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To cite this article: Dafna Langgut, Matthew J. Adams & Israel Finkelstein (2016) Climate, settlement patterns and olive horticulture in the southern Levant during the Early Bronze and Intermediate Bronze Ages (c. 3600–1950 BC), Levant, 48:2, 117-134, DOI: 10.1080/00758914.2016.1193323

To link to this article: http://dx.doi.org/10.1080/00758914.2016.1193323
Climate, settlement patterns and olive horticulture in the southern Levant during the Early Bronze and Intermediate Bronze Ages (c. 3600–1950 BC)

Dafna Langgut¹, Matthew J. Adams² and Israel Finkelstein¹

We report results of palynological investigation of a core of sediments extracted from the bottom of the Sea of Galilee. The core was sampled at high resolution for both palynological analysis (a sample was taken c. every 40 years) and radiocarbon dating. The article focuses on the Early Bronze and Intermediate Bronze Ages, c. 3600–1950 BC. The results enable reconstruction of the vegetation and thus climate in the lake’s fluvial and alluvial catchment, which includes large parts of northern Israel and Lebanon and south-western Syria. The study sheds light on topics such as changes in olive cultivation through time and regions, processes of urbanization and collapse and settlement expansion and retraction in the arid zones.

Keywords Early Bronze Age, Intermediate Bronze Age, southern Levant, olive domestication, climate change, urbanization, urban collapse, Egypt and the Levant

Introduction

The distinctive feature of the Early Bronze and Intermediate Bronze Ages (c. 3600–1950 BC) in the southern Levant is the rise and collapse of the earliest urban societies. The first wave of urbanism (for discussion of the appropriateness of the concept of ‘cities’ in this period see Chesson and Philip 2003; Greenberg 2011) commenced in the late Early Bronze IB (EB IB) (c. 3000 BC) and continued in the Early Bronze II (EB II, c. 3000–2900 BC) and Early Bronze III (EB III, 2900–2500 BC; for the up-to-date, radiocarbon-based chronological framework for the Early Bronze Age, see Regev et al. [2012a; 2012b; 2014]; for the date of transition to the Middle Bronze Age see, e.g., Bietak [2002]; for a nuanced description of the EB II–III see Greenberg [2014; in press]). While the EB III does feature some large fortified centres, evidence for sporadic abandonments and rebuildings as well as a sparse settlement distribution hints at the fragile nature of the system (Greenberg in press; Philip 2003; Regev et al. 2012b). The succeeding Intermediate Bronze Age (= Early Bronze IV; c. 2500–1950 BC) is characterized by a resurgence of agro-pastoral village-level societies, with little evidence for an urban component (Adams in press; Prag 2014).

Various explanations have been offered for these processes. For the rise of urban life there is general agreement that contacts with Egypt were a factor, but the underlying causes remain difficult to determine (Greenberg 2014; Regev et al. 2014). For the dissolution of the urban system, explanations have often pointed to the complex relationship between nomadic and sedentary populations, disintegration of exchange networks with Egypt, military action by Egypt, foreign invasions from the north, fragility of the agricultural economic base, and especially climate change (Adams in press; Bell 1971; Esse 1991; Höflmayer in press; Greenberg in press; de Miroshchadi 2009; Philip 2001; 2008; Rosen 2007; Weiss et al. 1993; Wiener 2014; Wilkinson et al. 2014). Other significant settlement phenomena which
characterize the periods under discussion are the expansion of settlement activity into the highlands in the EB I (Finkelstein and Gophna 1993) and into the arid zones of the Negev Highlands and Sinai in the EB II and the Intermediate Bronze Age (Beit-Arieh 2003; Cohen 1999); the societies in the marginal zones — or at least part of them — adapted to a pastoral nomadic subsistence strategy (Prag 2014), a phenomenon that has been interpreted as climate related (for the theory regarding a dry event in the late 3rd millennium BC, see Weiss et al. 1993; for a different view see Finkelstein and Langgut 2014: 224–26).

Climatic conditions have played a critical role in agriculture-based, pre-industrial economies, influencing location of settlements, preference in exploitation of land, agricultural yield, grazing opportunities and patterns of trade (e.g., Rosen 2007; Weiss et al. 1993; Wilkinson et al. 2014). An important method in the study of palaeoenvironments is palynology — the study of fossil pollen grains (e.g., Bryant 1989). Since vegetation is sensitive to climate change, the palynological record can produce high resolution climate information. Palynology can also help elucidate past human activities such as plant domestication, deforestation and agricultural and grazing activities.

Pollen tends to preserve well in anaerobic environments such as lakes and ponds (Bryant 1989: Faegri and Iversen 1989). A sediment core was extracted from the Sea of Galilee (Lake Kinneret) and was subjected to palynological investigation (Langgut et al. 2013; 2015: fig. 3). Here we use the Sea of Galilee pollen results to shed light on climatic conditions and human activities during the Early Bronze and Intermediate Bronze Ages in the southern Levant. Previous Eastern Mediterranean palaeoclimate records for these periods, such as lake level reconstructions and isotope analyses, are characterized by conflicting conclusions (e.g., Finné et al. 2011; Rambeau and Black 2011), mainly due to low sampling and dating resolutions and the occurrence of hiatuses. Several southern Levant pollen records were studied at a c. 200-year resolution or less, which can miss short-term changes. The core of sediments discussed here was subjected to high-resolution pollen sampling (one sample per c. 40 years), as well as intense radiocarbon dating, both aimed at avoiding these shortcomings.

Here we use this detailed palynological dataset to trace fluctuations in climate conditions for the time period of 3600–1950 BC. The study also focuses on changes in the extent of olive horticulture, including the questions of the date and venue of the domestication of this species (Olea europaea). The resulting environmental reconstruction is examined in relation to the picture derived from the archaeological record concerning changes in settlement patterns and economic strategies (for previous studies, in which we treated the situation in the Middle Bronze I and Late Bronze Age see Finkelstein and Langgut 2014; Langgut et al. 2013 respectively).

The research area
The area around the Sea of Galilee enjoys a typical Mediterranean climate. Like other regions of the Levant, it receives most of its precipitation from the mid-latitude Cyprus cyclones, which move eastward over the Mediterranean and then across the region, with precipitation reducing along the west–east axis (Dayan et al. 2007). Precipitation also decreases gradually from north to south, with the transition from the Mediterranean climate towards more semi-arid conditions south of the Sea of Galilee (Fig. 1a). The highest values are recorded on Mount Hermon, where precipitation, including snow, amounts to 1,600 mm annually. Over the Golan Heights and the Galilee precipitation (which at the highest summits may also include some snow), ranges from 1,000 mm in the Upper Galilee to 450–500 mm in the Lower Galilee. In the Jordan Valley, annual precipitation ranges from 700 mm in the Hula basin, through 400 mm over the Sea of Galilee, down to less than 300 mm in the Beth-Shean region. Further south the climate rapidly becomes fully arid (Ziv et al. 2006, Fig. 1a).

From a botanical perspective, the greater part of the northern Jordan Valley, down to the southern margins of the Sea of Galilee, belongs to the Mediterranean vegetation belt (precipitation > 400 mm/year) (Fig. 1). The area from this point southwards, along the central Jordan Valley, is characterized by semi-arid Irano–Turanian steppe vegetation (~400–200 mm rainfall/year; for a detailed account of the vegetation of the area and the possible origins of the pollen grains, see Supplementary Material).

Olive habitat
Olive (Olea europaea) grows best in its original natural habitat in the hilly Mediterranean forest zones of the southern Levant. However it can thrive
depends on temperatures throughout the year and on the amount of precipitation and/or the moisture available within the soil. An olive tree usually thrives in a climate that is characterized by hot conditions during the summer (which are required for oil accumulation and fruit ripening), low air humidity and relatively low winter temperatures (olives need a relatively cold resting period in order for bud differentiation to take place, but not freezing temperatures). An olive tree can survive under 200 mm of annual rainfall; yet, to be profitable an orchard requires at least 400–450 mm of annual precipitation. Modern orchards that receive 300–400 mm of rain are not profitable, while orchards that receive 200–300 mm of annual precipitation yield fruit only every three–four years (Zinger 1985:28). In the Mediterranean Levantine region, therefore, olives are most successful in the hill country and usually below 600 m above sea level, as freezing temperatures in the winter can destroy the yield. Lowland valleys with well-drained soils can also accommodate olive orchards, as can the coastal plains of the Mediterranean areas (Zinger 1985:29–30), but they were usually devoted to grain cultivation. The olive is a relatively slow-growing tree, with fruit production starting five to six years after planting. If well managed, long-lived olive trees can keep fruiting for hundreds of years (Zohary et al. 2012:116). Olive trees flower on branches that developed in the previous year. Therefore, the young growth has to survive both low temperatures in winter and water shortage in summer in order to produce a good crop. In the highlands, olive trees can succeed in patches of rich soil where other crops are unprofitable due to limited growing areas (Zinger 1985:29–30).

Fieldwork and palynological analysis

An 18 m core, covering almost the entire Holocene, was extracted from the northern inner part of the Sea of Galilee (Figs 1b and S1) in 2010. Five and a half meters of this profile, corresponding to the time interval from the EB IB to the end of the Iron Age (composite depth of 458.8–1006.6 cm), were analyzed at a 40-year time interval between pollen samples (Langgut et al. 2013:154; 2015:220), while other sections were investigated at a lower resolution of c. 120 years between samples (Schiebel 2013:26 and appendix 6). This paper presents the palynological data for the EB IB through the Intermediate Bronze Age (composite depth of 731.4–1006.6 cm).

Figure 1  1a: Phytogeographic zones of the southern Levant and rainfall isohyets (based on Zohary 1962 and Srebro and Soffer 2011, respectively), together with the watershed divide line of the region. 1b: The catchment area of the Sea of Galilee (the star indicates the coring site). The Hula Lake is depicted as it was before its desiccation in the 1950s (due to human interference).
The palynological samples were processed using standard pollen extraction techniques (Faegri and Iversen 1989). The simplified palynological diagram presented in Fig. 2 is comprised of a group of natural Mediterranean trees and cultivated olive trees versus groups of herbs and dwarf-shrubs. The olive trees were combined with the group of other Mediterranean trees, since in the Sea of Galilee area they occupy almost the same ecological niches (Baruch 1986; Horowitz 1979: 193). The herbs and dwarf shrubs (the non-arboreal group) are presented as a negative image to the arboreal group and therefore an increase in their percentages is parallel to a decrease in the percentages of the arboreal group (and vice versa): representing changes in humidity. Olive pollen, which mostly derive from cultivated olive trees (Baruch 1986; Horowitz 1979), are represented by dark green-coloured curve.

At least 500 terrestrial pollen grains were counted per sample. Pollen grains were identified to the lowest possible systematic level. A reference collection of Israel’s pollen flora (The Steinhardt Museum of Natural History, Tel Aviv University), as well as pollen atlases (e.g., Beug 2004; Reille 1995; 1998; 1999), were used for identification. A detailed pollen diagram of the Sea of Galilee is presented by Langgut et al. 2015.

Within this group, only trees common to the Mediterranean vegetation territory were included; the majority among them is wind-pollinated trees. The most dominant are evergreen and deciduous oaks (Quercus calliprinos and Quercus ithaburensis, respectively). Other Mediterranean trees appear in lower percentages: Phillyrea, Pistacia (pistachios), Pinus halepensis (Aleppo pine) and Ceratonia siliqua (carob tree).

The most dominant plants within this group are (in declining order): Poaceae (wild grasses), Cerealia (cereals), Asteraceae (daisy family), Chenopodiaceae (goosefoot family), Artemisia (sagebrush) and Brassicaceae (cabbage family).
Olive trees, like other Mediterranean trees, require at least 400 mm of rainfall in order to thrive (see above under ‘Olive habitat’). Already in antiquity, in the Sea of Galilee area, the Mediterranean forest/maquis had been replaced by olive orchards through human agency. The combined pollen curve (Mediterranean trees and olive trees), therefore, is used in this study to trace changes in humidity (Fig. 2). In Fig. 3 the Mediterranean arboreal pollen curve and the *Olea* (olive) pollen curve are presented separately.

The herbs and dwarf-shrubs (the non-arboreal group) are presented as a negative image to the arboreal group and therefore an increase in their percentages is parallel to a decrease in the percentages of the arboreal group (and vice versa). Olive pollen, which mostly derives from cultivated olive trees (Baruch 1986), is represented by an olive-coloured curve. Wind-pollinated olive trees have a very efficient pollen dispersal system (e.g., Baruch 1993) and a strong response to cessation and resumption of orchard cultivation, resulting in dramatic fluctuations in pollen production following abandonment or rehabilitation of olive orchards. *Olea* pollen is therefore considered as a reliable marker for identifying agricultural activities in antiquity (Langgut et al. 2014a: 129–30). Today, the evergreen olive tree occurs in Israel in the Mediterranean territory both as a cultivated (the vast majority) and natural element (Zohary 1973; Zohary et al. 2012: 116–17). Palynologically, wild and domesticated olive pollen grains are indistinguishable (Langgut et al. 2014a: n. 1; Liphschitz et al. 1991: fig. 2).

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**Figure 3** Survey regions, archaeological sites and the location of palaeoclimate records mentioned in the text.

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8Trees and shrubs common to the bank of the lake vegetation (hydrophilic plants), as well as aquatic plants, were excluded from the total pollen sum (*Arboreal Pollen + Non Arboreal Pollen = 100%*). The palynological diagram (Fig. 2) was plotted using the POLPAL program (Walanus and Nalepka 1999).

9In addition, some of the trees are feral and hybrids between domesticated and wild.
In order to evaluate the sources of the pollen grains and changes in pollen distribution as a function of sampling location within and around the lake (e.g., inner part vs. banks), we collected several samples from the recent ‘pollen rain’, i.e., from the uppermost lake bottom sediments. The results (presented in the Supplementary Material) show that the extraction of the core from the inner part of the lake gives a reliable picture of vegetation cover in its vicinity (Fig. S1 and Table S1).

Chronology of the pollen record presented here (Fig. 2) is based on the age-depth model established by Langgut, Finkelstein and Litt (2013: fig. 2) and presented in the Supplementary Material (Fig. S2). The Sea of Galilee core is characterized by a relatively homogenous lithology, with no evidence for any hiatus in the sediment record. Thus, sediment deposition can be reliably considered continuous (see details in Schiebel 2013). This is further supported by the uniformity in pollen concentrations values throughout the record (Fig. S2).

The age-depth model is based on six samples of terrestrial organic material, most of them are short-lived organic debris (small twigs) that were extracted from the sediments by flotation and were then identified for their origin by microscopy (terrestrial vs. lacustrine, in order to avoid the need for reservoir effect calculation; Table 1). These small twigs were than radiocarbon dated and calibrated to calendar years (cal. BP) defined by the 2σ envelope error using the OxCal v.4.2.2 Age deposition model (Bronk Ramsey 2008).

In order to evaluate the reliability of the 14C dates used in the age-depth model, we have recently floated, extracted and dated additional organic material (primarily tiny twigs) from the same stratigraphic layers, and therefore support our age-depth model.

Results and discussion

A note on olive domestication

Olive orchards constitute a major component of the southern Levantine landscape today, growing primarily in the Mediterranean vegetation zone. The wild olive (Olea europaea L.) has always been a minor component in the natural Levantine environment, as is reflected in Late Pleistocene palynological diagrams (Horowitz 1979; Langgut et al. 2011; Weinstein-Evron 1983). During the Chalcolithic period a sudden and profound rise in olive pollen percentages is observed in the region’s pollen diagrams, which is considered to reflect the intensification of (domesticated) olive cultivation (Weiss, 2015: 76–77). Based on the Birkat Ram pollen record, the estimated date for the marked rise in olive pollen percentages was fixed by Neumann et al. (2007: figs 4 and 5) at c. 5000 BC and by Schiebel (2013) at c. 4200 BC (the difference probably stems from methodological issues related to the radiocarbon dating). In the Sea of Galilee and the Dead Sea the estimated date is c. 4700 BC (Litt et al. 2012; Schiebel 2013).

A new high-resolution, relatively well-dated pollen record from the Syrian coast indicates that the prominent increase in Olea abundances occurred in the northern Levant only c. 2900 BC (Sorrel and Mathis 2016: fig. 5a). This evidence is further corroborated by the vast synthesis which was conducted by Riehl (2009): based on archaeobotanical data from 138 Levantine archaeological sites (spanning the period of 5500–2600 cal. BP) it is clear that during the Early Bronze Age most olive cultivation was centred in the southern Levant (Riehl 2009: fig. 7). Yet, this study does not distinguish between EB I/II/III. Better dated is the archaeobotanical evidence from Tell Fadous in northern Lebanon which indicates significant olive exploitation in the EB II–III (Genz et al. 2009: fig. 38; Höflmayer et al. 2014). Similar evidence derives from the archaeobotanical assemblages of Tell Mastuma in northern Syria (Yasuda 1997: 258, fig. 8). Therefore, based on the palynological and archaeobotanical evidence, it seems that the initial management of olive tree crops appears to have lagged somewhat in the northern Levant. Indeed, the recent finding of the oldest remnants world wide of olive oil production supports this assumption: traces of olive oil have been found in organic residue analysis in pottery vessels from En...
Zippori (northern Israel) dated to the Late Pottery Neolithic (the Wadi Rabah phase) (Namdar et al. 2015). Additionally, at the Pottery Neolithic site of Kfar Samir, a submerged terrestrial site on the Carmel coast region of Israel dated to c. 5600 BC, both archaeological and archaeobotanical finds indicate olive oil production (Galili et al. 1997). The archaeobotanical data from Tell el-Ghassul (Lovell 2002; Meadows 2001) and the sudden dramatic rise in the southern Levant olive pollen curves suggest a middle Chalcolithic date for the domestication of the olive (Weiss 2015). The Early Bronze Age I (c. 3600–3000 BC) The EB I is characterized by the highest percentages of arboreal vegetation (up to 59.5%) (Fig. 2), indicating a very wet phase. Since our pollen record starts only in the EB IB around 3150 BC, we refer to the Sea of Galilee lower resolution pollen record (Schiebel 2013: fig. 5.1, established on the same core presented in this study), which shows that the earlier phase of the EB I was also humid. An earlier, lower resolution Sea of Galilee pollen sequence, likewise indicates that during the second half of the 4th millennium BC the regional forest vegetation was far denser than at present (Baruch 1986; 1990). The Soreq Cave isotopic record also indicates relatively humid climate conditions in the region (Bar-Matthews and Ayalon 2011: fig. 6; Fig. 2e in this article). Relatively wet climate conditions are similarly evident from geoarchaeological data from the Jezreel Valley (Adams et al. 2014; Rosen 2006: 468–69).

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15The conflicting data concerning the region of olive domestication (southern vs. northern Levant) presented here, may derive from sampling issues within the Besnard et al. (2013) study, in which samples from Israel were collected only from one location (Mount Carmel; Besnard et al. 2013: supplementary information Table S1). Further, according to the authors, owing to the highly fragmented and human-disturbed Mediterranean habitat, oleaster populations were mainly collected from present-day orchards; yet, it could not be excluded that some of the sampled trees/populations were feral (i.e. issued from cultivants). In any event, further genetic analyses are required in order to solve this regional discrepancy.
In addition to wet climate conditions, the EB I features the highest frequency of olive pollen (reaching a maximum of 50.2%) for the 3rd millennium and, in fact, for the entire Bronze and Iron Age sequence. The extremely high Olea values for the EB IB indicate the development of specialized economy focused on olive orchards and their secondary products. Relatively high olive pollen percentages were also documented in the Birkat Ram record (the Golan Heights) north of Sea of Galilee (Neumann et al. 2007: figs 4 and 5) and in the En Gedi record in the south, near the Dead Sea (representing the situation mainly in the Judean Highlands; Litt et al. 2012), indicating that during EB I large-scale olive horticulture activity took place in the entire Mediterranean zone of the southern Levant. Archaeobotanical evidence from excavations indicates that olive wood was exploited at a remarkably high level in the EB I (see review of evidence in Genz 2003). As olive grows best in its original natural habitat in the hilly Mediterranean zones, it is no wonder that this period is characterized by large-scale settlement expansion into the hill country on both sides of the Jordan during this period (Bradbury et al. 2014; Finkelstein and Gophna 1993; Table 2 in this article).

As olive yields benefit more from an even pattern of rainy days over a long period of time, than from rain that fall in sudden torrents (as is the situation today in the region), the high arboreal and olive pollen frequencies may reflect a different precipitation regime. A similar suggestion was raised by Rosen (1991: 197) based on her study in the Lachish area.

Very humid climate conditions already appear to have been prevalent during the Chalcolithic period (Clarke et al. 2016: 117; Bar-Matthews and Ayalon 2011: fig. 6) and probably contributed to an increase in settlement activity in the semi-arid regions of the southern Levant. In the Beer-sheba Valley, for example, the phenomenon of large sites such as Shiqmim and Gilat has been, at least partially, explained as reflecting wet climate and the possibility of conducting floodwater irrigation in the broad wadi beds of the region (Levy 1981; 1987). Wet climate conditions in the EB I also appear to have facilitated the initial phase in the wave of settlement in the Negev Highlands (for the chronology see Avner and Carmi 2001; Sebbane et al. 1993). The picture is similar in the semi-arid regions of Transjordan, which feature more EB I than EB II–III sites (Philip 2008: 189; Bradbury et al. 2014: 211–14). The change in settlement patterns in the Chalcolithic/EB I transition in the Beer-sheba Valley (i.e., the disappearance of these Chalcolithic centres) may be linked to a short dry event that occurred c. 3700–3600 BC (Clarke et al. 2016: 117; Bar-Matthews and Ayalon 2011: fig. 6).

The exploitation of the olive and its secondary products has been linked to both the Chalcolithic/EB I transition (Lovell 2002; 2008; Lovell and Bradley 2011) and to the advent of the urbanization process during the EB IB (Joffé 1993). In the latter period, we see extensive settlement expansion in both previously settled areas in the lowlands (e.g., the Jezreel Valley; Finkelstein et al. 2006) and in sparsely settled regions such as the highlands (ideal for olive horticulture: Bar 2014; Bradbury et al. 2014), as well as in the semi-arid Negev and southern Transjordan. Many of the new highland settlements, for example, were located in the orchard niches in western Samaria (for the situation in the early 20th century, see Finkelstein and Gophna 1993; Government of Palestine 1942–43). While expansion into the marginal areas can be understood in the context of wetter climate conditions allowing for dry farming, the demographic growth in the highlands (Table 2) should be explained by the increase in olive exploitation, which was fuelled by demand originating in Egypt, where contemporary Naqada IIIB/C1 tombs such as Abydos tomb U-j have yielded storage vessels originating from the wine and olive growing regions of the southern Levantine highlands (Finkelstein and Gophna 1993; Joffé 1993; Porat 1989; Sowada 2009).

Commercial contacts between Egypt and the southern Levant in the EB I are evident from material culture items from both of these regions found in the other (Braun 2002; de Miroshedji 2002; Sowada 2009). These contacts intensified in the EB IB as illustrated by the several hundred Levantine vessels once containing wine found in Abydos tomb U-j of the Naqada IIIA period (c. 3300; Hartung 2002), and thereafter in the later EB IB (Naqada IIIB–C) in the Levantine southern coastal plain, where the incipient Egyptian state established settlements and interacted directly with the local inhabitants (Braun 2002; Hartung 2002; de Miroshedji 2002; Regev et al. 2014; Yekutieli 2007 and references). Secondary products from southern Levantine grapes seem to have been one of the major interests of the Egyptians (Hartung 2002). Considering the intensity of olive

16On the impact of olive cultivation upon perceptions of the landscape, and attitudes to territory, see Philip 2003.

17See questions concerning origin of these vessels raised by Porat and Goren 2002.

18Grape pollen (Vitis) is under represented in the palynological spectrum due to very low pollen dispersal efficiency, and therefore can hardly be traced in the Sea of Galilee pollen record.
growth in this period, as indicated in the pollen record, olives and their oil must have been produced in quantities beyond local consumption as a ‘cash crop’. Egypt had a strong interest in oil and a wide variety of types are represented in the earliest hieroglyphic inscriptions of the Naqada III period and First Dynasty, though from what these oils were extracted, as well as their points of origin are unclear.\(^{19}\) Egyptian demand for southern Levantine goods during the EB IB (Naqada IIb–IIIC1; 3500–3000 BC) must have accelerated the expansion of the settlement system into the hill country, intensified production in the olive orchards, encouraged the development of Egyptian marketing stations in the southern coastal plain (in Naqada IIIC1), and stimulated the growth of social and political complexity in the southern Levant (Finkelstein and Gophna 1993; de Miroschedji 2002; 2009; Regev \textit{et al}. 2014).

\(^{19}\) ‘Olive oil’ as a West Semitic loanword (\textit{zayit}) into Egyptian (\textit{ddt}) does not appear until the 13th century BC (Late Bronze Age). Many words for types of oil appear in the earliest Egyptian texts of the Naqada III to Old Kingdom (i.e. the Early Bronze Age), but many of these remain undeciphered and it is unclear which might refer to olive oil. However, Ahituv (1996) has argued well that the general word for oil \textit{buq} was probably used for olive oil through much of the Pharaonic period. The Early Bronze Age II (c. 3000–2900 BC)

A slight reduction in the arboreal vegetation is documented in the EB II (Fig. 2), which might signal a minor shrinkage of the natural Mediterranean forest/maquis (36.5–40.4\%) in comparison to the EB IB that is characterized by somewhat wetter climate (arboreal pollen: 46.1–59.5\%). Still, relatively humid climate conditions prevailed in the region during this phase of the Early Bronze Age. The Soreq Cave isotopic record also point to relatively humid climate conditions in the region (Bar-Matthews and Ayalon 2011: fig. 6). The reconstruction of the Dead Sea levels shows high stands during the EB II (lake levels reached 385 m below mean sea levels; Migowski \textit{et al}. 2006: fig. 3), indicating wet climate conditions not only in the Dead Sea area but also in the northern parts of the Dead Sea drainage basin (northward to the Sea of Galilee, throughout the Jordan Valley; Fig. 1b). Therefore, EB IB and EB II are both considered, based on the available southern Levant palaeoclimate records, to be humid periods in the region. The most striking feature of the EB II is the dramatic decline in the pollen percentages of olive trees — from a peak of more than 50\% in the EB IB to a

### Table 2 Rough estimate of number of sites and total built-up area in the highlands of Cisjordan (and the western Jezreel Valley): EB I–III and the Intermediate Bronze Age

<table>
<thead>
<tr>
<th>Geographical region</th>
<th>Settlement feature</th>
<th>Early Bronze Age I c. 3600-3000 BC</th>
<th>Early Bronze Age II c. 3000-2900 BC</th>
<th>Early Bronze Age III c. 2900-2500 BC</th>
<th>Intermediate Bronze Age c. 2500-1950 BC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judean Highlands(^{2})</td>
<td>No. of sites</td>
<td>10</td>
<td>3</td>
<td>5</td>
<td>4</td>
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<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>13.5</td>
<td>13.5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Gibeon plateau and Southern Samaria(^{3})</td>
<td>No. of sites</td>
<td>24</td>
<td>26</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>34</td>
<td>45</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Northern Samaria(^{4})</td>
<td>No. of sites</td>
<td>78</td>
<td>37</td>
<td>55</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>Western Jezreel Valley(^{5})</td>
<td>No. of sites</td>
<td>45</td>
<td>22</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>107</td>
<td>32</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Lower Galilee(^{6})</td>
<td>No. of sites</td>
<td>26</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>Upper Galilee(^{7})</td>
<td>No. of sites</td>
<td>18</td>
<td>39</td>
<td>9</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
<tr>
<td>Golan Heights(^{8})</td>
<td>No. of sites</td>
<td>33</td>
<td>93</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total built-up area (hectares)</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
<td></td>
</tr>
</tbody>
</table>

1. For the location of the different regions see Fig. 3
2. From Jerusalem (included) to the Beer-sheba Valley. Data based on Finkelstein 1991a; Finkelstein and Gophna 1993; Ofer 1994.
9. Only habitation sites are included. Cemeteries are excluded. Pastoral groups are not represented.
low of 5% during the EB II. Decreased olive pollen frequencies around 2900 BC were also documented in Lake Hula (van Zeist, Baruch and Bottema 2009: fig. 5).

The EB I/II transition c. 3000 BC witnesses significant change in the organization of society and the distribution of settlements in the southern Levant. This change included the abandonment of many EB I sites and the establishment of new, often fortified settlements, which in most areas were, overall, fewer in number. Standardization of material culture items and developed networks of intra-regional exchange appear to be characteristics of this new urban society (Greenberg in press). Perhaps significantly, urban features already began to surface in the very late EB I, after the Egyptian colonies in the southern coastal plain were abandoned (Adams et al. 2014; Regev et al. 2014).

Enduring wet conditions were especially significant for the marginal regions in the south and east. In EB II the wave of settlement in the Negev Highlands peaked (Cohen 1999) and the town at Arad in the Beer-sheba Valley reached its zenith, probably becoming a gateway community for southern trade (Finkelstein 1991b). Intensive activity has also been documented further to the south, in the Uvda Valley (Avner 2006) and in southern Sinai (Beit-Arieh 2003), but note that precipitation in these regions is also influenced by other (non-Mediterranean) climate systems.

The southernmost line of urban centres in the sedentary parts of the region was at et-Tell (‘Ai’) in the highlands and at Yarmouth in the Shephelah. That this line passed far to the north of the Arad and the Negev Highlands must, therefore, have stemmed from a territorio-political, historical situation rather than from climatic conditions. In Transjordan we see a reduction in the number of settlements and a rise of larger urban centres (Harrison 1997) such as Khirbet al-Batrawi in the marginal zone of upper Wadi Zarqa (Nigro 2012). The Kerak Plateau also features expansion in the EB II, and the exploitation of the arid regions further south appears to continue unabated throughout the Early Bronze Age (Philip 2008). Overall, then, characteristics of the EB I/II transition and its regional peculiarities appear to be the result of territorio-political or economic circumstances unrelated to any change in climate condition.

The same appears to be true of the dramatic decline in olive pollen (Fig. 2). In other words, decline in the levels of olive exploitation must be tied to modifications in geopolitical and exchange patterns and not to climate change. Thus, we now have high-resolution data indicating the convergence of three significant phenomena c. 3000 BC, irrespective of changes in climate conditions: 1. EB II nucleation and urbanism in most regions of the southern Levant including in marginal zones; 2. dramatic reduction of olive horticulture; 3. cessation of intensive interaction with Egypt.

The last of these appears to have occurred earliest in this tight sequence and may be the primary factor that influenced the other two (Adams in press; Regev et al. 2014). Egyptian demand for olive oil in the EB I sustained the southern Levantine political system and stimulated high level olive exploitation. In the late EB IB the Egyptian colonies in the southern coastal plain were abandoned (in the reign of Aha; c. 3111–3045 BCE; 68%; Dee et al. 2013), thus devastating the local olive oil market. With demand dramatically reduced, a significant number of southern Levantine olive orchards were left unattended, causing a termination in the production of pollen (Langgut et al. 2014a: 130) and a decline in settlement activity in the olive producing region of the highlands (Finkelstein and Gophna 1993). The response to this dramatic change in economic circumstances seems to have involved the process of urbanization in the EB II, whereby the new urban centres provided a stable economy in the face of the collapse of a horticultural industry that relied on exchange with a single partner. Whereas the EB I southern Levant might be described to some extent as a ‘Banana Republic’, the new EB II urban system was based on a diversified economy that compensated for the former’s collapse.21

The abandonment of the Egyptian colonies in the south is paralleled by the appearance of Egyptian exchange with the northern Levant. Beams cut from cedar of Lebanon were used for roofing in the tomb of the Egyptian King Aha and his successors and north Levantine pottery was deposited in other tombs of the Early Dynastic Period (Adams in press; Köhler and Thalmann 2014; Regev et al. 2014; Sowada 2009: 37ff.). By the end of the Second Dynasty Egyptian kings are attested on objects from Byblos, on the north Levantine coast, a city which would emerge as Egypt’s premier trading partner for

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20 Even though commercial relations between Egypt and the southern Levant most probably triggered the establishment of specialized olive oil production in the region during the EB I, it does not seem to have been crucial for its continuation on a lower scale (local consumption) during the EB II–III (Salavert 2008).

21 For the diverse economy of the EB II, including the manufacture of specialized products such as Northern Canaanite Metallic Ware and the establishment of new networks of exchange, see the latest syntheses, Greenberg 2011; 2014; in press; Milewski 2011. Further, Berger (2013) showed that the EB II inhabitants of Tel Bet Yerah added some new fruits to their diet in comparison to the EB I inhabitants (Berger 2013: fig. 14).
the remainder of the 3rd millennium. Egypt’s demand for olive oil seems to have been satisfied by the northern exchange. A new, high-resolution relatively well-dated pollen record from the Syrian coast near Tell Sukas suggests a significant increase in Olea abundances in the northern Levant at c. 2900 BC (Sorrel and Mathis 2016: fig. 5a; Fig. 4c in this article). Further archaeobotanical data from Tell Fadous in northern Lebanon indicates significant olive exploitation in the EB II–III (Genz et al. 2009; Höflmayer et al. 2014). A similar picture emerges from Tell Mastuma in northern Syria where a dramatic increase in recovery of olive stones has been documented (they account for more than 80% of the assemblages of seed and fruit remains) during the later stage of the Early Bronze Age (Yasuda 1997: 258, fig. 8). 22

In sum, the EB I/II transition and the relatively short EB II is a period in which the prevailing wet climatological conditions of the EB I continued, and which also saw dramatic socio-political changes in the southern Levant. Central to these changes was a decline in the exploitation of olive orchards in the southern Levant and their rise in the northern Levant (Figs 4b and 4c, respectively). Archaeological data suggest that this transformation was associated with the near cessation of Egyptian exchange with the south and the establishment of commercial contacts with the north. This phenomenon further explains the decline in settlements across north Sinai, the overland route to the southern Levant, and the increase of maritime links with the northern coast of the Levant (Marcus 2002). With these economic developments the cultures of the southern Levant adapted through the urbanization of the EB II. In the northern Levant the new relations with Egypt steadily increased through the EB III and would become most intense after 2500 BC in the EB IV (i.e. the southern Levantine Intermediate Bronze Age), contributing to, and benefiting from, the floruit of Syrian urbanism that defines this period (Adams in press).

The Early Bronze Age III (c. 2900–2500 BC)

Based on the Sea of Galilee pollen record, the EB III is also characterized by relatively high arboreal percentages (reaching up to 46.2%), indicating the continuity of relatively wet climate conditions in the area. The Soreq Cave isotopic record also indicates humid climate conditions in the region (Bar-Matthews and Ayalon 2011), with estimated annual rainfall above 500 mm (the mean annual rainfall today; Bar-Matthews and Ayalon 2004: fig. 12), yet a slight gradual decline was documented throughout this period. 23 The Olea pollen values retain their low frequencies throughout the EB III. Still, slightly higher olive pollen percentages were recorded in the early phase of this period (c. 2900–2650 BC) in comparison to the later phase (c. 2650–2500 BC) — reaching maximum of olive pollen values of 11.3% versus 5.4%, respectively.

This means that the settlement patterns that characterize the EB III are also not climate related. We refer to the possible decline in number of sites in the central hill country (Table 2) and at the same time to the southward expansion of urban settlement there (Ras et-Tawra in the Hebron Hills [Ofer 1994: 99] and Tell er-Rumeideh [Hebron, Eisenberg 2011]). Southward expansion of urbanism can also be observed in the Shephelah (e.g., Lachish, Tel Halif), the southern coastal plain (Tell el-Hesi, Tel Poran, Ashkelon, Tell es-Sakan [de Miroshchidji and Sadeq 2008 for the latter]) and the southern basin of the Dead Sea (Bab edh-Dhra, Numeira [Chesson and Goodale 2014; White et al. 2014], etc.). This phenomenon (and the decline of the EB II Arad desert polity) was probably related to the takeover of the southern copper trade by urban centres in the southern part of the settled land (for EB III copper production at Khirbet Hamrat Ildan in the Wadi Faynan area see Levy et al. 2002).

Based on data cited above, the large-scale olive horticulture activity in the northern Levant began only after the EB I; a pronounced reduction in olive frequencies was documented there only at the end of the Late Bronze Age and the beginning of the Iron Age I (Sorrel and Mathis 2016: fig. 5a; Fig. 4c in this article). The Sea of Galilee pollen record provides a mirror image: the lake’s Olea pollen percentages retained their low values from the EB II until the end of the Late Bronze Age, while at the beginning of the Iron Age I, around 1100 BC, they increased dramatically. 24 In both Levantine records — south and north — periods of high olive distribution point to export-targeted production, while periods of relatively

23The differences between the pollen and the isotopic records lie only within the fluctuations of the general trends, since both records point to relatively humid climate conditions during the period under discussion. The slight discrepancies may derive from differences in sampling resolution (the Soreq Cave record was sampled in higher resolution), and/or differences within the dating methods (14C vs. Uranium-Thorium) and/or can be related to the slower responses of the vegetation in comparison to the more sensitive isotopic proxy.

24The peak in Olea frequencies during the Iron Age I has also been noted in the high resolution Dead Sea (Zereilim) palynological record (Langgut et al. 2014b: fig. 2).
low olive percentages (which, however, are still above their frequencies as a natural element in the Mediterranean forest — Horowitz 1979; Langgut et al. 2011; Weinstein-Evron 1983), indicate cultivation mostly aimed at local consumption.

The Intermediate Bronze Age (c. 2500–1950 BC)

A much-discussed theory suggests that a global-scale climatological event occurred around 2200 BC (the 4.2 ka event), characterized by a substantial reduction in annual precipitation across the Near East (c. 30–50%; Weiss et al. 1993; update in Weiss 2014). Researchers have proposed relating this supposed dry event to the collapse of the Akkadian empire, Old Kingdom in Egypt, and the southern Levantine urban EB III (Bell 1971; Weiss et al. 1993; Wiener 2014). This theory has recently been challenged on different accounts (references in Finkelstein and Langgut 2014: n. 27). In any event, recent radiocarbon studies of the southern Levant now place the end of the EB III at c. 2500 BC (Regev et al. 2012a; Regev et al. 2014), that is, several centuries earlier than the supposed 4.2 ka event; therefore, the dissolution of the EB III urban society can no longer be understood in terms of climate change.

From the palynological perspective, the Intermediate Bronze Age should be divided into two stages, an early phase (c. 2500–2250 BC) and a later phase (c. 2250–1950 BC) differentiated by an increase in moist conditions in the latter, followed by a dry

Figure 4 Olive cultivation: southern Levant vs. northern Levant. 4a. Total Mediterranean arboreal pollen, Sea of Galilee (this study); 4b. *Olea* pollen, Sea of Galilee (this study); 4c. *Olea* pollen, Syrian coast near Tell Sukas (after Sorrel and Mathis 2016).

This figure shows that the Sea of Galilee (b) and the Syrian (c) olive pollen records provide a mirror image: the Sea of Galilee’s *Olea* pollen percentages retained their low values from the EB II until the end of the Late Bronze Age, while at the beginning of the Iron Age I, around 1100 BC, they increased dramatically. The northern olive record shows exactly the opposite trend. In both Levantine records — south and north — periods of high olive distribution point to export aimed production, while periods of relatively low olive percentages, indicate cultivation mostly aimed at local consumption.

The dating of the periods follows the radiocarbon results for Levantine sites from the last decade (Regev et al. 2012a for the Early Bronze Age and the transition to the Intermediate Bronze Age; Finkelstein and Piasetzky 2010; Toffolo et al. 2014 for the Iron Age); the transition from Middle to Late Bronze Age, currently broadly fixed in the mid-16th century BC, is yet to be radiocarbon dated (Bietak 2002 for the beginning of the Middle Bronze Age).
event in the MB I (Finkelstein and Langgut 2014).25 The pollen record reported here demonstrates that the regions in the southern Levantine pollen catchment zones experienced no substantial change in moisture in the transition from the EB III to the Intermediate Bronze Age. In comparison to the EB III, the early phase of the Intermediate Bronze Age shows only a slight reduction in the distribution of the Mediterranean trees (not exceeding 39.2%), while olive trees retain their low values (6.4–13.0%). This scale of olive horticulture is also evident in two additional high resolution pollen profiles from the region: Ze’elim on the western shore of the Dead Sea (Langgut et al. 2014b: fig. 2) and Birkat Ram in the northern Golan Heights (Neumann et al. 2007: fig. 4), as well as in the lower resolution records from Lake Hula in the north (van Zeist et al. 2009: fig. 5) and En Gedi along the western shore of the Dead Sea (Litt et al. 2012: fig. 3).26

A short dry event can be seen around 2300 BC; it is represented by a pronounced short duration decline in arboreal pollen at the Sea of Galilee to a minimum of 24.4%. But the later stage of the Intermediate Bronze Age (c. 2250–2000 BC) is characterized by an increase in Mediterranean tree pollen, representing more humid conditions. This relatively humid period was rather stable, with arboreal pollen in the range of 43.2–47.5%. The arboreal pollen decreased significantly only at the end of the period, after c. 2000 BC (to a minimum of 22.2%) and lasted through the MB I, until c. 1800 BC (Finkelstein and Langgut 2014: fig. 3); representing a shrinkage of the natural Mediterranean forest/maquis. Based on the lithological evidence from the Dead Sea, it seems that the decline in arboreal pollen percentages was a result of dryer climate conditions: in the Ze’elim-Dead Sea section at the end of the Intermediate Bronze Age sediments were deposited in a shore environment; sands and a thin beach ridge were embedded from c. 2000 BC to c. 1800 BC (Langgut et al. 2014b: fig. 2), representing shrinkage of the Dead Sea lake configuration as a result of a drop in the lake levels (Kagan et al. 2015: table 2 and fig. 4). The analysis of δ13C values in crop plants remains from several Levantine sites indicates increasing aridity during the period of 2000–1600 BC, in comparison to the previous period (2700–2000 BC) that was characterized by relatively high available moisture (Riehl et al. 2008).

With regard to olive exploitation, the regional palynological records that are proxies to the hilly areas — Ze’elim in the Dead Sea (Langgut et al. 2014b: fig. 2), En Gedi in the Dead Sea (Litt et al. 2012: fig. 3) and Lake Hula (van Zeist et al. 2009: fig. 5) — all demonstrate a peak in olive percentages in the second half of the Intermediate Bronze Age (c. 2200–2000 BC), indicating the expansion of olive horticulture in these areas. This Olea increase was not documented in the Sea of Galilee record, where olive percentages continued their previous values, not exceeding 13.4%.

The pastoral-nomadic theory for the Intermediate Bronze Age society has long been challenged. To be sure, there was an exodus from the cities of the EB

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25 The Soreq Cave speleothems isotopic record points to decrease in precipitation ~2000–1900 BC, which is mainly evident in the increasing values of the δ13C with a low at 2000 BC. However, the estimated annual rainfall during this aridity did not reach below 500 mm (the mean annual rainfall today; Bar-Matthews and Ayalon 2004: figs 10b and 12). Declining Dead Sea levels during the period of 2250–1900 BC also indicate increased arid conditions (Migowski et al. 2006: fig. 3). The isotopic composition of tamarisk wood from the Mount Sedom Cave on the south-western margins of the Dead Sea shows a succession of droughts at ~2200–1930 BC, with a prominent but short-lived dry event at approximately 2020 BC, followed by a longer event at approximately 1930 BC that ultimately killed the tree (Frumkin 2009), meaning that the dry event could have lasted even longer.

26 We were unable to compare our results with the late Holocene palynological study conducted by Baruch (1986) in Sea of Galilee, due to its low sampling resolution.
III (Greenberg in press), but there appears to have been regional variability in economic strategies, with most regions in the southern Levant subsisting on agro-pastoralism in sedentary villages, with the largest number of villages in the fertile Jezreel and Hula Valleys (Adams in press). In the former, for example, the number of Intermediate Bronze Age sites exceeds what is known for the EB II–III (Finkelstein and Langgut 2014; table 3; Finkelstein et al. 2006; for Transjordan see Palumbo 2008). The olive pollen data further supports the picture of extensive settled communities. The palynological records show that with the dissolution of EB III cities (and diminishing number of sites in many areas in the highlands — Table 2), olive orchards continued to be maintained at the same levels, and were perhaps even extended. Experimental study shows that olive orchards show a strong decline in pollen production following abandonment (Langgut et al. 2014a: 129–31), and therefore, sustained levels of pollen in the EB III/Intermediate Bronze transition is significant evidence for continuity in horticultural activity. In other words, the cultivation of olives in the Intermediate Bronze Age indicates a settled population with continuing horticultural expertise (Grigson 1995). Still, in both periods the relatively low olive values (in the Sea of Galilee not exceeding 13.0%), suggest that orchards were grown primarily for local consumption.

**Summary and conclusions**

In this paper we have investigated links between climate conditions, olive cultivation and historical processes in the southern Levant during the Early Bronze and Intermediate Bronze Ages. The data are based on the integration of our recently produced, high-resolution, well-dated Sea of Galilee pollen record, other, lower resolution regional pollen records, and the archaeological evidence, especially settlement patterns. Special attention has been paid to the highlands parts of the region (Table 3) because of their importance for olive cultivation.

We suggest that the southern Levant was the region where olives were first domesticated — in the late Neolithic–early Chalcolithic period. This is based on the marked rise in olive pollen curves in the southern Levant palynological records dated to the early Chalcolithic period (Litt et al. 2012; Neumann et al. 2007; Schiebel 2013; van Zeist et al. 2009) and the earliest evidence for olive oil production (Galili et al. 1997) plus molecular evidence for actual olive oil (Namdar et al. 2015), which are dated to the late Neolithic period. This laid the foundations for large-scale olive oil production as early as the EB I, when olive oil was widely produced on an industrial scale, and had become an important trading commodity with Egypt.

The main conclusions of this study are as follows:

1. The Sea of Galilee pollen record shows that in general the Early Bronze and the Intermediate Bronze Ages were characterized by humid climate conditions, suitable for olive horticulture. A very wet climate was prevalent during the EB I (c. 3600–3000 BC), while a minor reduction in moisture was documented during the EB II–III (c. 3000–2500). Another slight decline in moisture was recorded during the early phase of the Intermediate Bronze Age (c. 2500–2250), with a more pronounced short duration dry event within this phase, c. 2300 BC. At the later phase of the period (c. 2250–2000) wetter climate conditions were prevalent in the region. At the end of the Intermediate Bronze Age and during most of the Middle Bronze Age I, a significant, longer drier episode was documented (c. 2000–1800 BC; Finkelstein and Langgut 2014). There is no straightforward correlation between these changes, and transformations in urban life and other settlement patterns as most of the latter were stimulated by human induced processes.

2. The dramatic decline in olive pollen percentages during the EB I/II transition was linked to geopolitical changes. Based on the archaeological evidence, overland transportation between the southern Levant and Egypt weakened and maritime links between Egypt and the northern Levant intensified. Botanical and archaeological data from the northern Levant corroborates this picture. In general, the southern and northern Levant olive pollen curves show a ‘mirror image’ throughout the Bronze and Iron Ages, reflecting shifts in balance between regions from which olive oil was exported.

**Supplementary material**

Supplementary material for this article can be accessed online at http://dx.doi.org/10.1080/00758914.2016.1193323.

**Acknowledgments**

This study was funded by the European Research Council under the European Community’s Seventh Framework Program (FP7/2007–2013)/ERC grant agreement no. 229418. We wish to thank Michael Kitin for pollen sample preparation and Ahuva Almogi-Labin for her help in collecting recent pollen samples. Tal Langgut, Mark Cavanagh and Itamar Ben-Ezra are acknowledged for their help in drawing...
the different figures. Thanks are also due to Mordechai Stein (Israel Geological Survey) and Thomas Litt and his team from the Bonn Palynological Laboratory (University of Bonn) for their part in the extraction of the Sea of Galilee core. We would like to thank the Editor, Philip Graham, and the two anonymous reviewers for their constructive comments.

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