Galili and Sharvit, 1998; Stiros, 2010; Anzidei et al., 2014b, 2016a, b) generated by local or regional tectonics, as well as isostatic adjustments, or sea-level rise or fall; ii) settling of structures into unconsolidated sediments; iii) erosion and collapse of structures; iv) progradation of the coastline (e.g., Morhange et al., 2013). While archaeological features can directly benefit sea-level reconstructions, supporting (multi-proxy) datasets can significantly improve interpretations of past sea level (Vacchi et al., 2016b).

Later Holocene archaeological features used as sea-level markers can be divided into two broad categories (Flemming, 1978; Blackman, 1973; Galili and Sharvit, 1998; Sivan et al., 2001; Lambeck et al., 2010; Morhange and Marriner, 2015):

i) Features that need to be at or partially below sea level in order to function properly. These include pools that are fed by seawater driven by gravity, slipways, harbour installations, salt production installations, etc. These structures typically mark the uppermost or lowermost sea level at the time of construction (Fig. 11).
ii) Features that are located normally only on dry land, including dwellings, quarries, roads, water-wells, freshwater pools, etc. These structures usually provide the uppermost sea level at the time of construction (Pirazzoli, 1976, 1986; Galili and Sharvit, 1998).

An alternative classification, as described by Mourtzas et al. (2016) and Mourtzas and Kolaiti (2013), describes archaeological sea-level indicators in further detail. They are modified here as:

i) Ancient coastal settlements and buildings that were constructed above sea level along the coast, but lack accurate position in relation to the past shoreline. Their present position provides only limiting data to past sea level and should be used with caution.
ii) Maritime constructions that were partially built below sea level (e.g. harbours, piers, quays etc.). Such structures may be dated, with variable confidence, where recorded in ancient literature. These are generally more reliable than the previous category.
iii) Ancient maritime constructions whose function was strictly related to past sea levels, where age is confidently determined. Fish tanks and ancient ship sheds where spatial proximity to the contemporary shore can be determined, may provide reliable data.
iv) Coastal water tables and their changes in response to sea-level change. Usually coastal aquifers are in hydraulic connection with the adjacent sea. Therefore, sea-level rise may result in the flooding of water installation supplies of archaeological sites built on land near the shore (Mourtzas, 2010; Pagliarulo et al., 2013).
v) Indications of relative sea level-change based on historical sources such as ancient texts, drawings, etc.

Harbour installations such as breakwaters, jetties, docks and quays were originally built, at least partly, under water and thus are good limiting markers for sea levels. It is generally agreed that walking and working surfaces in harbours were planned to be above sea level. However, determining sea level using these features has some limitations: i) it is not always possible to determine whether the uppermost surface found today represents the original surface used in the past because some courses of stones may have been removed either by natural or cultural agents (Blackman, 1973: 124); ii) it is possible that some small harbour and coastal installations were not designed to function year-round and in all sea conditions; iii) some constructions seemed to be built deliberately under water and there is historical evidence for such activities (Galili and Sharvit, 1998: 158; Marsden as cited in Blackman, 1973: 138) iv) compaction and liquefaction of unconsolidated sediments may cause settling and subsidence of harbour installations.

At Caesarea, south of Haifa in Israel, there are ample indications for relative sea-level and tectonic stability in the past 2000 years (Sivan et al., 2001, 2004; Goodman-Tchernov and Katz, 2016). One of the best indicators is the presence throughout the site within

Fig. 10. Archaeological features partially submerged at Caesarea, Israel. While harbour features are useful sea-level markers, it is important to understand the original function and position of the features. (Photo: B. Goodman-Tchernov).

Fig. 11. The submerged site at Fizine, Slovenia (northern Adriatic Sea, #18 in Fig. 1) is interpreted to be a Classical *vivarium* or fishtank. Stones from the shallower sections of this site have been removed for re-use during historical periods. (Photo: J. Benjamin).

Roman and later coastal features of notches in both pools and harbours. However, while the portions of the large Roman harbour of Caesarea that were built directly on nearshore bedrock are stable, the offshore portions of it are today submerged between −1 and −5 m (Fig. 10). This is most likely due to either storm- wave pounding causing subsidence of the breakwaters in the sand (Galili

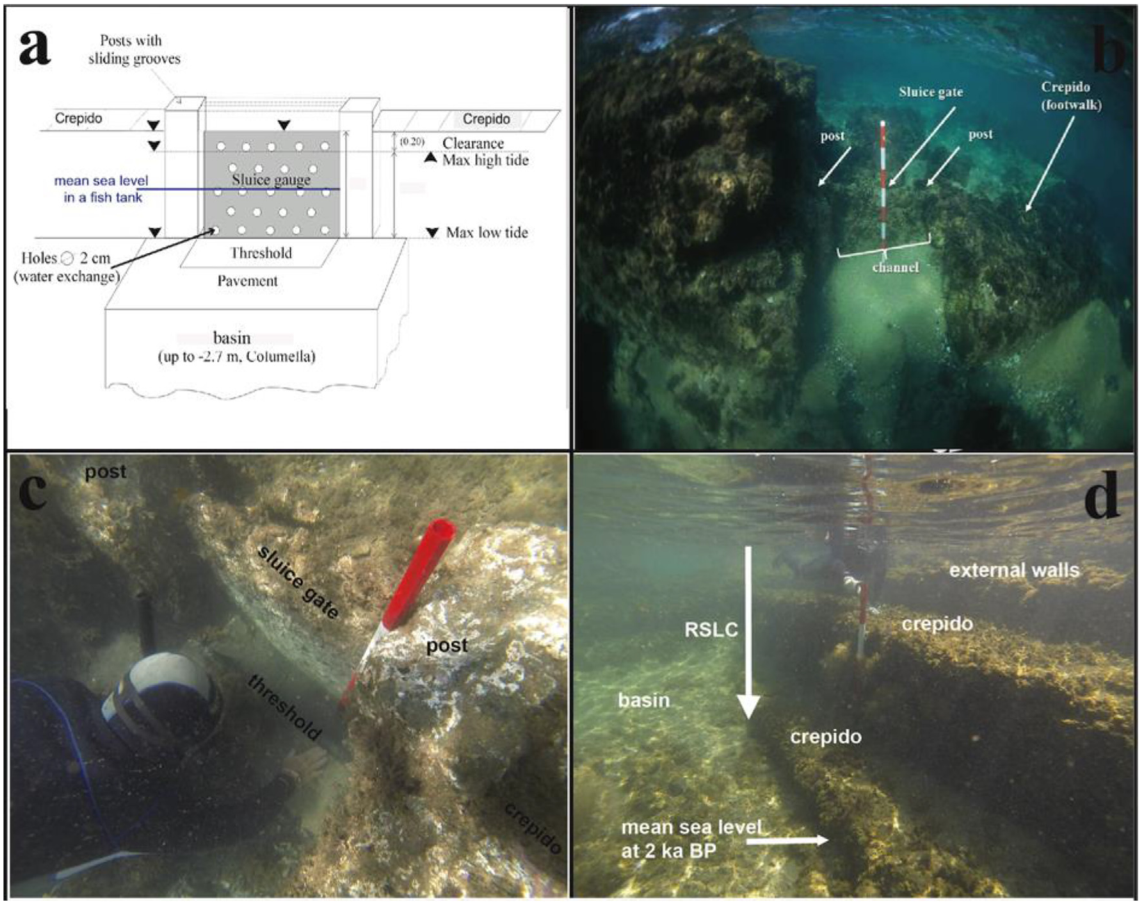

Fig. 12. The typical features of a fish tank, used as an archaeological sea-level marker. a) Sketch of the channel and the sluice gate with sliding posts, threshold and lowest level of crepido. The complete gate consist of: (i) a horizontal stone surface that defines the threshold with a groove to receive the gate; (ii) two vertical posts with grooves to guide the movement of the gate; (iii) an upper stone slab (missing in this specific case) with horizontal slot to extract the gate; (iv) the gate itself with small holes for water exchange. b) Underwater photo of the *in situ* sluice gate, channel and crepido at the fish tank La Banca, at Torre Astura (Italy). (Adapted from Lambeck et al., 2004b; photos: F. Antonioli & M. Anzidei).

and Sharvit 1998; Morhange et al. 2014) or the combined effects of tsunami damage and liquefaction (Reinhardt et al., 2006; Goodman-Tchernov et al., 2009a; Dey and Goodman-Tchernov, 2010, Goodman-Tchernov and Austin, 2015). Such variables, in an otherwise tectonically stable environment, serve as a reminder that local dynamic processes can influence the archaeological interpretation of key processes and events.

8.2. *The debate on Roman fishtanks*

Several studies have reconstructed past sea levels from rock-cut coastal fish tanks (Fig. 12) in Italy (Dreghorn, 1981; Auriemma and Solinas, 2009; Evelpidou et al., 2012b), Greece (Kolaiti and Mourtzas, 2016), Israel (Galili and Sharvit, 1998; Toker et al., 2012), Croatia (Florido et al., 2011) and Cyprus (Galili et al., 2015). Lambeck et al. (2004b) compiled an exhaustive analysis of the central Tyrrhenian Sea fish tanks placing sea level in the Roman period at −1.3 m RSL. This level corresponds to that reported by Mourtzas (2012a, b) along the coasts of central and eastern Crete (~1.25 m), by Schmiedt (1972) for some sites in Italy, and by Aucelli et al., 2017 along the Sorrento peninsula (Tyrrhenian coast of central Italy). The archaeological interpretation in Lambeck et al. (2004b) was based on field surveys and analysis of ancient Latin publications. An important fish tank feature is represented by the channel systems equipped with sluice gates (*cataracta*) that controlled the water exchange between the tanks and the open sea, preventing the fish from escaping. Water exchange took place through multiple channels, sometimes carved in bedrock. A breakwater is often built around the fish tank to protect the inner basin from sea waves. The latter are often delimited by foot walks (*crepido*), generally occurring at two or three levels that were not recognised or interpreted in earlier studies. These levels, together with the sluice gates, are key in interpretations of the position of former sea level in relation to the fish tanks.

Lambeck et al. (2004b) demonstrated that the top of the sluice gate corresponds to the elevation of the lowest level foot-walk (*crepido*) (Fig. 12). According to the Latin treatise *De Re Rustica XIII (*Columella*, early 1*st *century AD)*, the *crepido* should lie above the highest tidal level, as also reported in the description by Pliny the Elder (23–79 A.D., in Naturalis Historia) in a constructional part that looks at the water (*marginum eam partem, quae aquas spectat)*. Using sites with complete preservation of channels, sluice gates and foot-walks, Lambeck et al. (2004b) estimated that the palaeo high tide in Roman time was about 0.2 m below the lowest *crepido*. Further, Lambeck et al. (2004b), and subsequently Auriemma and Solinas (2009) and Mourtzas (2012a, b), suggested that the flow of water inside the fish tanks was tidally controlled and that the palaeo mean sea level was placed at the middle of the sluice gate, while mean low tide was denoted by the channel thresholds, often corresponding to the base of the mobile *cataracta*. Past RSL was then constrained by these structural features of the fishtanks (Fig. 12). Such interpretation was also applied at a number of sites throughout the Mediterranean (e.g. Antonioli et al., 2007; Anzidei et al., 2011a, 2014a).

Evelpidou et al. (2012b) also performed a detailed survey of some Tyrrhenian Sea fish tanks, previously observed by Schmiedt (1972) and Lambeck et al. (2004b) and proposed that RSL during the Roman period ranged between ~ −0.6 and ~−0.3 m. Evelpidou et al. (2012b) disagreed with the interpretation of an original supratidal position of the lowest *crepido* proposed by Lambeck et al. (2004b). Further, they stated that the height of the *cataracta* proposed by Lambeck et al. (2004b) would not be sufficient for the fish tanks to function properly. They suggested that the upper part of the *cataracta* corresponds to the upper *crepido* instead of the lower one. Evelpidou et al. (2012b) assumed that the top of the upper *crepido* was high enough to prevent the fish tank from flooding by sea surges, which could lead to a loss of fish. Pirazzoli and Evelpidou (2013) stated that the heights of the channel threshold and the base of the *cataracta* can vary and they argued, therefore, that this structural feature was too unreliable to precisely reconstruct the palaeo RSL.

In absence of a definitive interpretation of the sea level related to the fishtanks of the Mediterranean, Vacchi et al. (2016b) adopted the conservative solution to consider both the archaeological interpretations summarised above in the calculation of the palaeo sea level. As these structures are highly relevant for the reconstruction of sea level in the Common Era, it is necessary to implement field strategies beyond the archaeological interpretation of these indicators, and couple them with other independent sea-level proxies (e.g. sea level reconstruction from nearby or contextual fixed biological indicators). As an example, in the Tiber Delta, in *Portus*, the harbour of ancient Rome, Goiran et al. (2009, 2010) placed RSL during Roman time at −0.8 ± 0.2 m using fixed biological indicators. This is the only study that obtained dates on sessile fauna found *in situ* on a maritime archaeological structure in the area, and places the Roman-era sea level in between the two previously described interpretations.

9. Concluding remarks

This article has summarised the current knowledge and discussed some of the key gaps and debates in sea-level studies from geomorphological and archaeological perspectives, spanning ca. 132,000 years of human-environment interaction around the Mediterranean Sea. Focus has been mainly on the eastern and central Mediterranean, though some data have been introduced from other parts of the Mediterranean Sea to support overall themes of sea-level change and its impact on past human societies and the integration of archaeological and geomorphological data to study past coastal and sea-level changes, particularly where data remains sparse or fragmented.

In the past decade, issues related to modern climate change and future sea-level rise have motivated some archaeological studies to focus on the direct consequences of past climate change (e.g. Van de Noort, 2011, 2013) and the ‘Attacking Ocean’ (Fagan, 2013). Weninger et al. (2006, 2014) describe the rapid climate change which would have occurred immediately following the collapse of the Laurentide ice sheet and Hudson Bay outflow for its impact on contemporary populations. While it is possible that gradual inundation rates would have been slow enough to be invisible during a single generation, it is likely that oral histories would have conveyed this process culturally though time. It is all but certain that these climate events would have had a direct and profound impact on those past cultures who were unlucky enough to have chosen to live on low-lying coastal margins. Evidence of oral traditions may be difficult to obtain, however the archaeological signature of coastal defense or population retreat, may be a boon to the next generation of those studying past societies and sea-level change of the Mediterranean.

The Mediterranean, the micro-tidal cradle of western civilisation with low rates of isostasy, has a long-standing and important role to play in determining the global sea-level history in the late Holocene. Mediterranean data have featured prominently in late Holocene sea-level sections of various IPCC assessment reports. It is critical to establish the rate of late Holocene global sea-level rise, because it forms the background against which modern accelerations of sea level rise are evaluated (Gehrels, 2010a, b; Gehrels et al., 2011). Local rates of Holocene relative sea-level rise are important for estimating future sea levels as they reflect the rate of long-term background sea-level rise to which predictions, such as those by the Intergovernmental Panel on Climate Change (IPCC), can be added to generate local predictions of relative sea-level rise that are of interest to coastal management. Moreover, local rates allow us to evaluate in detail the tectonic displacement rates that closely relate to the same just aforementioned questions. Whilst many Mediterranean sea-level studies address local tectonics, the regional vertical land movements produced by GIA processes are also important; the modelling of these, not only for Holocene but also for Last Interglacial sea levels, remains a challenge that should be addressed in future work.

Relative sea-level changes in the Mediterranean Sea are complex and variable, primarily due to tectonics and volcanism, although, as mentioned, glacio-isostatic adjustment also plays a crucial role. Sea-level rise is predicted to increase up to five fold in the next century compared to the past 100 years. This will take place against a background of rapid vertical land motion in many coastal areas that have produced, and continue to produce, changes in the relative positions of land and sea, as demonstrated by geological and archaeological methods outlined in this review. Humans will continue to adapt to coastal change so it is of utmost societal importance that the past history of relative sea level is taken into account on local and regional scales for effective and strategic coastal management.

A fully integrated study of the entire Mediterranean Basin, including a comprehensive analysis of the greater region's sea-level history and its impacts on past societies, should include more data from the western Mediterranean and, especially, include increased attention to the shorelines of North Africa, where studies are scarce. This goal will require increased European-African cooperation by the communities of geo-scientists and archaeologists. As with many other aspects of physical environmental and archaeological sciences, there is a huge, largely untapped, opportunity for study along the Mediterranean coast of North Africa; the data gaps encountered by this review have highlighted this discrepancy between Mediterranean Eurasia and Mediterranean Africa. Filling these gaps will require a concerted multi-disciplinary effort by both archaeologists and geo-scientists. Such an approach will require the will, support and international cooperation of scientists, governments, funding agencies and industry partners from across the region. We hope this contribution will have highlighted the necessity for interdisciplinary research and trans-border collaboration and has gone some way to propel future regional studies related to Mediterranean sea levels, environment and culture.

Acknowledgements

The authors would like to thank INQUA for funding the MED-FLOOD community, particularly for providing early career scholars with an opportunity to attend MEDFLOOD workshops and field excursions through travel bursaries (INQUA Projects MEDFLOOD and MEDFLOOD MOPP, 1203P and1603P). Further acknowledgement are extended to the Institutional Strategy of the University of Bremen, funded by the German Excellence Initiative (ABPZuK-03/2014) and by ZMT, the Center for Tropical Marine Ecology as well as to the Labex Archimende (ANR-11-LABX-0032-01, France). RHI and MGMW were supported by the European Research Council through ERC Advanced Grant 269586. RHI also gratefully acknowledges funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 660343. Flinders University, Faculty of Education, Humanities and Law provided funding for the article's lead author through the EHL Establishment Grant scheme. Data in Fig.2. is a part of research funded by the Croatian Science Foundation(HRZZ) project no. 9419 LoLADRIA. The University of Haifa is acknowledged for help in organizing the 2014 MEDFLOOD workshop, where the first draft of this paper was conceived.

References

Almogi-Labin, A., Bar-Matthews, M., Shriki, D., Kolosovsky, E., Paterne, M., Schilman, B., Ayalon, A., Aizenshatat, Z., Matthews, A., 2009. Climatic variability during the last ~90ka of the southern and northern Levantine Basin as evident from marine records and speleothems. Quat. Sci. Rev. 28, 2882–2896.

Ammerman, A., 1989. On the Neolithic transition in Europe: a comment on Zvelebil & Zvelebil (1988). Antiquity 63, 162–165.

Ammerman, A., Cavalli-Sforza, L.L., 1971. Measuring the rate of spread of early farming in Europe. R. Anthropol. Inst. G. B. Irel. 6, 674–688.

Ammerman, A., Howitt-marshall, D., Benjamin, J., Turnbull, T., 2011. Underwater investigations at the early sites of Aspros and Nissi beach on Cyprus. In: Benjamin, J., Bonsall, C., Pickard, C., Fisher, A. (Eds.), Submerged Prehistory. Oxbow, Oxford, pp. 263–271.

Amorosi, A., Colalongo, M.L., Fiorini, F., Fusco, F., Pasini, G., Vaiani, S.C., Sarti, G., 2004. Palaeogeographic and palaeoclimatic evolution of the Po Plain from 150-ky core records. Glob. Planet. Change 40, 55–78.

Amorosi, A., Fontana, A., Antonioli, F., Primon, S., Bondesan, A., 2008. Post-LGM sedimentation and Holocene shoreline evolution in the NW Adriatic coastal area. GeoActa 7, 41–67.

Amorosi, A., Antonioli, F., Bertini, A., Marabini, S., Mastronuzzi, G., Montagna, P., Negri, A., Rossi, V., Scarpone, D., Taviani, M., Angeletti, L., Piva, A., Vai, G.B., 2014. The middle - upper Pleistocene fronte section (Taranto, Italy): an exceptionally preserved marine record of the last interglacial. Glob. Planet. Change 119, 23–38.

Anthony, E.J., Marriner, N., Morhange, C., 2014. Human influence and the changing geomorphology of Mediterranean deltas and coasts over the last 6000 years: from progradation to destruction phase? Earth Sci. Rev. 139, 336–361.

Antonioli, F., Chemello, R., Improta, S., Riggio, S., 1999. Dendropoma lower intertidal reef formations and their palaeoclimatological significance, NW Sicily. Mar. Geol. 161 (2), 155–170.

Antonioli, F., Ferranti, L., Lo Schiavo, F., 1996. The submerged Neolithic burials of the Grotta Verde at Capo Caccia (Sardinia, Italy) implication for the Holocene sea-level rise. Mem. Descr. Serv. Geol. Naz. 52, 290–312.

Antonioli, F., Bard, E., Potter, E.-K., Silenzi, S., Improta, S., 2004. 215-ka history of sea-level oscillations from marine and continental layers in Argentarola Cave speleothems (Italy). Glob. Planet. Change 43, 57–68.

Antonioli, F., Ferranti, L., Kershaw, S., 2006a. A glacial isostatic adjustment origin for double MIS 5.5 and Holocene marine notches in the coastline of Italy. Quat. Int. 145–146, 19–29.

Antonioli, F., Kershaw, S., Renda, P., Rust, D., Belluomini, G., Cerasoli, M., Radtke, U., Silenzi, S., 2006b. Elevation of the last interglacial highstand in Sicily (Italy): a benchmark of coastal tectonics. Quat. Int. 145–146, 3–18.

Antonioli, F., Anzidei, M., Lambeck, K., Auriemma, R., Gaddi, D., Furlani, S., Orrù, P., Solinas, E., Gaspari, A., Karinja, S., Kova, V., Surace, L., 2007. Sea-level change during the Holocene in Sardinia and in the northeastern Adriatic (central Mediterranean Sea) from archaeological and geomorphological data. Quat. Sci. Rev. 26, 2463–2486.

Antonioli, F., Ferranti, L., Fontana, A., Amorosi, A., Bondesan, A., Braitenberg, C., Dutton, A., Fontolan, G., Furlani, S., Lambeck, K., Mastronuzzi, G., Monaco, C., Spada, G., Stocchi, P., 2009. Holocene relative sea-level changes and vertical movements along the Italian and Istrian coastlines. Quat. Int. 221, 37–51.

Antonioli, F., Lo Presti, V., Morticelli, M., Bonfiglio, L., Mannino, M., Palombo, M.R., Sannino, G.M., Ferranti, L., Furlani, S., Lambeck, K., Canese, S., Catalano, R., Chiocci, F., Mangano, G., Scicchitano, G., Tonielli, S., 2014. Timing of the emergence of the Europe-Sicily bridge (40–17 ka cal BP) and its implications for the spread of modern humans 2014. In: Harff, J., Bailey, G., Lüth, F. (Eds.), Geology and Archaeology: Submerged Landscapes of the Continental Shelf, vol. 411. Geological Society London Spec. Publ., pp. 111–144

Antonioli, F., Lo Presti, V., Rovere, A., Ferranti, L., Anzidei, M., Furlani, S., Mastronuzzi, G., Orru, P.E., Scicchitano, G., Sannino, G., Spampinato, C.R., Pagliarulo, R., Deiana, G., de Sabata, E., Sansò, P., Vacchi, M., Vecchio, A., 2015. Tidal notches in Mediterranean Sea: a comprehensive analysis. Quat. Sci. Rev. 119, 66–84.

Antonioli, F., Lo Presti, V., Rovere, A., Ferranti, L., Anzidei, M., Furlani, S., Mastronuzzi, G., Orrù, P.E., Scicchitano, G., Sannino, G., Spampinato, C.R., 2016. Reply to comment by Evelpidu N., and Pirazzoli P. on "Tidal notches in the Mediterranean sea: a comprehensive analysis". Quat. Sci. Rev. 131, 238–241.

Antonioli, F., Anzidei, M., Amorosi, A., Lo Presti, V., Mastronuzzi, G., Deiana, G., De Falco, G., Fontana, A., Fontolan, G., Lisco, S., Marsico, A., Moretti, M., Orrù, P.E., Sannino, G.M., Serpelloni, E., Vecchio, A., 2017a. Sea-level rise and potential drowning of the Italian coastal plains: flooding risk scenarios for 2100. Quat. Sci. Rev. 158, 29–43. http://dx.doi.org/10.1016/j.quascirev.2016.12.021.

Antonioli, F., Anzidei, M., Amorosi, A., Presti, A., Mastronuzzi, G., Deiana, G., De Falco, G., Fontana, A., Fontolan, G., Lisco, S., Marsico, A., 2017b. Sea-level rise and potential drowning of the Italian coastal plains: flooding risk scenarios for 2100. Quat. Sci Rev 158, 29–43.

Anzidei, M., Antonioli, F., Benini, A., Lambeck, K., Sivan, D., Serpelloni, E., Stocchi, P., 2011a. Sea-level change and vertical land movements since the last two millennia along the coasts of southwestern Turkey and Israel. Quat. Int. 232, 13–20.

Anzidei, M., Antonioli, F., Lamback, K., Benini, A., Sussi, M., Lakhdar, R., 2011b. New insights on relative sea-level changes during Holocene along the coasts of Tunisia and western Libya from archaeological and geomorphological markers. Quat. Int. 232, 5–11.

Anzidei, M., Lambeck, K., Antonioli, F., Furlani, S., Mastronuzzi, G., Serpelloni, E., Vannucci, G., 2014b. Coastal structure, sea-level changes and vertical motion of the land in the Mediterranean. Geol. Soc. Lond. Spec. Publ. 388 http://dx.doi.org/10.1144/SP388.20.

Anzidei, M., Esposito, A., Benini, A., 2014a. Evidence of active subsidence at Basiluzzo island (Aeolian islands, southern Italy) inferred from a Roman age wharf. Quat. Int. 332, 143–150. http://dx.doi.org/10.1016/j.quaint.2014.03.019.

Anzidei, M., Bosman, A., Casalbore, D., Tusa, S., La Rocca, R., 2016a. New insights on the subsidence of Lipari island (Aeolian islands, southern Italy) from the submerged Roman age pier at Marina Lunga. Quat. Int. 401, 162–173.

Anzidei, M., Bosman, A., Carluccio, R., Casalbore, D., D'Ajello Caracciolo, F., Esposito, A., Nicolosi, I., Pietrantonio, G., Vecchio, A., Carmisciano, C., Chiappini, M., Chiocci, F.L., Muccini, F., Sepe, V., 2016b. Flooding scenarios in coastal volcanic areas due to land subsidence and sea level rise: a case study for Lipari Island (Italy). Terra Nova 29 (No. 1), 44–51. http://dx.doi.org/10.1111/ter.12246.

Asioli, A., Capotondi, L., Cita Sironi, M.B., 2005. The Tyrrhenian stage in the Mediterranean: definition, usage and recognition in the deep-sea record. A proposal. Rendiconti Lincei 16 (4), 297–310.

Aucelli, P., Cinque, A., Mattei, G., Pappone, G., 2017. Historical sea level changes and effects on the coasts of Sorrento Peninsula (Gulf of Naples): new constrains from recent geoarchaeological investigations. Palaeogeogr. Palaeoclimatol., Palaeoecol. 463, 112–125.

Auriemma, R., Solinas, E., 2009. Archaeological remains as sea-level change markers: a review. Quat. Int. 206, 134–146.

Bailey, G.N., Flemming, N., 2008. Archaeology of the continental shelf: marine resources, submerged landscapes and underwater archaeology. Quat. Sci. Rev. 27, 2153–2165.

Bailey, G.N., Milner, N., 2002. Coastal hunter-gatherers and social evolution: marginal or central? Before Farming 4 (1), 1–15.

Bailey, G.N., Carrion, J., Fa, D., Finlayson, C., Finlayson, G., Rodriguezvidal, J., 2008. The coastal shelf of the Mediterranean and beyond: Corridor and refugium for human populations in the Pleistocene. Quat. Sci. Rev. 27, 2095–2099.

Bailey, G.N., Devès, M.H., Inglis, R.H., Meredith-Williams, M.G., Momber, G., Sakellariou, D., Sinclair, A., Rousakis, G., Al Ghamdi, S., Alsharekh, A.M., 2015. Blue Arabia: Palaeolithic and underwater survey in SW Saudi Arabia and the role of coasts in Pleistocene dispersals. Quat. Int. 382, 42–57.

Bard, E., Hamelin, B., Arnold, M., Montaggioni, L.F., Cabioch, G., Faure, G., Rougerie, F., 1996. Deglacial sea-level record from Tahiti corals and the timing of global meltwater discharge. Nature 382, 241–244.

Bard, E., Hamelin, B., Delanghe-Sebatier, D., 2010. Deglacial meltwater pulse 1B and Younger Dryas sea-levels revisited with boreholes at Tahiti. Science 327, 1235–1237.

Barker, G., Antoniadou, A., Armitage, S., Brooks, I., Candy, I., Connell, K., et al., 2010. The Cyrenaican Prehistory Project 2010: the fourth season of investigations of the Haua Fteah cave and its landscape, and further results from the 2007–2009 fieldwork. Libyan Stud. 41, 63–88.

Barker, G., Bennett, P., Farr, L., Hill, E., Hunt, C., Lucarini, G., et al., 2012. The Cyrenaican prehistory project 2012: the fifth season of investigations at the Haua Fteah cave. Libyan Stud. 43, 115–136.

Barnett, R.L., Newton, T.L., Charman, D.J., Gehrels, W.R., 2017. Salt-marsh testate amoebae as precise and widespread indicators of sea-level change. Earth Sci. Rev. 164, 193–207.

Barton, R.N.E., Bouzouggar, A., Bronk-Ramsey, C., Collcutt, S., Higham, T.F.G., Humphrey, L.T., et al., 2007. Abrupt climatic change and chronology of the upper Palaeolithic in Northern and Eastern Morocco. In: Mellars, P., Boyle, K., Bar-Yosef, O., Stringer, C. (Eds.), Rethinking the Human Revolution. McDonald Institute, Cambridge, pp. 177–186.

Bar-Yosef, O., 2002. The upper Paleolithic revolution. Annu. Rev. Anthropol. 31, 363–393.

Bar-Yosef Mayer, D.E., Vandermeersch, B., Bar-Yosef, O., 2009. Shells and ochre in middle Paleolithic Qafzeh Cave, Israel: indications for modern behavior. J. Hum. Evol. 56 (3), 307–314.

Bass, G.F., Pulak, C., Collon, D., Weinstein, J., 1984. The Bronze age Shipwreck at Ulu Burun: 1986 Campaign. Am. J. Archaeol. 93, 1–29.

Belmaker, M., Hovers, E., 2011. Ecological change and the extinction of the Levantine Neanderthals: implications from a diachronic study of micromammals from Amud Cave, Israel. Quat. Sci. Rev. 30, 3196–3209.

Benazzi, S., Douka, K., Fornai, C., Bauer, C.C., Kullmer, O., Svoboda, J., et al., 2011. Early dispersal of modern humans in Europe and implications for Neanderthal behaviour. Nature 479, 525–528.

Benjamin, J., 2010. Submerged prehistoric landscapes and underwater site discovery: reevaluating the "Danish model" for international practice. J. Isl. Coast. Archaeol. 5 (2), 253–270.

Benjamin, J., Bonsall, C., 2009. A feasibility study for the investigation of submerged sites along the Coast of Slovenia. Int. J. Naut. Archaeol. 38 (1), 163–172.

Benjamin, J., Bekić, L., Komšo, D., Uhač, I.K., Bonsall, C., 2011. Investigating the submerged prehistory of the Eastern Adriatic: progress and prospects. In: Benjamin, J., Bonsall, C., Pickard, C., Fisher, A. (Eds.), Submerged Prehistory. Oxbow, Oxford, pp. 193–206.

Berger, A., Crucifix, M., Hodell, D.A., Mangili, C., McManus, J.F., Otto-Bliesner, B., Pol, K., Raynaud, D., Skinner, L.C., Tzedakis, P.C., Wolff, E.W., Yin, Q.Z., Abe-Ouchi, A., Barbante, C., Brovkin, V., Cacho, I., Capron, E., Ferretti, P., Ganopolski, A., Grimalt, J.O., Honisch, N., 2015. Interglacials of the last 800,000 years. Rev. Geophys. 54, 162–219. http://dx.doi.org/10.1002/2015RG000482.Received.

Blackman, D.J., 1973. Evidence of sea-level change in ancient harbours and coastal installations. In: Blackman, B.J. (Ed.), Marine Archaeology. Butterworth, London, pp. 115–138.

Blanc, G.A., 1920. Grotta Romanelli. I. Stratigrafia dei depositi e natura e origine di essi. Arch. l'Antropol. l'Etnol. 50, 1–39.

Bocquet-Appel, J.-P., 2011. When the world's population took off. Science 333, 560–561.

Bonifay, E., Mars, P., 1959. Le Tyrrhénien dans le cadre de la chronologie quaternaire méditerranéenne. Bulletin Societe Geologique Francaise. Series 7 (1), 62–78.

Boulton, S.J., Stewart, I.S., 2013. Holocene coastal notches in the Mediterranean region: indicators of palaeoseismic clustering? Geomorphology 237, 29–37.

Bourne, A., Lowe, J.J., Trincardi, F., Asioli, A., Blockley, S.P.E., Wulf, S., Matthews, I.P., Piva, A., Vigliotti, L., 2010. Distal tephra record for the last ca 105,000 years from core PRAD 1-2 in the central Adriatic Sea: implications for marine tephrostratigraphy. Quat. Sci. Rev. 29 (23–24), 3079–3094.

Bouzouggar, A., Barton, R.N.E., Vanhaeren, M., Collcutt, S., Higham, T., Hodge, E., et al., 2007. 82,000-year-old shell beads from North Africa and implications for the origins of modern human behavior. Proc. Natl. Acad. Sci. U. S. A. 104, 9964–9969.

Brocas, W.M., Felis, T., Obert, J.C., Gierz, P., Lohmann, G., Scholz, D., Kölling, M., Scheffers, S.R., 2016. Last interglacial temperature seasonality reconstructed from tropical Atlantic corals. Earth Planet. Sci. Lett. 449, 418–429.

Broodbank, C., 2006. The origins and early development of Mediterranean maritime activity. J. Mediterr. Archaeol. 19 (2), 199–230.

Broodbank, C., 2013. The Making of the Middle Sea. Oxford University Press, Oxford, 672.

Brown, K., Fa, D.A., Finlayson, G., Finlayson, C., 2011. Small game and marine resource exploitation by Neanderthals: the evidence from Gibraltar. In: Bicho, N.F., Haws, J.A., Davis, L.G. (Eds.), Trekking the Shore: Changing Coastlines and the Antiquity of Coastal Settlement. Springer, New York, pp. 247–272.

Brückner, H., Müllenhoff, M., Gehrels, R., Herda, A., Knipping, M., Vött, A., 2006. From archipelago to floodplain-geographical and ecological changes in Miletus and its environs during the past six millennia (Western Anatolia, Turkey). Z. für Geomorphol. N. F. 142, 63–83.

Budja, M., 2009. Early Neolithic pottery dispersals and demic diffusion in Southeastern Europe. Doc. Praehist. 36 (1), 117–137.

Cabioch, G., Banks-Cutler, K.A., Beck, W.J., Burr, G.S., Corrège, T., Edwards, R.L., Taylor, F.W. , 2003. Continuous reef growth during the last 23 cal kyr BP in a tectonically active zone (Vanuatu, South West Pacific). Quat. Sci. Rev. 22, 1771–1786.

Cacho, I., Grimalt, J.O., Pelejero, C., Canals, M., Sierro, F.J., Flores, J.A., Shackleton, N.J., 1999. Dansgaard-Oeschger and Heinrich events imprints in the Alboran Sea paleotemperatures. Paleoceanography 14, 698–705.

Campbell, P., 2017. The Archaeology of Underwater Caves. Highfield Press, Southampton (in press). doi: 9780992633677.

Carlson, A.E., LeGrande, A.N., Oppo, D.W., Came, R.E., Schmidt, G.A., Anslow, F.S., Licciardi, J.M., Obbink, E.A., 2008. Rapid early Holocene deglaciation of the Laurentide Ice sheet. Nat. Geosci. 1, 620–624.

Cattaneo, A., Trincardi, F., 1999. The Late-Quaternary transgressive record in the Adriatic epicontinental sea: basin widening and facies partitioning. In: Bergman, K.M., Snedden, J.W. (Eds.), Isolated Shallow Marine Sand Bodies: Sequence Stratigraphic Analysis and Sedimentologic Interpretation, 64. SEPM Special Publication, pp. 127–146.

Caruso, A., Cosentino, C., Pierre, C., Sulli, A., 2011. Sea-level change during the last 41 ka in the other shelf of southern Tyrrhenian sea. Quat. Int. 232, 137–149.

Chiocci, F.L., Ercilla, G., Torres, J., 1997. Stratal architecture of Western Mediterranean Margins as the result of the stacking of Quaternary lowstand deposits below glacio-eustatic fluctuation base-level. Sediment. Geol. 112, 195–217.

Clark, P.U., Dyke, A.S., Shakun, J.D., Carlson, A.E., Clark, J., Wohlfarth, B., Mitrovica, J.X., Hostetler, S.W., McCabe, A.M., 2009. The last glacial maximum. Science 324, 720–714.

Clark, P.U., Mitrovica, J.X., Milne, G.A., Turon, J.L., Siani, G., 2002. Sea-level fingerprint as a direct test for the source of global Meltwater Pulse 1A. Science 295, 2438–2441.

Clark, P.U., Marshall McCabe, A., Mix, A.C., Weaver, A.J., 2004. Rapid rise of sea-level 19000 years ago and its Global implications. Science 304, 1141–1144.

Cliquet, D., Coutard, S., Clet, M., Allix, J., Tessier, B., Lelong, F., Baltzer, A., Mear, Y., Poizot, E., Auguste, P., Alix, P., Olive, J., Guesnon, J., 2011. The middle Palaeolithic underwater site of La Mondrée, Normandy, France. In: Benjamin, J., Bonsall, C., Pickard, C., Fisher, A. (Eds.), Submerged Prehistory. Oxbow, Oxford, pp. 111–128.

Columella, (L. Iunius Moderatus, 4 A.D. - c. 70 A.D.). De Re Rustica, Liber Octavus, In latin. Available at: http://www.thelatinlibrary.com/columella.html.

Colonese, A.C., Mannino, M.A., Bar-Yosef Mayer, D.E., Fa, D.A., Finlayson, J.C., Lubell, D., 2011. Marine mollusc exploitation in Mediterranean prehistory: an overview. Quat. Int. 239 (1–2), 86–103.

Correggiari, A., Roveri, M., Trincardi, F., 1996. Late Pleistocene and holocene evolution of the North Adriatic Sea. Il Quat. Italian J. Quat. Sci. 9, 697–704.

Cortés-Sánchez, M., Morales-Muñiz, A., Simón-Vallejo, M.D., Lozano-Francisco, M.C., Vera-Peláez, J.L., Finlayson, C., Martínez-Aguirre, M.A., 2011. Earliest known use of marine resources by Neanderthals. PloS One 6 (9), e24026.

Cramp, A., O'Sullivan, G., 1999. Neogene sapropels in the Mediterranean: a review. Mar. Geol. 153, 11–28.

Creveling, J.R., Mitrovica, J.X., Clark, P.U., Waelbroeck, C., Pico, T., 2017. Predicted bounds on peak global mean sea level during marine isotope stages 5a and 5c. Quat. Sci. Rev. 163, 193–208.

Creveling, J.R., Mitrovica, J.X., Hay, C.C., Austermann, J., Kopp, R.E., 2015. Revisiting tectonic corrections applied to Pleistocene sea-level highstands. Quat. Sci. Rev. 111, 72–80.

Cutler, K.B., Edwards, R.L., Taylor, F.W., Cheng, H., Adkins, J., Gallup, C.D., Cutler, P.M., Burr, G.S., Bloom, A.L., 2003. Rapid sea-level fall and deep-ocean temperature change since the last interglacial period. Earth Planet. Sci. Lett. 206, 253–271.

D'Errico, F., Vanhaeren, M., Barton, N., Bouzouggar, A., Mienis, H., Richter, D., et al., 2009. Out of Africa: modern human origins special feature: additional evidence on the use of personal ornaments in the Middle Paleolithic of North Africa. Proceding Natl. Acad. Sci. U. S. A. 106 (38), 16051–16056.

Darlas, A., 2007. Le Moustérien de Grèce à la lumière des récentes recherches. L'Anthropologie 111, 346–366.

Davies, S.M., Abbott, P.M., Pearce, N.J.G., Wastegård, S., Blockley, S.P.E., 2012. Integrating the INTIMATE records using tephrochronology: rising to the challenge. Quat. Sci. Rev. 36, 11–27.

De Marchi, L., 1922. Variazioni del livello dell'Adriatico in corrispondenza con le espansioni Glaciali. Atti Accad. Sci. Veneto-Trentino-Istriana XII–XIII, 1–15.

De Vivo, B., Rolandi, G., Gans, P.B., Calvert, A., Bohrson, W.A., 2001. New constraints on the pyroclastic eruptive history of the Campanian volcanic Plain (Italy). Mineral. Petrol. 73, 47–65.

Deschamps, P., Durand, N., Bard, E., Hamelin, B., Camoin, G., Thomas, A.L., Henderson, G.M., Okuno, J., Yokoyama, Y., 2012. Ice-sheet collapse and sea-level rise at the Bølling warming 14,600 years ago. Nature 483, 559–564.

Desruelles, S., Fouache, É., Ciner, A., Dalongeville, R., Pavlopoulos, K., Kosun, E., Potdevin, J.L., 2009. Beachrocks and sea level changes since Middle Holocene: comparison between the insular group of Mykonos–Delos–Rhenia (Cyclades, Greece) and the southern coast of Turkey. Glob. Planet. Change 66 (1), 19–33.

Dey, H.W., Goodman-Tchernov, B., 2010. Mediterranean tsunamis and the port of Caesarea Maritima over the Longue Durée: a geoarchaeological perspective. J. Roman Archaeol. 23, 265–284.

Dorale, J.P., Onac, B.P., Fornós, J., Ginés, J., Ginés, A., Tuccimei, P., Peate, D.W., 2010. Sea-level highstand 81,000 years ago in Mallorca. Science 327, 860–863.

Douka, K., Spinapolice, E.E., 2012. Neanderthal shell tool production: evidence from middle Palaeolithic Italy and Greece. J. World Prehistory 25, 45–79.

Douka, K., Grün, R., Jacobs, Z., Lane, C., Farr, L., Hunt, C., et al., 2014. Redating the Haua Fteah cave (Cyrenaica, northeast Libya) and its implications for North African prehistory. J. Hum. Evol. 66, 39–63.

Dreghorn, W., 1981. Recent uplift in northern Cyprus. Geol. Mijnb. 60, 281–284.

Drinia, H., Antonarakou, A., Anastasakis, G., 2014. Late Quaternary micropalaeontological record of a semi-enclosed marine basin, North Evoikos, central Aegean Sea. Quat. Int. 345, 18–31.

Dutton, A., Bard, E., Antonioli, F., Esat, T.M., Lambeck, K., McCulloch, M.T., 2009. Phasing and amplitude of sea-level and climate change during the penultimate interglacial. Nat. Geosci. 2 (5), 355–359.

Dutton, A., Carlson, A.E., Long, A.J., Milne, G.A., Clark, P.U., DeConto, R., Horton, B.P., Rahmstorf, S., Raymo, M.E., 2015. Sea-level rise due to polar ice-sheet mass loss during past warm periods. Science 349, 4019.

Dutton, A., Lambeck, K., 2012. Ice volume and sea-level during the last interglacial. Science 337, 216–219.

Edwards, R.L., Beck, J.W., Burr, G.S., Donahue, D.J., Chappell, J.M.A., Bloom, A.L., Druffel, E.R.M., Taylor, F.W., 1993. A large drop in atmospheric ^{14}C/^{12}C and reduced melting in the Younger Dryas, documented with ^{230}Th ages of corals. Science 260, 962–968.

Edwards, R.J., Horton, B.P., 2000. Reconstructing relative sea-level change using UK salt-marsh foraminifera. Mar. Geol. 169, 41–56.

Edwards, R.L., 2006. Sea-levels: change and variability during warm intervals. Prog. Phys. Geogr. 30, 785–796.

Erlandson, J.M., 2001. The archaeology of aquatic adaptations: Paradigms for a new millennium. J. Archaeol. Res. 9 (4), 287–350.

Evelpidou, N., Kampolis, I., Pirazzoli, P.A., Vassilopoulos, A., 2012a. Global sea-level rise and the disappearance of tidal notches. Glob. Planet. Change 92, 248–256.

Evelpidou, N., Pirazzoli, P., Vassilopoulos, A., Spada, G., Ruggieri, G., Tomasin, A., 2012b. Late Holocene sea-level reconstructions based on observations of Roman fish tanks, Tyrrhenian coast of Italy. Geoarchaeology 27, 259–277.

Evelpidou, N., Pirazzoli, P., 2015. Comment on «Tidal notches in the Mediterranean Sea: a comprehensive analysis» by Fabrizio Antonioli, Valeria Lo Presti, Alessio Rovere, Luigi Ferranti, Marco Anzidei, Stefano Furlani, Giuseppe Mastronuzzi, Paolo E. Orru, Giovanni Scicchitano, Gianmaria Sannino, Cecilia R. Spampinato, Rossella Pagliarulo, Giacomo Deiana, Eleonora de Sabata, Paolo Sansò, Matteo Vacchi and Antonio Vecchio. Quaternary Science Reviews 119 (2015) 66–84. Quat. Sci. Rev. 131, 237–238.

Fagan, B., 2013. The Attacking Ocean. Bloomsbury Press, New York, p. 288.

Fairbanks, R.G., 1989. A 17.000-yr glacio-eustatic sea-level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. Nature 342, 637–642.

Faivre, S., Bakran-Petricioli, T., Horvatinčić, N., Sironić, A., 2013. Distinct phases of relative sea level changes in the central Adriatic during the last 1500 years-influence of climatic variations? Palaeogeogr. Palaeoclimatol. Palaeoecol. 369, 163–174.

Fedele, F.G., Giaccio, B., Hajdas, I., 2008. Timescales and cultural process at 40,000 BP in the light of the Campanian Ignimbrite eruption, Western Eurasia. J. Hum. Evol. 55, 834–857.

Ferentinos, G., Gkioni, M., Geraga, M., Papatheodorou, G., 2012. Early seafaring activity in the southern Ionian Islands, Mediterranean Sea. J. Archaeol. Sci. 39 (7), 2167–2176.

Ferranti, L., Antonioli, F., Mauz, B., Amorosi, A., Dai Para, G., Mastronuzzi, G., 2006. Markers of the last interglacial sea-level highstand along the coast of Italy: tectonic implications. Quat. Int. 145–146, 54–30.

Finlayson, C., 2008. On the importance of coastal areas in the survival of Neanderthal populations during the Late Pleistocene. Quat. Sci. Rev. 27, 2246–2252.

Finlayson, C., Pacheco, F.G., Rodriguez-Vidal, J., Fa, D.A., Gutierrez Lopez, J.M., Santiago Perez, A., et al., 2006. Late survival of Neanderthals at the southernmost extreme of Europe. Nature 443 (7113), 850–853.

Fischer, A. (Ed.), 1995. Man and Sea in the Mesolithic. Oxbow, Oxford, p. 440.

Fitzpatrick, S.M., Rick, T.C., Erlandson, J.M., 2015. Recent progress, trends, and developments in island and coastal archaeology. J. Isl. Coast. Archaeol. 10, 1–25.

Flemming, N.C., 1969. Archaeological evidence for eustatic changes of sea-level and earth movement in the western Mediterranean in the last 2000 years. Special Pap. Geol. Soc. Am. 109, 1–98.

Flemming, N.C., 1978. Holocene eustatic changes and coastal tectonics in the northeast Mediterranean? Implications for model of crustal consumption. Philos. Trans. R. Soc. Lon. Ser. A Math. Phys. Sci. 289, 405–458.

Flemming, N., Bailey, G.N., Sakellariou, D., 2012. Migration: value of submerged early human sites. Nature 486, 34.

Flemming, N.C., Çağatay, M.N., Chiocci, F.L., et al., 2014. Land beneath the waves: submerged landscapes and sea level change. A joint geoscience-humanities research strategy for European Continental Shelf Prehistoric Research. In: Chu, N.-C., McDonough, N. (Eds.), Position Paper 21 of the European Marine Board. Ostend, Belgium.

Florido, E., Auriemma, R., Faivre, S., Radic Rossi, I., Antonioli, F., Furlani, S., 2011. Istrian and Dalmatian fishtanks as sea level markers. Quat. Int. 232, 105–113.

Fontana, A., Mozzi, P., Marchetti, M., 2014. Alluvial fans and megafans along the southern side of the Alps. Sediment. Geol. 301, 150–171.

Fontana, A., Vinci, G., Tasca, G., Mozzi, P., Vacchi, M., Bivi, G., Salvador, S., Rossato, S., Antonioli, F., Asioli, A., Bresolin, M., Di Mario, F., Hajdas, I., 2017. Lagoon settlements and relative sea level during Bronze Age in Northern Adriatic: geoarchaeological evidence and paleogeographic constraints. Quat. Int. (439), 17–36.

Forenbaher, S., Miracle, P., 2005. The spread of farming in the Eastern Adriatic. Antiquity 79, 514–528.

Furlani, S., Ninfo, A., Zavagno, E., Paganini, P., Zini, L., Biolchi, S., Antonioli, F., Coren, F., Cucchi, F., 2014a. Submerged notches in Istria and the Gulf of Trieste: results from the Geoswim project. Quat. Int. 332, 37–47.

Furlani, S., Pappalardo, M., Gomez-Pujol, L., Chelli, A., 2014b. The rock coasts of the Mediterranean and Black Seas. In: Kennedy, D.M., Stepheenson, W.J., Naylor, L.A. (Eds.), Rock Coast Geomorphology: a Global Synthesis, vol. 40. Geological Society, London Memoirs, pp. 89–123.

Galili, E., Weinstein-Evron, M., 1985. Prehistory and Paleoenvironments of submerged sites along the Carmel Coast of Israel. Paléorient 11 (1), 37–52.

Galili, E., Nir, Y., 1993. The Submerged Pre-Pottery Neolithic water well of Atlit Yam, northern Israel, and its palaeoenvironmental implications. The Holocene 3, 265–270.

Galili, E., Weinstein-Evron, M., Ronen, A., 1988. Holocene sea-level changes based on submerged archaeological sites off the Northern Carmel Coast in Israel. Quat. Res. 29, 36–42.

Galili, E., Weinstein-Evron, M., Hershkovitz, I., Gopher, A., Kislev, M., Lernau, O., Kolska Horowitz, L., Lernau, H., 1993. Atlit Yam: a prehistoric site on the sea floor off the Israeli Coast. J. Field Archaeol. 20, 133–156.

Galili, E., Sharvit, J., 1998. Ancient coastal installations and the tectonic stability of the Israeli coast in historical times. In: Stewart, I.S., Vita-Finzi, C. (Eds.), Coastal Tectonics, Geological Society, vol. 146. Special Publications, London, pp. 147–163.

Galili, E., Zviely, D., Weinstein-Evron, M., 2005. Holocene sea-level changes and landscape evolution on the northern Carmel coast (Israel). Mediterranée 1 (2), 1–8.

Galili, E., Zviely, D., Ronen, A., Mienis, H.K., 2007. Beach deposits of MIS 5e high sea stand as indicators for tectonic stability of the Carmel coastal plain, Israel. Quat. Sci. Rev. 26 (19–21), 2544–2557.

Galili, E., Ronen, A., Mienis, H.K., Horwitz, L.K., 2017. Beach deposits containing Middle Paleolithic archaeological remains from northern Israel. Quat. Int. (in press).

Galili, E., Rosen, B., 2011. Submerged Neolithic settlements off the Mediterranean coast of Israel. In: Benjamin, J., Bonsall, C., Pickard, C., Fisher, A. (Eds.), Submerged Prehistory. Oxbow, Oxford, pp. 272–286.

Galili, E., Sevketoglu, M., Salamon, A., Zviely, D., Mienis, H.K., Rosen, B., Moshkovitz, S., 2015. Late Quaternary morphology, beach deposits, sea-level changes and uplift along the coast of Cyprus and its possible implications on the early colonists. In: Harff, J., Bailey, G., Lüth, F. (Eds.), Geology and Archaeology: Submerged Landscapes of the Continental Shelf. Geological Society, London. Special Publications 411.

Galili, E., 2017. Prehistoric archaeology on the continental shelf: a global review. J Island Coastal Archaeol. 12 (1), 147–149. http://dx.doi.org/10.1080/15564894.2016.1225323.

Garašić, M., 2006. Found and documented deepest speleothems in the sea (in Croatian). Spelaeol. Croata 7, 58.

Garcea, E.A.A., 2012. Successes and failures of human dispersals from North Africa. Quat. Int. 270, 110–128.

Gehrels, W.R., 2010a. Late Holocene relative sea-level changes and crustal motion around the British Isles: implications for future sea-level predictions. Quat. Sci. Rev. 29, 1648–1660.

Gehrels, W.R., 2010b. Sea-level changes since the last glacial maximum: an appraisal of the IPCC fourth assessment report. J. Quat. Sci. 25, 26–38.

Gehrels, W.R., Dawson, D.A., Shaw, J., Marshall, W.A., 2011. Using Holocene relative sea-level data to inform future sea-level predictions: an example from Southwest England. Glob. Planet. Change 78, 116–126.

Gehrels, W.R., 1994. Determining relative sea-level change from salt-marsh foraminifera and plant zones on the Coast of Maine, U.S.A. J. Coast. Res. 10, 990–1009.

Gignoux, M., 1913. Les formations marines pliocenes et quaternaires de l'Italie du sud et de la Sicilie. Ann. l'Univ. Lyon 36, 693.

Goiran, J.P., Tronchere, H., Collalelli, U., Salomon, F., Djerbi, H., 2009. Decouverte d'un niveau marin biologique sur les quais de Portus: le port antique de Rome. Mediterranee 1, 59–67.

Goiran, J.P., Tronchere, H., Salomon, F., Carbonel, P., Djerbi, H., Ognard, C., 2010. Palaeoenvironmental reconstruction of the ancient habours of Rome: Claudius and Trajan's marine habours on the Tiber delta. Quat. Int. 216, 3–13.

Goodman, B., Reinhardt, E., Dey, H., Boyce, J., Schwarcz, H., Sahoglu, V., Erkanal, H., Artzy, M., 2008. Evidence for holocene marine transgression and shoreline progradation due to barrier development in Iskele, bay of Izmir, Turkey. J. Coast. Res. 245, 1269–1280.

Goodman-Tchernov, B.N., Dey, H.W., Reinhardt, E.G., McCoy, F., Mart, Y., 2009a. Tsunami waves generated by the Santorini eruption reached Eastern Mediterranean shores. Geology 37, 943–946.

Goodman-Tchernov, B.N., Reinhardt, E.G., Dey, H.W., Boyce, J.I., Schwarcz, H.P., Sahoğlu, V., Erkanal, H., Artzy, M., 2009b. Multi-proxy geoarchaeological study redefines understanding of the paleocoastlines and ancient harbours of Liman Tepe (Iskele, Turkey). Terra Nova 21, 97–104.

Goodman-Tchernov, B.N., Austin, J.A., 2015. Deterioration of Israel's Caesarea Maritima's ancient harbor linked to repeated tsunami events identified in geophysical mapping of offshore stratigraphy. J. Archaeol. Sci. Rep. 3, 444–454.

Goodman-Tchernov, B., Katz, O., 2016. Holocene-era submerged notches along the southern Levantine coastline: punctuated sea-level rise? Quat. Int. 401, 1–11.

Grant, K.M., Rohling, E.J., Bar-Matthews, M., Ayalon, A., Medina-Elizalde, M., Bronk Ramsey, C., Satow, C., Roberts, A.P., 2012. Rapid coupling between ice volume and polar temperature over the past 150 kyr. Nature 491, 744–747.

Grant, K.M., Rohling, E.J., Ramsey, C.B., Cheng, H., Edwards, R.L., Florindo, F., Heslop, D., Marra, F., Roberts, A.P., Tamisiea, M.E., Williams, F., 2014. Sea-level variability over five glacial cycles. Nat. Commun. 5, 5076.

Grant, K.M., Grimm, R., Mikolajewicz, U., Marino, G., Ziegler, M., Rohling, E.J., 2016. The timing of Mediterranean sapropel deposition relative to insolation, sea-level and African monsoon changes. Quat. Sci. Rev. 140, 125–141.

Grün, R., Stringer, C., 1991. Electron spin resonance dating and the evolution of modern humans. Archaeometry 33 (2), 153–199.

Grün, R., Stringer, C., McDermitt, F., Nathan, R., Porat, N., Robertson, S., Taylor, L., Mortiner, G.E., Eggins, S., McCulloch, M., 2005. U-series and ESR analyses of bones and teeth relating to the human burials from Skhul. J. Hum. Evol. 49 (3), 316–334.

Gzam, M., Noureddine, El M., Younes, J., 2016. Late quaternary sea-level changes of Gabes coastal plain and shelf: identification of the MIS 5c and MIS 5a onshore highstands, southern Mediterranean. J. Earth Syst. Sci. 125, 13–28.

Haak, W., Balanovsky, O., Sanchez, J.J., Koshel, S., Zaporozhchenko, V., Adler, C.J., Cooper, A., 2010. Ancient DNA from European early Neolithic farmers reveals their near eastern affinities. PLoS Biol. 8 (11), e1000536.

Hardy, B.L., Moncel, M.H., 2011. Neanderthal use of fish, mammals, birds, starchy plants and wood 125–250,000 Years ago. PLoS One 6 (8), e23768.

Hearty, P.J., 1986. An inventory of last interglacial (sensu lato) age deposits from the Mediterranea Basin: a study of Isoleucine Epimerizationet U-Series dating. Z. Geomorphol. 62, 51–69 (Suppl. –Bd).

Hearty, P.J., Hollin, J.T., Neumann, A.C., O'leary, M.J., McCulloch, M., O'Leary, M.J., 2007. Global sea-level fluctuations during the Last Interglaciation (MIS 5e). Quat. Sci. Rev. 26, 2090–2112.

Hemming, S.R., 2004. Heinrich events: massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint. Rev. Geophys. 42 (1).

Henderson, J.C., Gallou, C., Flemming, N.C., Spondylis, E., 2011. The Pavlopetri Underwater Archaeology Project: investigating an ancient submerged town. In: Benjamin, J., Bonsall, C., Pickard, C., Fisher, A. (Eds.), Submerged Prehistory. Oxbow, Oxford, 17.

Hershkovitz, I., Galili, E., 1990. 8000 Year-old human remains on the sea floor near Atlit, Israel. J. Hum. Evol. 5 (4), 319–358.

Hershkovitz, I., Marder, O., Ayalon, A., Bar-Matthews, M., Yasur, G., Boaretto, E., et al., 2015. Levantine cranium from Manot Cave (Israel) foreshadows the first European modern humans. Nature 520, 216–219.

Hibbert, F.D., Rohling, E.J., Dutton, A., Williams, F.H., Chutcharavan, P.M., Zhao, C., Tamisiea, M.E., 2016. Coral indicators of past sea-level change: a global repository of U-series dated benchmarks. Quat. Sci. Rev. 145, 1–56.

Higham, T., Douka, K., Wood, R., Ramsey, C.B., Brock, F., Basell, L., et al., 2014. The timing and spatiotemporal patterning of Neanderthal disappearance. Nature 512, 306–309.

Hiscock, P., 2008. Archaeology of Ancient Australia. Routledge, London, 330.

Hopley, D., 1986. In: Plassche, O.V.D. (Ed.), Beachrock as a Sea-level Indicator. Sea-level Research, Amsterdam, pp. 157–173.

Hughes, P.D., Gibbard, P.L., Ehlers, J., 2013. Timing of glaciation during the last glacial cycle: evaluating the meaning and significance of the 'Last Glacial Maximum' (LGM). Earth Sci. Rev. 125, 171–198.

Imbrie, J., Hays, J.D., Martinson, D.G., McIntyre, A., Mix, A.C., Morley, J.J., Pisias, N.G., Prell, W.L., Shackleton, N.J., 1984. The orbital theory of Pleistocene climate: support from a revised chronology of the marine d^{18}O record. In: Berger, A.L., et al. (Eds.), Milankovitch and Climate. Part 1. D. Reidel, Dordrecht, Netherlands, pp. 269–305.

Issel, A., 1914. Lembi fossiliferi quaternari e recenti nella Sardegna meridionale. Accad. Naz. dei Lincei 23, 759–770 ser. 5.

Jedoui, Y., Reyss, J.L., Kallel, N., Montacer, M., Ismaı̈l, H.B., Davaud, E., 2003. U-series evidence for two high Last Interglacial sea levels in southeastern Tunisia. Quat. Sci. Rev. 22 (2), 343–351.

Jennings, R., Finlayson, C., Fa, D., Finlayson, G., 2011. Southern Iberia as a refuge for the last Neanderthal populations. J. Biogeogr. 38 (10), 1873–1885.

Jones, S., Antoniadou, A., Barton, H., Drake, N., Farr, L., Hunt, C., Inglis, R., Reynolds, T., White, K., Barker, G., 2016. Patterns of hominin occupation and cultural diversity across the Gebel Akhdar of Northern Libya over the last ~200 ka. In: Jones, S., Stewart, B. (Eds.), Africa from MIS 6–2: Population Dynamics and Palaeoenvironments. Springer, Dordrecht, pp. 77–99.

Jouet, G., Berne, S., Rabineau, M., Bassetti, M.A., Bernier, P., Dennielou, B., Sierro, F.J., Flores, J.A., Taviani, M., 2006. Shoreface migrations at the shelf edge and sea-level changes around the last glacial maximum (Gulf of Lions, NW Mediterranean). Mar. Geol. 234, 21–42.

Kelletat, D., 2006. Beachrock as sea-level indicator? Remarks from a geomorphological point of view. J. Coast. Res. 226, 1558–1564.

Kennedy, D.M., 2015. Where is the seaward edge? A review and definition of shore platform morphology. Earth Sci. Rev. 147, 99–108. http://dx.doi.org/10.1016/j.earscirev.2015.05.007.

Kindler, P., Guillevic, M., Baumgartner, M., Schwander, J., Landais, A., Leuenberger, M., 2014. Temperature reconstruction from 10 to 120 kyr b2k from the NGRIP ice core. Clim. Environ. Phys. 10 (2), 887–902.

Klein, R., Scott, K., 1986. Re-analysis of faunal assemblages from the Haua Fteah and other Late Quaternary archaeological sites in Cyrenaican Libya. J. Archaeol. Sci. 13, 515–542.

Kolaiti, E., Mourtzas, N.D., 2016. Upper Holocene sea level changes in the West Saronic Gulf, Greece. Quat. Int. 401, 71–90.

Kopp, R.E., Simmons, F.J., Mitrovica, J.X., Maloof, A.C., Oppenheimer, M., 2009. Probabilistic assessment of sea-level during the last interglacial stage. Nature 462, 863–867.

Kraft, J.C., Rapp, G.R., Kayan, I., Luce, J.V., 2003. Harbor areas at ancient Troy: sedimentology and geomorphology complement Homer's Iliad. Geology 31, 163–166.

Laborel, J., 1986. Vermetid gastropods as sea-level indicators. In: Sea-level Research. Springer Netherlands, pp. 281–310.

Laborel, J., 1996. Biological indicators of holocene sea-level and climatic variations on rocky coasts of tropical and subtropical regions. Quat. Int. 31, 53–60.

Laborel, J., Laborel-Deguen, F., 1994. Biological indicators of relative sea-level variations and of Coseismic displacements in the Mediterranean region. J. Coast. Res. 10, 395–415.

Lambeck, K., Antonioli, F., Purcell, A., Silenzi, S., 2004a. Sea-level change along the Italian coast for the past 10,000 yrs. Quat. Sci. Rev. 23, 1567–1598.

Lambeck, K., Anzidei, M., Antonioli, F., Benini, A., Esposito, E., 2004b. Sea-level in Roman time in the Central Mediterranean and implications for modern sea-level rise. Earth Planet. Sci. Lett. 224, 563–575.

Lambeck, K., Purcell, A., 2005. Sea-level change in the Mediterranean Sea since the LGM: model predictions for tectonically stable areas. Quat. Sci. Rev. 24, 1969–1988.

Lambeck, K., Woodroffe, C.D., Antonioli, F., Anzidei, M., Gehrels, W.R., Laborel, J., Wright, A.J., 2010. Paleoenvironmental records, geophysical modeling, and reconstruction of sealevel trends and variability on centennial and longer timescales. In: Woodworth, P.L., Aarup, T., Wilson, W.S. (Eds.), Understanding Sea Level Rise and Variability. Blackwell, Oxford, pp. 61–121.

Lambeck, K., Antonioli, F., Anzidei, M., Ferranti, L., Leoni, G., Scicchitano, G., Silenzi, S., 2011. Sea-level change along Italian coast during Holocene and a protection for the future. Quat. Int. 232, 250–257.

Lambeck, K., Rouby, H., Purcell, A., Sun, Y., Sambridge, M., 2014. Sea level and global ice volumes from the last glacial maximum to the holocene. Proc. Natl. Acad. Sci. U. S. A. 111, 15296–15303.

Lighty, R.G., Macintyre, I.G., Stuckenrath, R., 1982. Acropora palmata reef framework: a reliable indicator of sea level in the western Atlantic for the past 10,000 years. Coral Reefs 1 (2), 125–130.

Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic d^{18}O records. Paleoceanography 20. http://dx.doi.org/10.1029/2004PA001071. PA1003.

Lisiecki, L.E., Stern, J.V., 2016. Regional and global benthic d18O stacks for the last glacial cycle. Paleoceanography 31, 1–27. http://dx.doi.org/10.1002/2016PA003002.

Long, A.J., Barlow, N., Busschers, F., Cohen, K., Gehrels, W., Wake, L., 2015. Near-field sea-level variability in northwest Europe and ice sheet stability during the last interglacial. Quat. Sci. Rev. 126, 26–40.

Lowe, J.J., Blockley, S., Trincardi, F., Asioli, A., Cattaneo, A., Matthews, I.P., Pollard, M., Wulf, S., 2007. Age modelling of late Quaternary marine sequences in the Adriatic: towards improved precision and accuracy using volcanic event stratigraphy. Cont. Shelf Res. 27, 560–582.

Lyell, C., 1833. Principles of Geology, Being an Attempt to Explain the Former Changes of the Earth's Surface, by Reference to Causes Now in Operation, vol. 3. Murray, London, pp. 1830–1833.

May, S.M., Vött, A., Brückner, H., Grapmayer, R., Handl, M., Wennrich, V., 2012. The Lefkada barrier and beachrock system (NW Greece)—Controls on coastal evolution and the significance of extreme wave events. Geomorphology 139, 330–347.

Marco-Barba, J., Holmes, J.A., Mesquita-Joanes, F., Miracle, M.R., 2013. The influence of climate and sea-level change on the Holocene evolution of a Mediterranean coastal lagoon: evidence from ostracod palaeoecology and geochemistry. Geobios 46 (5), 409–421.

Marean, C.W., 2014. The origins and significance of coastal resource use in Africa and Western Eurasia. J. Hum. Evol. 77, 17–40.

Maselli, V., Trincardi, F., Cattaneo, A., Ridente, D., Asioli, A., 2010. Subsidence pattern in the central Adriatic and its influence on sediment architecture during the last 400 kyr. J. Geophys. Res. 115, B12106. http://dx.doi.org/10.1029/2010JB007687.

Masters, P., Flemming, N.C., 1983. Quaternary Coastlines and Marine Archaeology. Acadamic Press, Orlando, London, p. 641.

Mauz, B., Fanelli, F., Elmejdoub, N., Barbieri, R., 2012. Coastal response to climate change: Mediterranean shorelines during the Last Interglacial (MIS 5). Quat. Sci. Rev. 54, 89–98.

Mauz, B., Ruggieri, G., Spada, G., 2015a. Terminal Antarctic melting inferred from a far-field coastal site. Quat. Sci. Rev. 116, 122–132.

Mauz, B., Vacchi, M., Green, A., Hoffmann, G., Cooper, A., 2015b. Beachrock: a tool for reconstructing relative sea level in the far-field. Mar. Geol. 362, 1–16.

Mazzini, I., Anadon, P., Barbieri, M., Castorina, F., Ferreli, L., Gliozzi, E., Vittori, E., 1999. Late Quaternary sea-level changes along the Tyrrhenian coast near Orbetello (Tuscany, central Italy): palaeoenvironmental reconstruction using ostracods. Mar. Micropaleontol. 37 (3), 289–311.

Mellars, P., Gori, K.C., Carr, M., Soares, P.A., Richards, M.B., 2013. Genetic and archaeological perspectives on the initial modern human colonization of southern Asia. Proc. Natl. Acad. Sci. U. S. A. 110 (26), 10699–10704.

Micallef, A., Foglini, F., Le Bas, T., Angeletti, L., Maselli, V., Pasuto, A., Taviani, M., 2012. Submerged Palaeolandscape of the Maltese islands: morphology, evolution and relation to quaternary environmental change. Mar. Geol. 335, 129–147.

Milli, S., Mancini, M., Moscatelli, M., Stigliano, F., Marini, M., Cavinato, G.P., 2016. From river to shelf, anatomy of a high-frequency depositional sequence: the late Pleistocene to Holocene tiber depositional sequence. Sedimentology 63 (7), 1886–1928.

Milne, G.A., Gehrels, W.R., Hughes, C.W., Tamisiea, M.E., 2009. Identifying the causes of sea-level change. Nat. Geosci. 2, 471–478.

Milne, G.A., Mitrovica, J.X., 2008. Searching for eustasy in deglacial sea-level histories. Quat. Sci. Rev. 27, 2292–2302.

Mitchell, S.G., Matmon, A., Bierman, P.R., Enzel, Y., Caffee, M., Rizzo, D., 2001 Mar 10. Displacement history of a limestone normal fault scarp, northern Israel, from cosmogenic 36Cl. J. Geophys. Res. Solid Earth 106 (B3), 4247–4264.

Mlekuz, D., 2003. Early herders of the Eastern Adriatic. Doc. Praehist. 30, 139–152.

Moreno, A., Cacho, I., Canals, M., Prins, M.A., Sánchez-Goñi, M.-F., Grimalt, J.O., et al., 2002. Saharan dust transport and high-latitude glacial climatic variability: the Alboran Sea record. Quat. Res. 58, 318–328.

Moreno, A., Cacho, I., Canals, M., Grimalt, J.O., Sanchez-Goni, M.F., Shackleton, N.J., et al., 2005. Links between marine and atmospheric processes oscillating on a millennial time-scale. A multi-proxy study of the last 50,000 yr from the Alboran Sea (Western Mediterranean Sea). Quat. Sci. Rev. 24, 1623–1636.

Morhange, C., Laborel, J., Hesnard, A., Prone, A., 1996. Variation of relative mean sea-level during the last 4000 years on the northern shores of the Lacydon, the ancient harbor of Marseille. J. Coast. Res. 12 (4), 841–849.

Morhange, C., Laborel, J., Hesnard, A., 2001. Changes of relative sea level during the past 5000 years in the ancient habour of Marseilles, Southern France. Palaeogeogr. Palaeoclimatol. Palaeoecol. 166 (3), 319–329.

Morhange, C., Pirazzoli, P.A., 2005. Mid-Holocene emergence of southern Tunesian coasts. Mar. Geol. 220, 205–213.

Morhange, C., Pirazzoli, P.A., Marriner, N., Montaggioni, L.F., Nammour, T., 2006. Late Holocene relative sea-level changes in Lebanon, Eastern Mediterranean. Mar. Geol. 230 (1), 99–114.

Morhange, C., Marriner, N., Excoffon, P., Bonnet, S., Flaux, C., Zibrowius, H., Goiran, J.P., Amouri, M.E., 2013. Relative sea-level changes during roman times in the Northwest Mediterranean: the 1st century AD fish tank of Forum Julii, Fréjus, France. Geoarchaeology 28 (4), 363–372.

Morhange, C., Salamon, A., Bony, G., Flaux, C., Galili, E., Goiran, J.P., Zviely, D., 2014. Geoarchaeology of tsunamis and the revival of neo-catastrophism in the Eastern Mediterranean. La Sapienza Stud. Archaeol. Palestine Trans Jordan ROSAPAT 11, 61–81.

Morhange, C., Marriner, N., 2015. Archaeological and biological relative sea-level indicators. In: Shennan, I., Long, A., Horton, B.P. (Eds.), Handbook of Sea Level Research. Wiley, pp. 146–156.

Morhange, C., Giaime, M., Marriner, N., Abu Hamid, A., Bruneton, H., Honnorat, A., Kaniewski, D., Magnin, F., Porotov, A.V., Wante, J., Zviely, D., 2016. Geoarchaeological evolution of Tel Akko's ancient harbour (Israel). J. Archaeol. Sci. Rep. 7, 71–81.

Moscon, G., Correggiari, A., Stefani, C., Fontana, A., Remia, A., 2015. Very-high resolution analysis of a transgressive deposit in the Northern Adriatic Sea (Italy). Alp. Mediterr. Quat. 28 (2), 121–129.

Mourtzas, N.D., 2010. Sea level changes along the coasts of Kea island and paleogeographical coastal reconstruction of archaeological sites. Bull. Geol. Soc. Greece 43 (1), 453–463.

Mourtzas, N., 2012a. Archaeological indicators for sea level change and coastal neotectonic deformation: the submerged roman fish tanks of the gulf of Matala, Crete, Greece. J. Archaeol. Sci. 39, 884–895.

Mourtzas, N., 2012b. Fish tanks of eastern Crete (Greece) as indicators of the Roman sea level. J. Archaeol. Sci. 39, 2392–2408.

Mourtzas, D.N., Kolaiti, E., 2013. Historical coastal evolution of the ancient harbor of Aegina in relation to the Upper Holocene relative sea level changes in the Saronic Gulf, Greece. Palaeogeogr. Palaeoclimatol. Palaeoecol. 392, 411–425.

Mourtzas, N., Kolaiti, E., 2016. Holocene sea level changes and palaeogeographic reconstruction of the Ayia Irini prehistoric settlement (Keos Island, Cyclades archipelago, Greece). In: Ghilardi, M. (Ed.), Géoarchéologie des îles de Méditerranée. CNRS éditions alpha, Paris, pp. 119–135.

Mourtzas, N.D., Kolaiti, E., Anzidei, M., 2016. Vertical land movements and sea level changes along the coast of Crete (Greece) since Late Holocene. Quat. Int. 401, 43–70.

Muhs, D.R., Kathleen, R., Simmons, Joaquín, M., Porat, N., 2015. Uranium-series ages of fossil corals from Mallorca, Spain: the “Neotyrrhenian” highstand of the Mediterranean Sea revisited. Palaeogeogr. Palaeoclimatol. Palaeoecol. 438, 408–424.

Naughton, F., Sanchez Goñi, M.F., Kageyama, M., Bard, E., Duprat, J., Cortijo, E., Desprat, S., Malaize, B., Joly, C., Rostek, F., Turon, J.L., 2009. Wet to dry climatic trend in north-western Iberia within Heinrich events. Earth Planet. Sci. Lett. 284, 329–342.

Negri, A., Colleoni, F., Masina, S., 2012. Mediterranean sapropels: a mere geological problem or a resource for the study of a changing planet? Alp. Mediterr. Quat. 25, 81–89.

Négris, Ph. M., 1903a. Observations concernant les variations du niveau de la mer depuis les temps historiques et préhistoriques. Comptes Rendus Séances l'Acad. Sci. 132 (2), 222–224.

Négris, Ph. M., 1903b. Règression et transgression de la mer depuis l'époque glaciaire jusqu'à nos jours. Rev. Univ. Des. Mines 3, 249–281.

Négris, Ph. M., 1904. Vestiges antiques submergés. Athen. Mittl. 29, 340–363.

Nixon, F.C., Reinhardt, E.G., Rothaus, R., 2009. Foraminifera and tidal notches: dating neotectonic events at Korphos, Greece. Mar. Geol. 257, 41–53.

North Greenland Ice Core Project Members, 2004. High-resolution record of Northern Hemisphere climate extending into the last interglacial period. Nature 431, 147–151.

O'Connor, S., Ono, R., Clarkson, C., 2011. Pelagic fishing at 42,000 Years before the present and the maritime skills of modern humans. Science 334, 1117–1121.

O'Leary, M.J., Hearty, P.J., Thompson, W.G., Raymo, M.E., Mitrovica, J.X., Webster, J.M., 2013. Ice sheet collapse following a prolonged period of stable sea levelsea-level during the last interglacial. Nat. Geosci. 6, 796–800.

Olivieri, A., Achilli, A., Pala, M., Battaglia, V., Fornarino, S., Al-Zahery, N., et al., 2006. The mtDNA legacy of the Levantine early upper Palaeolithic in Africa. Science 314, 1767–1770.

Ozturk, M.Z., Erginal, A.E., Kiyak, N.G., Ozturk, T., 2016. Cement fabrics and optical luminescence ages of beachrock, North Cyprus: implications for Holocene sea-level changes. Quat. Int. 401, 132–140.

Pagliarulo, R., Antonioli, F., Anzidei, M., 2013. Sea level changes since the middle ages along the coast of the Adriatic sea: the case of St. Nicholas Basilica, Bari, Southern Italy. Quat. Int. 288, 139–145.

Palombo, M.R., Antonioli, F., Lo Presti, V., Mannino, M., Melis, M.R., Orrù, Stocchi, P., Talamo, S., Quarta, G., Calcagnile, L., Deiana, G., Altamura, S., 2017. The Late Pleistocene to Holocene palaeogeographic evolution of the Porto Conte area: clues for a better understanding of human colonization of Sardinia and faunal dynamics during the last 30 ka. Quat. Int. 439 (Part A), 117–140.

Pavlopoulos, K., Kapsimalis, V., Theodorakopoulou, K., Panagiotopoulos, I.P., 2011. Vertical displacement trends in the Aegean coastal zone (NE Mediterranean) during the Holocene assessed by geo-archaeological data. The Holocene 22, 717–728.

Pedoja, K., Husson, L., Regard, V., Cobbold, P.R., Ostanciaux, E., Johnson, M.E., Weill, P., 2011. Relative sea-level fall since the last interglacial stage: are coasts uplifting worldwide? Earth Sci. Rev. 108, 1–15.

Pedoja, K., Husson, L., Johnson, M.E., Melnick, D., Witt, C., Pochat, S., Nexer, M., Delcaillau, B., Pinegina, T., Poprawski, Y., Authemayou, C., Elliot, M., Regard, V., Garestier, F., 2014. Coastal staircase sequences reflecting sea-level oscillations and tectonic uplift during the Quaternary and Neogene. Earth Sci. Rev. 132, 13–38.

Peirano, A., Morri, C., Bianchi, C.N., Aguirre, J., Antonioli, F., Calzetta, G., Carobene, L., Mastronuzzi, G., Orrù, P., 2004. The Mediterranean coral *Cladocora caespitosa*: a proxy for past climate fluctuations? Glob. Planet. Change 40 (1), 195–200.

Peirano, A., Morri, C., Mastronuzzi, G., Bianchi, C.N., 1998. The coral Cladocora caespitosa (Anthozoa, Scleractinia) as a bioherm builder in the Mediterranean Sea. Mem. Descr. Carta Geol. d'It 52 (1994), 59–74.

Pellegrini, C., Maselli, V., Gamberi, F., Asioli, A., Bohacs, K.M., Drexler, T.M., Trincardi, F., 2017. How to make a 350-m-thick lowstand systems tract in 17,000 years: the Late Pleistocene Po River (Italy) lowstand wedge. Geology. http://dx.doi.org/10.1130/G38848.1.

Peltier, W.R., Fairbanks, R.G., 2006. Global glacial ice volume and Last Glacial Maximum duration from an extended Barbados sea-level record. Quat. Sci. Rev. 25, 3322–3337.

Phoca-Cosmetatou, N., Rabett, R.J., 2014a. Pleistocene island occupation in the Mediterranean: insights from a tied-biome approach to glacial refugia. In: Boyle, K., Ryan, J., Rabett, Hunt C.O. (Eds.), Living in the Landscape: Essays in Honour of Graeme Barker. McDonald Institute Monograph Series, pp. 83–108.

Phoca-Cosmetatou, N., Rabett, R.J., 2014b. Reflections on Pleistocene island occupation. J. Mediterr. Archaeol. 27 (2), 255–278.

Pikelj, K., Juračić, M., 2013. Eastern Adriatic Coast (EAC): geomorphology and Coastal Vulnerability of a Karstic Coast. J. Coast. Res. 29, 944–957.

Pirazzoli, P.A., 1976. Les Variation du niveau main depuis 2000 ans. Memoires Lab. Geomorphol. l'Ecole Prat. Hautes Etudes 30, 1–421.

Pirazzoli, P.A., 1986. Marine notches. In: Van de Plassche, O. (Ed.), Sea-level Research, pp. 361–400. Norwich.

Pirazzoli, P.A., 2005. A review of possible eustatic, isostatic and tectonic contributions in eight late-Holocene relative sea-level histories from the Mediterranean area. Quat. Sci. Rev. 24, 1989–2001.

Pirazzoli, P.A., Evelpidou, N., 2013. Tidal notches: a sea-level indicator of uncertain archival trustwothiness. Palaeogeogr. Palaeoclimatol. Palaeoecol. 369, 377–384.

Pluciennik, M., 2008. The Coastal Mesolithic of the European Mediterranean. In: Bailey, G., Spikens, P. (Eds.), Mesolithic Europe. Cambridge University Press, Cambridge, pp. 328–356.

Porat, N., Sivan, D., Zviely, D., 2008. Late Holocene embayment and sedimentological infill processes in Haifa Bay, SE Mediterranean. Israel J. Earth Sci. 57, 21–23.

Raban, A., 1983. Submerged prehistoric sites off the Mediterranean coast of Israel. In: Masters, P., Flemming, N.C. (Eds.), Quaternary Coastlines and Marine Archaeology. Academic Press, Orlando, London.

Raymo, M.E., Mitrovica, J.X., 2012. Collapse of polar ice sheets during the stage 11 interglacial. Nature 483, 453–456.

Reinhardt, E., Goodman, B., Boyce, J., Lopez, G., van Hengstum, P., Rink, W., Mart, Y., Raban, A., 2006. The tsunami of 13 December A.D. 115 and the destruction of Herod the Great's harbor at Caesarea Maritima, Israel. Geology 34, 1061–1064.

Richards, M.P., 2003. Sharp shift in diet at onset of Neolithic. Nature 425, 366.

Richards, M.P., Trinkaus, E., 2009. Isotopic evidence for the diets of European Neanderthals and early modern humans. Proc. Natl. Acad. Sci. U. S. A. 106, 16034–16039.

Ridente, D., Trincardi, F., Piva, A., Asioli, A., Cattaneo, A., 2008. Sedimentary response to climate and sea level changes during the past 400 ka from borehole PRAD1–2 (Adriatic margin). Geochem. Geophys. Geosyst. 9, 1–20.

Ridente, D., Trincardi, F., Piva, A., Asioli, A., 2009. The combined effect of sea-level and supply during Milankovitch cyclicity: evidence from shallow-marine δ18O records and sequence architecture (Adriatic margin). Geology 37, 1003–1006.

Robinson, D., Goddio, F. (Eds.), 2015. Thonis-Heracleion in Context. Oxford Centre for Maritime Archaeology Monograph 8, Oxford.

Rodriguez Vidal, J., Cáceres, L.M., Finlayson, J.C., Gracia, F.J., Martınez-Aguirre, A., 2004. Neotectonics and shoreline history of the Rock of Gibraltar, Southern Iberia. Quat. Sci. Rev. 23, 2017–2029.

Rohling, E.J., Fenton, M., Jorissen, F.J., Bertrand, P., Ganssen, G., Caulet, J.P., 1998. Magnitudes of sea-level lowstands of the past 500,000 years. Nature 394, 162–165.

Rohling, E.J., Marsh, R., Wells, N.C., Siddall, M., Edwards, N.R., 2004. Similar meltwater contributions to glacial sea level changes from Antarctic and northern ice sheets. Nature 430, 1016–1021. http://dx.doi.org/10.1038/nature02859.

Rohling, E.J., Grant, K., Hemleben, Ch, Kucera, M., Roberts, A.P., Schmeltzer, I., Schulz, H., Siccha, M., Siddall, M., Trommer, G., 2008a. New constraints on the timing and amplitude of sea-level fluctuations during Marine Isotope Stage 3. Paleoceanography 23. PA 3219.

Rohling, E.J., Grant, K., Hemleben, Ch, Siddall, M., Hoogakker, B.A.A., Bolshaw, M., Kucera, M., 2008b. High rates of sea-level rise during the last interglacial period. Nat. Geosci. 1, 38–42.

Rohling, E.J., Marinoa, G., Grant, K.M., 2015. Mediterranean climate and oceanography, and the periodic development of anoxic events (sapropels). Earth Sci. Rev. 143, 62–97.

Romagnoli, F., Martini, F., Sarti, L., 2015. Neanderthal use of Callista chione Shells as raw material for retouched tools in South-east Italy: analysis of Grotta del Cavallo Layer L assemblage with a new methodology. J. Archaeol. Method

Theory 22, 1007–1037.

Ronen, A., Neber, A., Mienis, H., Horwitz, L.K., Frumkin, Amos, Boenigk, W., Galili, E., 2008. A Mousterian Occupation on an OIS 5e Shore near the Mount Carmel Caves, Israel. In: Sulgostowska, Z., Tomaszewski, A.J. (Eds.), Man, Millennia, Environment, Institute of Archaeology and Ethnology. Polish Academy of Sciences, pp. 197–205.

Rossignol-Strick, M., Nesterof, H., Olive, P., Vergnaud-Grazzini, C., 1982. Mediterranean stagnation and sapropel formation. Nature 295, 105–110.

Rovere, A., Vacchi, M., Firpo, M., Carobene, L., 2011. Underwater geomorphology of the rocky coastal tracts between Finale ligure and Vado ligure (western Liguria, NW Mediterranean sea). Quat. Int. 232, 187–200.

Rovere, A., Furlani, S., Benjamin, J., Fontana, A., Antonioli, F., 2012. MEDFLOOD project: MEDiterranean sea-level change and projection for future FLOODing. Alp. Mediterr. Quat. 25, 3–5.

Rovere, A., Antonioli, F., Bianchi, C.N., 2015. Fixed biological indicators. In: Shennan, I., Long, A.J., Horton, B.P. (Eds.), Handbook of Sea-level Research. Wiley, pp. 268–280.

Rovere, A., Raymo, M.E., Vacchi, M., Lorscheid, T., Stocchi, P., Gómez-Pujol, L., Harris, D.L., Casella, E., O'Leary, M.J., Hearty, P.J., 2016a. The analysis of Last Interglacial (MIS 5e) relative sea-level indicators: reconstructing sea-level in a warmer world. Earth Sci. Rev. 159, 404–427.

Rovere, A., Stocchi, P., Vacchi, M., 2016b. Eustatic and relative sea-level changes. Curr. Clim. Change Rep. 2, 221–231.

Sankararaman, S., Patterson, N., Li, H., Pääbo, S., Reiche, D., 2012. The date of Interbreeding between Neandertals and modern humans. PLoS Genet. 8 (10), e1002947.

Schmiedt, G., 1972. Il livello antico del mar Tirreno, p. 326. Firenze.

Scott, D.S., Medioli, F.S., 1978. Vertical zonations of marsh foraminifera as accurate indicators of former sea-levels. Nature 272, 528–531.

Serandrei-Barbero, R., Albani, A., Donnici, S., Rizzetto, F., 2006. Past and recent sedimentation rates in the Lagoon of Venice (Northern Italy). Estuar. Coast. Shelf Sci. 69 (1), 255–269.

Shackleton, N.J., Hall, M.A., Vincent, E., 2000. Phase relationships between millennial-scale events 64,000–24,000 years ago. Paleoceanography 15, 565–569.

Shaw, T.A., Kirby, J.R., Holgate, S., Tutman, P., Plater, A.J., 2016. Contemporary saltmarsh foraminiferal distribution from the Adriatic coast of Croatia and its potential for sea-level studies. J. Foraminifer. Res. 46 (3), 314–332.

Shea, J., 2003. The middle Palaeolithic of the East Midterranean Levant. J. World Prehistory. 17 (4), 313–394.

Shennan, I., Long, A.J., Horton, B.P. (Eds.), 2015. Handbook of Sea-level Research. John Wiley & Sons, p. 581.

Shtienberg, G., Dix, J., Waldmann, N., Makovsky, Y., Golan, A., Sivan, D., 2016. Late-Pleistocene evolution of the continental shelf of central Israel, a case study from Hadera. Geomorphology 261, 200–211.

Shtienberg, G., Dix, J., Roskin, J., Waldmann, N., Bookman, R., Bialik, O.M., Porat, N., Taha, N., Sivan, D., 2017. New perspectives on coastal landscape reconstruction of central Israel during the Late Quaternary. Palaeogeogr. Palaeoclimatol. Palaeoecol. (Palaeo3) 468, 503–519.

Skoglund, P., Malmstrom, H., Raghavan, M., Stora, J., Hall, P., Willerslev, E., Jakobsson, M., 2012. Origins and genetic legacy of Neolithic farmers and hunter-gatherers in Europe. Science 336, 466–469.

Siddall, M., Kaplan, M.R., Schaefer, J.M., Putnam, A., Kelly, M.A., Goehring, B., 2010. Changing influence of Antarctic and Greenlandic temperature records on sea-level over the last glacial cycle. Quat. Sci. Rev. 29, 410–423.

Simmons, A., 2007. The Neolithic Revolution in the Near East: Transforming the Human Landscape. University of Arizona Press, Tucson, p. 360.

Sisma-Ventura, G., Sivan, D., Shtienberg, G., Bialik, O.M., Filin, S., Greenbaum, N., 2017. Last interglacial sea level highstand deduced from well preserved abrasive notches exposed on the Galilee coast of northern Israel. Palaeogeogr. Palaeoclimatol. Palaeoecol. (Palaeo3) 470, 1–10.

Sivan, D., Gvirtzman, G., Sass, E., 1999. Quaternary stratigraphy and Paleogeography of the Galilee Coastal plain, Israel. Quat. Res. 51, 280–294.

Sivan, D., Wdowinski, S., Lambeck, K., Galili, E., Raban, A., 2001. Holocene sea-level changes along the Mediterranean coast of Israel, based on archaeological observations and numerical model. Palaeogeogr. Palaeoclimatol. Palaeoecol. 167, 101–117.

Sivan, D., Lambeck, K., Toueg, R., Raban, A., Porath, Y., Shirnam, B., 2004. Ancient coastal wells of Caesarea Maritima, Israel, an indicator for relative sea-level changes during the last 2000 years. Earth Planet. Sci. Lett. 222 (1), 315–330.

Sivan, D., Schattner, U., Morhange, C., Boaretto, E., 2010. What can a sessile mollusc tell about the Neotectonics of Eastern Mediterranean? Earth Planet. Sci. Lett. 296, 451–458.

Sivan, D., Sisma-Ventura, G., Greenbaum, N., Bialik, O.M., Williams, F.H., Tamisiea, M.E., Rohling, E.J., Frumkin, A., Avnaim-Katav, S., Shtienberg, G., Stein, M., 2016. Eastern Mediterranean sea levels through the last interglacial from a coastal-marine sequence in northern Israel. Quat. Sci. Rev. 145, 204–225.

Spratt, R.M., Lisiecki, L.E., 2016. A Late Pleistocene sea level stack. Clim. Past 12, 1079–1092.

Spry-Marqués, V.P., 2012. The Adriatic Plain: a Last Glacial Maximum Human Refugium? Epigravettian Subsistence Strategies at the Site of Vela Spila, Korčula (Croatia). Unpublished PhD Thesis. Department of Archaeology and Anthropology, University of Cambridge.

Stanford, J.D., Hemingway, R., Rohling, E.J., Challenorb, P.G., Medina-Elizaldea, M., Lesterc, A.J., 2011. Sea-level probability for the last deglaciation: a statistical analysis of far-field records. Glob. Planet. Change 79, 193–203.

Stanford, D., Lowery, D., Jodry, M., Bradley, B.A., 2015. New evidence for a possible Paleolithic occupation of the eastern North American continental shelf at the last glacial maximum. In: Evans, A.M., et al. (Eds.), Prehistoric Archaeology on the Continental Shelf: a Global Review. Springer, New York.

Stanley, J.D., Bernasconi, M.P., 2012. Buried and submerged Greek archaeological coastal Structures and artifacts as gauges to measure late Holocene seafloor subsidence off Calabria, Italy. Geoarchaeology 27, 189–205.

Stanley, D.J., 1995. A global sea-level curve for the late Quaternary: the impossible dream? Mar. Geol. 125 (1–2), 1–6.

Stearns, C.E., Thurber, D.L., 1965. Th230/U234 dates of late Pleistocene marine fossils from the Mediterranean and Moroccan littorals. Prog. Oceanogr. 4, 293–305.

Stiros, S.C., 2010. The 8.5+ magnitude, AD 365 earthquake in Crete: coastal uplift, topography changes, archaeological and historical signature. Quat. Int. 216, 54–63.

Stewart, J.R., Stringer, C.B., 2012. Human evolution out of Africa: the role of refugia and climate change. Science 335, 1317–1321.

Stiner, M.C., 1993. Small animal exploitation and its relation to hunting, scavenging, and gathering in the Italian Mousterian. Archaeol. Pap. Am. Anthropol. Assoc. 4, 107–125.

Stiner, M.C., Munro, N.D., 2011. On the evolution of diet and landscape during the upper Paleolithic through Mesolithic at Franchthi Cave (Peloponnese, Greece). J. Hum. Evol. 60, 618–636.

Stiner, M.C., Kuhn, S.L., Gulec, E., 2013. Early Upper Paleolithic shell beads at Üçağızlı Cave I (Turkey): technology and the socioeconomic context of ornament life-histories. J. Hum. Evol. 64, 380–398.

Stocchi, P., Spada, G., 2007. Glacio and hydro-isostasy in the Mediterranean Sea: Clark's zones and role of remote ice sheets. Ann. Geophys. 50, 741–761.

Stocchi, P., Spada, G., 2009. Influence of glacial isostatic adjustment upon current sea level variations in the Mediterranean. Tectonophysics 474, 56–68.

Strabo (Geografia, V, 1, 5).

Strasser, T., Runnels, C., Wegmann, K., Pangopoulou, E., McCoy, F., Digregorio, C., Karkanas, P., Thompson, N., 2011. Dating Palaeolithic sites in Southwestern Crete, Greece. J. Quat. Sci. 26 (5), 553–560.

Stringer, C., 2000. Coasting out of Africa. Nature 405, 24–27.

Stringer, C.B., Finlayson, J.C., Barton, R.N., Fernandez-Jalvo, Y., Caceres, I., Sabin, R.C., et al., 2008. Neanderthal exploitation of marine mammals in Gibraltar. Proc. Natl. Acad. Sci. U. S. A. 105 (38), 14319–14324.

Surić, M., Juračić, M., Horvatinčić, N., Krajcar Bronić, I., 2005. Late Pleistocene-Holocene sea-level rise and the pattern of coastal karst inundation: records from submerged speleothems along the eastern Adriatic coast (Croatia). Mar. Geol. 214, 163–175.

Surić, M., Richards, D.A., Hoffmann, D.L., Tibljaš, D., Juračić, M., 2009. Sea level change during MIS 5a based on submerged speleothems from the eastern Adriatic Sea (Croatia). Mar. Geol. 262, 62–67.

Surić, M., Roller-Lutz, Z., Mandić, M., Krajcar Bronić, I., Juračić, M., 2010. Modern C, O, and H isotope composition of speleothem and dripwater from Modrič Cave, eastern Adriatic coast (Croatia). Int. J. Speleol. 39 (2), 91–97.

Taviani, M., 2014. Unpersisting Persististrombus: a Mediterranean story. Vieraea 42, 9–18.

Taviani, M., Angeletti, L., Çağatay, M.N., Gasperini, L., Polonia, A., Wesselingh, F.P., 2014. Sedimentary and faunal signatures of the post-glacial marine drowning of the Pontocaspian Gemlik "lake"(Sea of Marmara). Quat. Int. 345, 11–17.

Toker, E., Sivan, D., Stern, E., Shirman, B., Tsimplis, M., Spada, G., 2012. Evidence for centennial scale sea level variability during the Medieval climate optimum (Crusader Period) in Israel, eastern Mediterranean. Earth Planet. Sci. Lett. 315–316, 51–61.

Törnqvist, T.E., Hijma, M.P., 2012. Links between early Holocene ice-sheet decay, sea-level rise and abrupt climate change. Nat. Geosci. 5, 601–606.

Trenhaile, A.S., 1987. The Geomorphology of Rock Coasts. Oxford University Press, USA.

Trenhaile, A.S., 2016. Modelling coastal notch morphology and developmental history in the Mediterranean. Geo. Res. J. 9–12, 77–90.

Tric, E., Valent, J.-P., Tucholka, P., Paterne, M., Labeyrie, L., Guichard, F., Tauxe, L., Fontugne, M., 1992. Paleointensity of the geomagnetic field during the last 80,000 years. J. Geophys. Res. 97 (B6), 9337–9351.

Trincardi, F., Cattaneo, A., Correggiari, A., Ridente, D., 2004. Evidence of soft sediment deformation, fluid escape, sediment failure and regional weak layers within the late Quaternary mud deposits of the Adriatic Sea. Mar. Geol. 213, 91–119.

Trincardi, F., Argnani, A., Correggiari, A., 2011a. Carta Geologica dei Mari Italiani alla scala 1:250.000-Foglio NK 33–1/2 Ancona. S.EL.CA., Firenze, 2 sheets, 143.

Trincardi, F., Argnani, A., Correggiari, A., 2011b. Carta Geologica dei Mari Italiani alla scala 1:250.000-Foglio NK 33–5 Pescara. S.EL.CA., Firenze, 2 sheets, 167.

Turney, C.S.M., Brown, H., 2007. Catastrophic early Holocene sea level rise, human migration and the Neolithic transition in Europe. Quat. Sci. Rev. 26, 2036–2041.

Ulzega, A., Hearty, P.J., 1986. Geomorphology, stratigraphy and geochronology of Late Quaternary marine deposits in Sardinia. Z. für Geomorphol. 62 (Suppl. Bd), 119–129.

Vacchi, M., Rovere, A., Chatzipetros, A., Zouros, N., Firpo, M., 2014. An updated database of Holocene relative sea level changes in NE Aegean Sea. Quat. Int. 328, 301–310.

Vacchi, M., Rovere, A., Zouros, N., Desruelles, S., Caron, V., Firpo, M., 2012. Spatial distribution of sea-level markers on Lesvos Island (NE Aegean Sea): evidence of differential relative sea-level changes and the neotectonic implications.

Geomorphology 159, 50–62.

Vacchi, M., Ghilardi, M., Spada, G., Currás, A., Robresco, S., 2016a. New insights into the sea-level evolution in Corsica (NW Mediterranean) since the late Neolithic. J. Archaeol. Sci. Rep. http://dx.doi.org/10.1016/j.jasrep.2016.07.006.

Vacchi, M., Marriner, N., Morhange, C., Spada, G., Fontana, A., Rovere, A., 2016b. Multiproxy assessment of Holocene relative sea-level changes in the western Mediterranean: Sea-level variability and improvements in the definition of the isostatic signal. Earth Sci. Rev. 155, 172–197.

Van Andel, T.H., Runnels, C.N., 1995. The earliest farmers in Europe. Antiquity 69, 481–500.

Van Andel, T.H., Davies, W., Weninger, B., 2003. The human presence in Europe during the last glacial period I: human migrations and the changing climate. In: van Andel, T.H., Davies, W. (Eds.), Neanderthals and Modern Humans in the European Landscape during the Last Glaciation. McDonald Institute, Cambridge, pp. 31–56.

Vanhaeren, M., D'Errico, F., Stringer, C., James, S.L., Todd, J.A., Mienis, H.K., 2006. Middle Paleolithic shell beads in Israel and Algeria. Science 312, 1785–1788.

Van de Noort, R., 2011. Conceptualising climate change archaeology. Antiquity 85, 1039–1048.

Van de Noort, R., 2013. Climate Change Archaeology. Oxford University Press, Oxford, p. 288.

Van de Plassche, O. (Ed.), 1986. Sea-level Research: a Manual for the Collection and Evaluation of Data. Springer, p. 603.

Van Neer, W., Zohar, I., Lernau, O., 2005. Paléorient 31 (1), 131–157.

Vesica, P., Tuccimei, P., Turi, B., 2000. Late Pleistocene Paleoclimates and sea-level change in the Mediterranean as inferred from stable isotope and U-series studies of overgrowths on speleothems, Mallorca, Spain. Quat. Sci. Rev. 19, 865–879.

Vött, A., 2007. Relative sea level changes and regional tectonic evolution of seven coastal areas in NW Greece since the mid-Holocene. Quat. Sci. Rev. 26, 894–919.

Vött, A., Bareth, G., Brückner, H., Curdt, C., Fountoulis, I., Grapmayer, R., Hadler, H., Hoffmeister, D., Klasen, N., Lang, F., Masberg, P., May, S.M., Ntageretzis, K., Sakellariou, D., Willershäuser, T., 2010. Beachrock-type calcarenitic tsunamites along the shores of the eastern Ionian Sea (western Greece) - case studies from Akarnania, the Ionian Islands and the western Peloponnese. Z. Geomorphol. 54, 1–50. Suppl. Issues.

Vousdoukas, M.I., Velegrakis, A.F., Plomaritis, T.A., 2007. Beachrock occurrence, characteristics, formation mechanisms and impacts. Earth Sci. Rev. 85 (1), 23–46.

Waelbroeck, C., Labeyrie, L., Michel, E., Duplessy, J.C., Lambeck, K., McManus, J.F., Balbon, E., Labracherie, M., 2002. Sea-level and deep water temperature changes derived from benthic foraminifera isotopic records. Quat. Sci. Rev. 21, 295–305.

Walter, R.C., Buffler, R.T., Bruggeman, J.H., Guillaume, M.M.M., Berhe, S.M., Negassi, B., et al., 2000. Early *human* occupation of the Red Sea coast of Eritrea during the last interglacial. Nature 405, 68–69.

Weaver, A.J., Saenko, O.A., Clark, P.U., Mitrovica, J.X., 2003. Meltwater pulse 1A from Antarctica as a trigger of the Bølling-Allerød warm interval. Science 299, 1709–1713.

Weninger, B., Alram-Stern, E., Bauer, E., Clare, L., Danzeglocke, U., Jöris, O., van Andel, T.H., 2006. Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. Quat. Res. 66 (3), 401–420.

Weninger, B., Clare, L., Gerritsen, F., Horejs, B., Krauß, R., Linstädter, J., Rohling, E.J., 2014. Neolithisation of the Aegean and southeast Europe during the 6600 – 6000 calBC period of rapid climate change. Doc. Praehist. 41, 1–32.

Wreschner, E.E., 1973. The submerged Neolithic settlement of Newe-Yam. Eretz Isr. 13, 259–270.

Wright, H.E., 1993. Environmental determinism in near eastern prehistory. Curr. Anthropol. 34 (4), 458–469.

Wulf, S., Brauer, A., Kraml, M., Keller, J., Negendank, J.F.W., 2004. Tephrochronology of the 100 ka lacustrine sediment record of Lago Grande di Monticchio (southern Italy). Quat. Int. 122, 7–30.

Wulf, S., Kraml, M., Kuhn, T., Schwarz, M., Inthorn, M., Keller, J., Kuscu, I., Halbach, P., 2002. Marine tephra from the Cape Riva eruption (22 ka) of Santorini in the sea of Marmara. Mar. Geol. 183, 131–141.

Zazo, C., Goy, J.L., Dabrio, C.J., Bardají, T., Hillaire-Marcel, C., Ghaleb, B., González-Delgado, J.A., Soler, V., 2003. Pleistocene raised marine terraces of the Spanish Mediterranean and Atlantic coasts: records of coastal uplift, sea-level high-stands and climate changes. Mar. Geol. 194, 103–133.

Zazo, C., Goy, J.L.L., Dabrio, C.J.J., Lario, J., González-Delgado, J.A., Bardají, T., Hillaire-Marcel, C., Cabero, A., Ghaleb, B., Borja, F., Silva, P.G.G., Roquero, E., Soler, V., 2013. Retracing the Quaternary history of sea-level changes in the Spanish Mediterranean-Atlantic coasts: geomorphological and sedimentological approach. Geomorphology 196, 36–49.

Zeder, M.A., 2006. Central questions in the domestication of plants and animals. Evol. Anthropol. 15 (3), 105–117.

Zeder, M.A., 2008. Domestication and early agriculture in the Mediterranean Basin: origins, diffusion, and impact. Proc. Natl. Acad. Sci. U. S. A. 105, 11597–11604.

Zilhão, J., 1997. Maritime pioneer colonisation in early Neolithic of West Mediterranean. Testing the model against the evidence. Mesolithic Eur. 46, 19–42.

Zilhão, J., 2001. Radiocarbon evidence for maritime pioneer colonization at the origins of farming in west Mediterranean Europe. Proc. Natl. Acad. Sci. U. S. A. 98 (24), 14180–14185.

Zilhão, J., Angelucci, D.E., Badal-Garcia, E., d'Errico, F., Daniel, F., Dayet, L., et al., 2010. Symbolic use of marine shells and mineral pigments by Iberian Neandertals. Proc. Natl. Acad. Sci. U. S. A. 107 (3), 1023–1028.

Zohar, I., 2017. Fish exploitation during the quaternary. In: Enzel, Y., Bar-Yosef, O. (Eds.), Quaternary Environments and Humans in the Levant. Cambridge University Press, pp. 369–376. ISBN: 9781107090460.

Zvelebil, M., Zvelebil, K.V., 1988. Agricultural transition and Indo-European dispersals. Antiquity 62, 574–583.