

This discussion paper is/has been under review for the journal Climate of the Past (CP).
Please refer to the corresponding final paper in CP if available.

Impacts of climate and humans on the vegetation in NW Turkey: palynological insights from Lake Iznik since the Last Glacial

A. Miebach^{1,*}, P. Niestrath¹, P. Roeser¹, and T. Litt¹

¹Steinmann Institute for Geology, Mineralogy, and Paleontology, University of Bonn, Germany

* Invited contribution by A. Miebach, recipient of the EGU Young Scientists Outstanding Poster Paper Award 2015.

Received: 15 October 2015 – Accepted: 26 October 2015 – Published: 10 November 2015

Correspondence to: A. Miebach (a.miebach@uni-bonn.de)

Published by Copernicus Publications on behalf of the European Geosciences Union.

CPD

11, 5157–5201, 2015

Impacts of climate
and humans on the
vegetation in NW
Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Abstract

The Marmara region in northwestern Turkey provides a unique opportunity for studying the vegetation history in response to climate changes and anthropogenic impacts because of its location between different climate and vegetation zones and its long settlement history. Geochemical and mineralogical investigations of the largest lake in the region, Lake Iznik, already registered climate related changes of the lake level and the lake mixing. However, a palynological investigation encompassing the Late Pleistocene to Middle Holocene was still missing. Here, we present the first pollen record of the last ca. 31 ka cal BP (calibrated kilo years before 1950) inferred from Lake Iznik sediments as an independent proxy for paleoecological reconstructions. Our study reveals that the vegetation in the Iznik area changed generally between steppe during glacial/stadial conditions, forest-steppe during interstadial conditions, and oak dominated mesic forest during interglacial conditions. Moreover, a pronounced succession of pioneer trees, cold temperate, warm temperate, and Mediterranean trees appeared since the Lateglacial. Rapid climate changes, which are reflected by vegetation changes, can be correlated with Dansgaard–Oeschger (DO) events such as DO-4, DO-3, and DO-1, the Younger Dryas, and probably also the 8.2 event. Since the mid-Holocene, the vegetation was influenced by anthropogenic activities. During early settlement phases, the distinction between climate-induced and human-induced changes of the vegetation is challenging. Still, evidence for human activities consolidates since the Early Bronze Age (ca. 4.8 ka cal BP): cultivated trees, crops, and secondary human indicator taxa appeared, and forests got cleared. Subsequent fluctuations between extensive agricultural use and regeneration of the natural vegetation become apparent.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



1 Introduction

The reconstruction of past climatic and environmental conditions is crucial to understand the living conditions and migration processes of former societies. After the first spread of modern humans into Europe during the Last Glacial (e.g., Benazzi et al., 2011; Higham et al., 2011), different population dynamics into and out of Europe followed. These population dynamics also include the spatial expansion of farming and husbandry, which happened between ca. 11 600 and 5500 years ago. The Marmara region, situated between the Mediterranean Sea and the Black Sea at the principal corridor of human dispersal from Africa via the Middle East to the Balkans, functioned as an important bottleneck for all migrated societies (Richter et al., 2012).

The Last Glacial is characterized by unstable climatic conditions changing between glacial/stadial conditions and milder interstadial conditions. Several rapid climate changes described as Dansgaard–Oeschger (DO) events (Dansgaard et al., 1982) and Heinrich events (Heinrich, 1988; Bond et al., 1992) occurred. DO events are associated with an abrupt warming followed by a gradual re-cooling, which are well documented in the Greenland ice core records (e.g., NGRIP members, 2004). Heinrich events are associated with cold periods (also called Heinrich Stadials (HS); Sanchez Goñi and Harrison, 2010), when ice-rafted debris deposited in the North Atlantic due to massive discharges of icebergs (Bond et al., 1992). Climatic imprints related to DO events and HS are documented in many northern-hemispheric records (e.g., Hemming, 2004; Sanchez Goñi and Harrison, 2010; Müller et al., 2011; Panagiotopoulos et al., 2014; Pickarski et al., 2015). However, the magnitude, nature, and duration of each event might have varied from region to region (Sanchez Goñi and Harrison, 2010). Therefore, further records, also in Turkey, are needed to establish a complete picture of the influence of rapid climate changes on environmental conditions (Fletcher et al., 2010).

Lake Iznik, the largest lake in the Marmara region, serves as a valuable archive to study the relationship between vegetation, climate, and anthropogenic activities. The detection of human impacts on the vegetation is particularly interesting because the

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



eastern Marmara region has a long occupation history, and archaeological settlements are in close proximity to Lake Iznik (e.g., Roodenberg and Roodenberg, 2008).

Previous studies reconstructed the paleoenvironmental and tectonic history of the Iznik Basin and investigated Lake Iznik's recent and paleo-limnology since the late Pleistocene based on seismicity, sedimentology, geochemistry, and minerology (Alpar et al., 2003; Franz et al., 2006; Öztürk et al., 2009; Roeser et al., 2012; Ülgen et al., 2012; Viehberg et al., 2012; Roeser, 2014). Those studies also revealed climate related changes of the lake level and the lake mixing (Roeser et al., 2012; Ülgen et al., 2012; Roeser, 2014). A preliminary pollen analysis inferred from Lake Iznik sediments was published by Ülgen et al. (2012). The pollen record, which is only presented in ecological plant groups, encompasses the last 2400 years. A palynological investigation of sediments from Lake Iznik encompassing the late Pleistocene to late Holocene was still missing.

To provide a better view on the environmental conditions in the Marmara region during the last ca. 31 000 years, we investigated the pollen assemblage and selected non-pollen palynomorphs (NPP) of a ca. 18 m composite profile from Lake Iznik. It comprises a continuous and undisturbed sediment record with a robust chronology (Roeser et al., 2012; Ülgen et al., 2012; Roeser, 2014). Here, we present a new vegetation and climate study, which also provides insights into human activities in the catchment area of Lake Iznik by showing different phases of human exploitation on the vegetation. It demonstrates the sensitivity of the vegetation in the eastern Marmara region to reflect northern hemispheric climate changes documented in Greenland ice cores (NGRIP members, 2004). The comparison with other records reflects the complex pattern of vegetation dynamics in the Eastern Mediterranean.

CPD

11, 5157–5201, 2015

Impacts of climate
and humans on the
vegetation in NW
Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



2 Study area

2.1 Regional setting

Lake Iznik (Turkish: İznik Gölü) is located in the southeast of the Turkish Marmara region (Fig. 1). The Marmara region is a tectonically active area surrounding the Mar-
mara Sea. Lake Iznik lies at the middle strand of the North Anatolian Fault, which is the
boundary between the Anatolian and Eurasian plate (Öztürk et al., 2009).

With a surface area of 313 km², 32 km in length and 12 km in width, Lake Iznik is the
largest lake in the Marmara region (Fig. 2). Lake Iznik is situated 85 m above present
mean sea level (m.a.s.l.) and reaches a maximal water depth of 80 m (Wester, 1989;
Franz et al., 2006). The alkaline freshwater lake receives fluvial input from five main
rivers (Nadir, Kuru, Kara, Kiran, and Sölöz), while the only output stream is Karsak
(Viehberg et al., 2012). The catchment area is about 920 km² (Wester, 1989). Several
mountain ridges surround the Iznik Basin: Samanlı Mts. in the north, Gemiç Mts. in the
southwest, and Katirli Mts. in the south. Their summits range from 810 to 1293 m.a.s.l.
(Öztürk et al., 2009).

2.2 Current climate

Lake Iznik's catchment area is situated in a climatic transition zone, which is influenced
by the Mediterranean climate and the Pontic climate. Warm, dry summers and mild,
moist winters are typical for the Mediterranean climate (Köppen, 1900). In contrast, the
Pontic climate is characterized by an absence of summer drought due to higher pre-
cipitation throughout the year and lower mean temperatures (Kürschner et al., 1997).
The annual average air temperature at the Iznik Basin is around 14.4 °C, and the
monthly average minimal air temperature never drops below 0 °C (Wester, 1989; Ta-
ble 1). Since Lake Iznik is surrounded by mountain ranges, one can find notable lower
average temperatures close by (Akbulak, 2009). Most precipitation falls in winter and
spring, whereas June to September are arid months. A gradient in precipitation from

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



west to east is characteristic not only for the Iznik Basin (Orhangazi – Iznik; Table 1) but also for the whole region (Aegean Sea/Marmara Sea – Central Anatolia; Mayer and Aksoy, 1986; Wester, 1989). Precipitation can rise up to about 1200 mm in higher elevations near Lake Iznik (Akbulak, 2009). The prevailing wind direction is west in summer and east in autumn and winter. The wind is unstable in spring and changes directions (Wester, 1989).

2.3 Current vegetation

The potential natural vegetation of northwestern Anatolia is divided into five vegetation zones, from which three directly influence the catchment of Lake Iznik (Fig. 3).

A band of Euxinian and sub-Euxinian mesic deciduous and mixed forest extends along the southern and eastern coasts of the Black Sea (Zohary, 1973; Shumilovskikh et al., 2012). In northwestern Anatolia, it reaches into Thrace (European Turkey) and south of the Marmara Sea almost to the Aegean Sea. The forest is dominated by oriental beech (*Fagus orientalis*) and deciduous oaks (Zohary, 1973). Other important summer-green trees include *Fagus sylvatica*, *Alnus glutinosa*, *Acer campestre*, *Populus tremula*, *Carpinus*, *Fraxinus*, and *Ulmus* (Mudie et al., 2002). Conifers like *Pinus sylvestris*, *P. nigra*, *Abies nordmanniana*, and *Picea orientalis* are present in low altitudes, but they become more frequent in higher altitudes (Zohary, 1973). The Pontic forest is associated with more than 600 mm mean annual precipitation (Roberts and Wright, 1993). Zohary (1973) divided the vegetation zone into an Euxinian type near the coast and a more continental sub-Euxinian type. The rain shadow of the Pontic Mountains favors the latter type, which is characterized by a high amount of *Carpinus* and *Pinus nigra*. The natural tree line near Lake Iznik reaches an elevation of about 2000 m (Louis, 1939).

The Aegean coasts and southeastern coasts of the Marmara Sea are characterized by a climax of Mediterranean woodland. According to Zohary (1973), there is an evergreen subzone from sea level to an elevation of 1000 m and an oro-Mediterranean subzone reaching up to 1600 m. The evergreen subzone is dominated by *Quercus*

calliprinos, *Olea europaea*, *Ceratonia siliqua*, *Myrtus communis*, *Phillyrea media*, *Arbutus*, and *Pistacia*. But there are also some deciduous and coniferous elements like *Quercus infectoria*, *Q. ithaburensis*, *Styrax officinalis*, *Crataegus azarolus*, *Spartium junceum*, *Juniperus phoenicea*, and *Pinus brutia* (Zohary, 1973; van Zeist et al., 1975).

- 5 The oro-Mediterranean subzone is dominated by summer-green trees and conifers. Important elements are deciduous oaks (mainly *Quercus cerris*) and pines (mainly *Pinus nigra*). Additionally, the range of characteristic arboreal taxa includes: *Ostrya carpinifolia*, *Castanea sativa*, *Fraxinus ornus*, *Cotinus coggygria*, *Fontanesia phillyreoides*, *Acer*, *Juniperus*, *Cornus*, *Buxus*, several Rosaceae (e.g., *Crataegus monogyna*), and several Fabaceae (e.g., *Colutea arborescens*; Zohary, 1973).

- 10 However, the potential natural vegetation differs considerably from the vegetation one will find nowadays, which is shaped by human activities of several thousand years (Mayer and Aksoy, 1986). Due to agriculture (e.g., olive cultivation, cereal cropping, and husbandry), forests were cleared, large areas were overgrazed, landscapes were
15 burned, and soils eroded (Zohary, 1973; Mayer and Aksoy, 1986). Former Mediterranean woodlands degraded to macchia vegetation with *Arbutus*, *Juniperus*, *Pistacia*, *Phillyrea latifolia*, *Spartium junceum*, and evergreen oaks (Kürschner et al., 1997; Atalay et al., 2014). In case this xeromorphic shrub vegetation were further overexploited, it degraded to phrygana vegetation. These are open landscapes with herbs and dwarf
20 shrubs, which are often thorned (Kürschner et al., 1997). An important element of the Eastern Mediterranean phrygana is the dwarf shrub *Sarcopoterium spinosum*, which benefits from land degradation and extensive grazing (Le Houërou, 1981; Bottema and Woldring, 1990).

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



3 Material and methods

3.1 Core setting, composite profile, and age-depth model

For the current study, a composite profile was constructed by using different sediment cores, which were collected in two separate coring campaigns. All of these cores descended from the central sedimentary ridge of Lake Iznik, which separates the northern and the southern basin, at a water depth of ca. 50 m (Fig. 2). The cores were recovered from floating platforms with the help of percussion piston corers (Roeser et al., 2012; Ülgen et al., 2012).

Sediment samples for pollen analyses originated from different cores: core IZN05/LC1 (coring location: 40°26.033 N, 29°31.999 E; recovered in summer 2005) from the composite profile IZN05/SC4E&LC1 (Ülgen et al., 2012) and cores IZN09/LC2 (coring location: 40°26.57 N, 29°32.35 E) and IZN09/LC3 (coring location: 40°26.92 N, 29°32.61 E; both recovered in autumn 2009) from the composite profile IZN09/LC2&LC3 (Roeser et al., 2012).

The composite profiles IZN05/SC4E&LC1 and IZN09/LC2&LC3 could be clearly correlated through Ca/Ti ratios. The tie point between the two composite profiles is a tephra from a Vesuvius eruption, an Avellino Pumice (AP) tephra, which was geochemically identified in both records. The final composite profile has a composite length of ca. 18 m (Roeser et al., 2012). The age-depth model from Roeser (2014) was extended with dates from core IZN05/LC1 (Ülgen et al., 2012) in order to expand it to recent times (Roeser et al., 2015). Sampling depths of radiocarbon ages and tephra layers, which were used to establish the age-depth model, are shown in the Supplement.

3.2 Palynological analyses

33 sediment samples from core IZN05/LC1 were taken in a mean resolution of 12.6 cm ranging from the uppermost part of the core (0.51 m composite depth) to the AP tephra

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



(4.58 m composite depth). After a first low-resolution screening of the composite profile IZN09/LC2&LC3, additional samples were processed in sections where climatic events were already known from geochemical analysis (Roeser et al., 2012; Roeser, 2014), the temporal resolution was very low, or palynological events were detected. Finally, 78 sediment samples from composite profile IZN09/LC2&LC3 were taken in a mean resolution of 17.5 cm ranging from the AP tephra to the end of the record (18.14 m composite depth). All samples had a sediment volume of mostly ca. 4 cm³ (sampled with plastic syringes).

For the pollen preparation of the 111 sediment samples, we followed a standard protocol described in Faegri and Iversen (1989). The chemical treatment included 10 % hot hydrochloric acid (HCl) to remove carbonates (10 min), 40 % hydrofluoric acid (HF) to remove silicates (at least 48 h), 10 % hot HCl (10 min), glacial acetic acid ($C_2H_4O_2$), hot acetolysis with 1 part concentrated sulfuric acid (H_2SO_4) and 9 parts concentrated acetic anhydride ($C_4H_6O_3$) to remove cellulose (max. 3 min), and $C_2H_4O_2$. Coarser particles than 200 μm and finer particles than 10 μm were removed by sieving and ultrasonic sieving, respectively. Lycopodium tablets with 18584 ± 371 spores were added to each sample as markers to calculate absolute pollen and NPP concentrations (Stockmarr, 1971). With the help of the concentration and sedimentation rates, influx (pollen accumulation) rates were calculated. Samples were preserved in glycerol and were stained with safranin.

Microscopic analyses were carried out with Zeiss Axio Lab.A1 light microscopes using a magnification of 400. The pollen reference collection of the Steinmann Institute (University of Bonn) and palynomorph keys (Faegri and Iversen, 1989; Moore et al., 1991; Reille, 1995, 1998, 1999; Chester and Raine, 2001; Beug, 2004) were used for the palynomorph identification. We mainly followed Beug (2004) for the nomenclature of pollen types. A minimum of 500 terrestrial pollen grains were counted in each sample (joint analyses by Phoebe Niestrath (0.51–4.58 m) and Andrea Miebach (4.58–18.14 m)). Obligate aquatic plants were excluded from the total pollen sum to exclude local taxa growing in the lake (Moore et al., 1991). Furthermore, destroyed,

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

▶

▶

[Back](#)

Close

Full Screen / Esc

[Printer-friendly Version](#)

Interactive Discussion



Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



immature, and unknown pollen were excluded from the total pollen sum, which was used to calculate percentages of the pollen assemblage. Pollen types were grouped as follows: conifers, arid trees and shrubs (*Ephedra*, *Haloxylon*, *Hippophaë rhamnoides*), Mediterranean trees and shrubs (*Celtis*, *Ceratonia siliqua*, Ericaceae, *Fraxinus ornus*, *Olea europaea*, *Phillyrea*, *Pistacia*, evergreen *Quercus*), temperate trees and shrubs (all other trees and shrubs), steppic herbs (*Artemisia*, Chenopodiaceae), and other herbs.

Pollen diagrams were prepared with Tilia, Version 1.7.16 (©1991–2011 Eric C. Grimm). A stratigraphically constrained cluster analysis using a square root transformation was applied by CONISS (Grimm, 1987). All taxa with more than 2 % of the total pollen sum and the sum of arboreal pollen (AP) were used for the cluster analysis. On this basis and visual pattern, local pollen assemblage zones (LPAZ) were determined.

4 Results and discussion

Selected pollen and spore data are presented in Fig. 4. According to the present age-depth model (Roeser et al., 2015), the temporal resolution of the record varies between 1139 and 57 years with an average of 278 years. 8 local pollen assemblage zones (LPAZ) were defined and are summarized in Table 2. The LPAZ are in agreement with previously defined lithological units, which are known to relate to specific climate phases (Roeser et al., 2012; Roeser, 2014). A complete pollen diagram with all taxa can be found in the Supplement.

4.1 MIS 3-2 transition: ca. 31.1–28.4 ka cal BP (LPAZ 8)

Lake Iznik's LPAZ 8 corresponds to the transition of Marine Isotope Stages (MIS) 3 and 2 (definition after Lisiecki and Raymo, 2005). The pollen assemblage documents a predominance of steppe vegetation with dwarf shrubs, herbs, and grasses dominated by wormwood (*Artemisia*), Tubuliflorae, Chenopodiaceae, and Poaceae (Fig. 4). Such

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



mer temperatures (Roeser et al., 2012; Fig. 5). Furthermore, an almost absence of the green algae *Pediastrum* and *Botryococcus* and the occurrence of dinoflagellate cysts of *Spiniferites cruciformis* at Lake Iznik (Fig. 5) suggest a low aquatic bioproductivity and oligotrophic conditions (low nutrient level; Jankovská and Komárek, 2000; Kouli et al., 2001). Increasing *Spiniferites cruciformis* amounts might be a result of higher water temperatures (Shumilovskikh et al., 2014).

The comparison of this study to vegetation studies from the southern Black Sea (Shumilovskikh et al., 2014; Fig. 6) and the Marmara Sea (core MAR94-5; Mudie et al., 2002) suggests a rather uniform vegetation in NW Turkey. However, higher pollen concentrations and higher abundances of AP in core MAR94-5 suggest a denser vegetation and more favorable conditions for tree growth in the central Marmara region (Mudie et al., 2002). The spread of deciduous oaks during DO events seems to be a general pattern in the north-eastern Mediterranean, although several pollen records do not show a response to every interstadial. In fact, climatic conditions during DO-3 and DO-4 were probably still too harsh or favorable conditions lasted too short that several records do not show significant changes in the vegetation (Fletcher et al., 2010 and references therein).

A temporal offset of the Lake Iznik record is recognized by comparing it to the NGRIP $\delta^{18}\text{O}$ record (NGRIP members, 2004; Fig. 6) and the isotopic record from the well-dated Sofular Cave in northern Anatolia (Fleitmann et al., 2009; Fig. 6). Fleitmann et al. (2009) already described an age difference for the onset of DO-4 and DO-3 of the Sofular Cave compared to the NGRIP data of 586 and 277 years, respectively. The temporal offset of Lake Iznik's record is even larger. Although timing and amplitude of climate changes and its impact on vegetation can differ from region to region, slight inaccuracies in the lower part of the current age-depth model for Lake Iznik are likely.

4.2 Pre-LGM and LGM: ca. 28.4–18.4 kcal BP (LPAZ 7)

A steppe vegetation predominated in the Iznik area during the pre-LGM and LGM (Last Glacial Maximum, i.e. the period with maximal global ice volume dating back

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



to 23–19 kcal BP according to Yokoyama et al., 2000, and Tzedakis, 2007). The abundance of the arboreal species *Hippophaë rhamnoides* suggests a cool and dry steppe (Tarasov et al., 1998), which is supported by a very low vegetation productivity (low pollen concentration and influx; Fig. 4). In contrast to adjacent LPAZs, a significant increase in percentages of the herbaceous Tubuliflorae and Liguliflorae as typical openland indicators (Litt et al., 2012) is evident. The vegetation composition and the extremely low vegetation productivity suggest that precipitation rates were very low, probably comparable with 100–300 mm annual precipitation of today's Central Anatolian dwarf shrub steppe (Roberts and Wright, 1993; Fig. 3). Pollen influx values of all taxa are lower than in adjacent LPAZ, which indicates that high percentages are not a result of increased pollen amounts of the concerned taxa but result from statistical effects. The high AP ratio must therefore be interpreted with cautions. Nevertheless, some taxa like Tubuliflorae, Liguliflorae, *Hippophaë rhamnoides*, and *Pinus* were more abundant compared to other taxa. This could be explained by (1) they were not as much effected by the harsh conditions as other taxa, (2) these plants lived in special habitats where microclimatic conditions were more favorable, or (3) pollen were brought by long distance transport. Due to the low pollen production by the upland vegetation of the Iznik area during the LPAZ 7 phase, the proportion of long-distance transported pollen is much larger (especially for *Pinus*; van Zeist et al., 1975; Faegri and Iversen, 1989).

The geochemical and sedimentological results from Lake Iznik indicate a low lacustrine bioproductivity coupled to a low endogen carbonate production (low Ca/Ti ratios) as a result of lower summer temperatures during the LGM (Roeser et al., 2012; Fig. 5). The deposition of dropstones within a clay matrix suggest the occurrence of at least a partial ice cover of Lake Iznik (Roeser, 2014). Still, the water conditions allowed the occurrence of *Botryococcus* (Fig. 5), which has a wider ecological tolerance than *Pediastrum* and can also survive in very cold or nutrient poor waters (Jankovská and Komárek, 2000). Peaking values of the magnetic susceptibility are ascribed to the deposition of the Y2 tephra (Roeser et al., 2012; Fig. 5), which is related to the

ca. 22 ka calBP Cape Riva eruption of Santorini (Pichler and Friedrich, 1976; Eriksen et al., 1990).

In general, most paleoclimate records and models of the Eastern Mediterranean agree on cold and arid conditions during the LGM (van Zeist and Bottema, 1988; Robinson et al., 2006; Tzedakis, 2007; Valsecchi et al., 2012 (Fig. 6); but also see Şenkul and Doğan, 2013 for another conclusion). Likewise the pollen record from southern Black Sea indicates colder and drier climatic conditions compared to today, although an increased moisture availability compared to MIS 3 allowed the expansion of woodland (Shumilovskikh et al., 2014; Fig. 6).

Though, ambiguous data are present for the millennia prior to the LGM, including the detection of rapid climate events. Although many high-resolution Eastern Mediterranean pollen records generally document vegetation changes in response to DO events, the majority of records do not register DO-2 (reviewed by Fletcher et al., 2010). Compared to other DO events, the amplitude of the $\delta^{18}\text{O}$ curve from North Greenland in response to DO-2 is in fact quite low (NGRIP members, 2014; Fig. 6). However, the Tenaghi Philippon pollen record indicates the spread of pines in response to DO-2 (Müller et al., 2011). A vegetation response to DO-2 is not visible in Lake Izник's pollen record because the environmental advantages did probably not cross a critical threshold for tree growth in the eastern Marmara region (but also note the rather low temporal resolution of samples; Table 2). Likewise, there is no unambiguous evidence for a vegetation change in response to Heinrich Stadial 2 (26.5–24.3 ka BP; Sanchez Goñi and Harrison, 2010) in Lake Izник's pollen record. Environmental changes related to this rapid climate event were documented in some Eastern Mediterranean records e.g., from the northwestern Black Sea (Kwiecien et al., 2009) and from the Dead Sea (Torfstein et al., 2013). However, other records e.g., from the Tenaghi Philippon site (Tzedakis et al., 2004) and from southern Black Sea (Shumilovskikh et al., 2014; Fig. 6) do not indicate a vegetation response related to Heinrich Stadials. In areas, where tree populations were already close to their climatic tolerance limit, differences between harsh Heinrich Stadials and other stadials might not be detected because even mod-

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



[Back](#)

Close

Full Screen / Esc

[Printer-friendly Version](#)

Interactive Discussion



erate stadial conditions could cross the ecological threshold for tree growth (Tzedakis et al., 2004). This explanation could also pertain for the catchment of Lake Iznik. Still, a higher sampling resolution might result in the detection of rapid climate changes of centennial scale during that time.

4.3 Post-LGM: ca. 18.4–15 ka cal BP (LPAZ 6)

The onset of LPAZ 6 corresponds to the termination of the LGM and is marked by a ratio change of steppe components in Lake Iznik's pollen record: mainly *Artemisia* displaces Tubuliflorae, Liguliflorae, Brassicaceae, Caryophyllaceae, and *Hippophaë rhamnoides* (Fig. 4). The occurrence of *Ephedra*, a genus, which is associated with the desert biome (Prentice et al., 1996), points to seasonal moisture deficiencies. However, increasing pollen concentrations and decreasing open steppe indicators (especially Tubuliflorae and Liguliflorae) suggest a denser vegetation. The general higher plant productivity was supported by increased summer insulations (Berger, 1978; Berger et al., 2007; Fig. 6) implying higher temperatures and longer growing seasons. Moreover, pioneer trees of the Cupressaceae family (*Juniperus* and/or *Cupressus sempervirens*) and birch (*Betula*) formed open forests patches, which were accompanied by pines and successively also by deciduous oaks. The development of an open woodland with *Juniperus*, *Pinus*, *Betula*, and *Quercus* is typical for the pre-temperate phase of a glacial–interglacial cycle in southern Europe and corresponds to a climatic warming (Tzedakis, 2007).

Steadily increasing Ca/Ti ratios at Lake Iznik result from an increasing lacustrine bioproductivity in response to milder climatic conditions (Roeser et al., 2012; Fig. 5). The denser catchment vegetation contributes to an increased terrestrial proportion of accumulated organic matter, which is reflected by increasing TOC/TN ratios (Roeser, 2014; Fig. 5) and is supported by a decreasing magnetic susceptibility (Roeser et al., 2012; Fig. 5).

An ongoing dominance of steppe vegetation during the post-LGM is reflected in many Eastern Mediterranean records. Still, regional variations occurred: while East-

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



ern Anatolia was dominated by a cold semi-desert steppe with almost no arboreal taxa (Litt et al., 2009), more trees (primary pines) occurred in northern Turkey (van Zeist and Bottema, 1991; Shumilovskikh et al., 2012; Fig. 6), and the amount of arboreal pollen were even higher in the Aegean region (Kotthoff et al., 2008) and in Greece (Lawson et al., 2004; Müller et al., 2011). In contrast to our study, Kwiecien et al. (2009) and Valsecchi et al. (2012) proposed harsher climatic conditions during the post-LGM compared to the LGM for NW Turkey in response to Heinrich Stadial 1 (18–15.6 ka BP; Sanchez Goñi and Harrison, 2010). Valsecchi et al. (2012) suggested colder and/or drier conditions in the Marmara region due to increased pollen percentages of steppic plants and decreased percentages of temperate trees (Fig. 6).

4.4 Lateglacial: ca. 15–12.1 kcal BP (LPAZ 5)

The onset of LPAZ 5 is characterized by shortly peaking values of Poaceae followed by an enormous increase of deciduous oaks and a peak of *Pinus* pollen amounts (Fig. 4). Simultaneously, steppe components like Chenopodiaceae decrease abruptly. The change in the vegetation composition suggests warmer and moister climatic conditions. A similar pattern was already found during DO-3 and DO-4 in Lake Iznik's pollen assemblage. Likewise, this vegetation change corresponds to DO-1, which can be used as a synonym for the Lateglacial Interstadial (Bølling-Allerød) and started ca. 14.6 kcal BP according to the NGRIP record (Rasmussen et al., 2014). Pioneer forests of *Betula* and *Juniperus/Cupressus sempervirens* got successively replaced by temperate summer-green trees going along with a rapid forest expansion. However, pollen concentrations indicate that the forest expansion and the spread of oaks was somewhat slower than percentages may suggest. Therefore, the fully development of the forests in the catchment of Lake Iznik did not take place before the early Holocene.

During LPAZ 5, two retreats in forest expansion are noticeable. A peak of *Artemisia* together with a decrease of AP and a slowdown of the *Quercus* expansion indicate a weakening of favorable climatic conditions for tree growth and a short-term stagnation of forest expansion around ca. 13.3 kcal BP. The period might correspond to

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



a cooler sub-event during DO-1 (Rasmussen et al., 2014). The second forest retreat within LPAZ 5 (around ca. 12.3 kcalBP) is much more pronounced. An abrupt decline of several trees and shrubs (with the exception of *Ephedra*), an expansion of mainly Chenopodiaceae and Poaceae, and a decrease of pollen concentrations mark a period of dryer and/or cooler climate in the catchment of Lake Iznik. This climate change is associated with the Younger Dryas (YD).

The rapid increase of deciduous oaks at ca. 15 kcalBP coincides with a rapid rise of *Pediastrum* (Fig. 5), which indicates increasing lake water temperatures or a higher nutrient supply to the lake (Jankovská and Komárek, 2000). Increasing TOC/TN values might support a general higher biomass, although increasing proportions of terrestrial organic material in Lake Iznik can be related to phases of lower lake levels as indicated by independent proxies (Roeser, 2014; Fig. 5). The enhanced endogen carbonate production clearly outlines increasing summer temperatures (higher Ca/Ti ratios; Roeser et al., 2012; Fig. 5).

During the DO-1, a short phase of lower algae concentrations (Fig. 5), lower Ca/Ti ratios (Roeser et al., 2012; Fig. 5), and lower TOC/TN ratios (Roeser, 2014; Fig. 5) also lead to the interpretation of a rapid cooling, which is expressed by the short-term stagnation of forest expansion. During the YD, the retreat of forests relates to lower summer temperatures (lowering Ca/Ti ratios) and colder water temperatures (low NPP concentrations). A 2 cm thick layer of coarse sediments possibly represents a timely coincident distal deposition of a mass movement. This coarser layer is overprinted by iron monosulfides expressed by a peak in the magnetic susceptibility (Roeser et al., 2012; Fig. 5). The YD is condensed in Lake Iznik's sediments due to low sedimentation rates. According to the well-dated NGRIP chronology (Rasmussen et al., 2014; NGRIP members, 2004; Fig. 6) and varve chronologies from Lake Van (Wick et al., 2003) and Europe (Litt et al., 2001), the YD phase lasted about 1100 to 1200 years.

The spread of deciduous oaks in response to the onset of DO-1 is a common pattern in the Eastern Mediterranean. It is registered in many pollen records from northwestern Turkey and Greece e.g., from Tenaghi Philippon (Müller et al., 2011), from Ioannina

The first consistent occurrence of the *Sanguisorba minor* pollen type and of *Pistacia* at the onset of the Holocene is a typical pattern of pollen records from the Eastern Mediterranean and can therefore be used as a stratigraphic marker (Rossignol-Strick, 1995; Kotthoff et al., 2008; Valsecchi et al., 2012). Our study confirms the stratigraphic character of these pollen types.

4.6 Mid-Holocene: ca. 9–3.5 kcal BP (LPAZ 3)

The mid-Holocene in the Iznik area was characterized by a general continuing of temperate deciduous forest and mild and warm climatic conditions (Figs. 4 and 7). Though, the amount of conifers raised. The increased frequency of *Abies* and *Fagus*, which started already at ca. 9.8 kcal BP but amplifies in LPAZ 3, suggests slightly moister climatic conditions compared to the early Holocene. The abundance of *Abies* was probably even higher than suggested by the pollen percentages because they are known for their under-representation in pollen diagrams (van Zeist et al., 1975). Firs and beeches probably grew in the mountain areas surrounding Lake Iznik.

Several phases of decreased forest cover and simultaneous drops of pollen concentrations and influxes are visible in LPAZ 3. Potential climatic triggers causing these vegetation changes are especially probable for periods when no or few anthropogenic indicator taxa (cultivated plants and non-cultivated plants, which benefit from anthropogenic influences; e.g. Behre, 1990; Bottema and Woldring, 1990; Fig. 7) appeared simultaneously. The most pronounced of these periods are centered at ca. 8, ca. 6.5, and ca. 4.1 kcal BP. However, the determination of the exact timing and duration of those changes is challenging because corresponding radiocarbon dates of the age-depth model might be subjected to a reservoir effect (Roeser, 2014). In addition, possible rapid fluctuations of the sedimentation rate would potentially affect the duration of recorded events and eventually bias the pollen influx. Such expected rapid fluctuations are generally not accounted for by age-depth models, which reflect rather the average sedimentation. The high synchronicity of pollen concentrations and NPP concentrations support this assumption (Fig. 5).

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Several anthropogenic indicator taxa appear in LPAZ 3 (Fig. 7). For instance, a small peak of *Olea europaea* percentages is visible around 7.7 kcal BP. Still, this is no unambiguous evidence for olive cultivation, because olives are natural components of the Mediterranean vegetation (Zohary, 1973), the increase is just represented by a single sample and therefore needs further investigation, and olive cultivation started most likely about 2000 years later (Zohary and Hopf, 2000) and is therefore very unlikely. Although also other anthropogenic indicator taxa can occur naturally in the Marmara region (Zohary, 1973), evidence for human activities consolidates when anthropogenic indicator taxa show higher abundances, several anthropogenic indicator taxa occur simultaneously, and natural forests retreat contemporaneously. Likewise, the first unambiguous evidence for human induced changes of the vegetation documented in Lake Iznik's pollen record starts at ca. 4.8 kcal BP. Olives and cereals were most likely cultivated. Although Cerealia type percentages only slightly increase, those changes are still informative due to their under-representation in pollen diagrams (van Zeist et al., 1975; Faegri and Iversen, 1989). The increase of the *Plantago lanceolata* pollen type may point to area disturbance or grazing (van Zeist et al., 1975; Behre, 1990). The simultaneous occurrence of Ericaceae pollen, which probably originated from *Arbutus*, indicates the development of macchia vegetation (Kürschner et al., 1997).

Moister conditions since ca. 9 kcal BP are also suggested by geochemical analysis from Lake Iznik (Roeser et al., 2012; Roeser, 2014). The abrupt retreat in carbonate accumulation indicates a lake level rise that lasted circa 500 years (decreasing Ca/Ti ratios; Roeser et al., 2012; Fig. 5).

Similar to the Lake Iznik record, also other studies document a moisture rise during the mid-Holocene. An increase in humidity since ca. 9.6 kcal BP was inferred from the Sofular cave record based on high stalagmite growth rates and low ($^{234}\text{U}/^{238}\text{U}$)_o ratios (Göktürk et al., 2011), while the pollen record from southern Black Sea indicates moister and warmer climatic conditions since ca. 8.3 kcal BP due to a rapid spread of temperate forest (Shumilovskikh et al., 2012; Fig. 6).

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



The 8.2 ka cold event is the most prominent rapid climate change (RCC) at northern high latitudes during the Holocene (Johnsen et al., 2001; NGRIP members, 2004; Fig. 6). Phases with reduced precipitation were described in several Eastern Mediterranean records, but they often lasted longer compared to the sharp and short 8.2 ka event at northern high latitudes (e.g., Staubwasser and Weiss, 2006; Kotthoff et al., 2008; Weninger et al., 2009; Göktürk et al., 2011). The vegetation change in the Iznik area around 8 kcalBP might also correspond to the 8.2 event. However, the synchronous appearance of several archaeological settlements (Bottema et al., 2001; Gerritsen et al., 2013a, b; Fig. 7) makes it difficult to separate anthropogenic and climatic influences on the vegetation. Also Bottema et al. (2001) considered human impacts for a contemporaneous destruction of forests in the Yenişehir area, south of Lake Iznik.

According to Roberts et al. (2011), a dry phase took place in the Eastern Mediterranean ca. 6600 years ago. The forest retreat in the Iznik area around 6.5 kcalBP might correspond to this climate event. However, the magnitude of the vegetation change is large, which leads to the assumption of (additional) anthropogenic influences. Although anthropogenic indicator species are rare and there is no evidence for settlements near Lake Iznik at that time (Fig. 7), the subsequent spread of pines might indicate a permanent opening of forests by humans. Pines can have a pioneer role in anthropogenic influenced landscapes, and they quickly distribute in abandoned areas (Litt et al., 2012). Though, a similar spreading pattern of *Pinus* is also found in the pollen record from Marmara Sea (Valsecchi et al., 2012; Fig. 6; note that pines are often considerably over-represented in marine pollen assemblages) and therefore counters against a local vegetation development.

The unambiguous evidence for human induced vegetation changes in the Iznik area at ca. 4.8 kcalBP is in accordance with documented settlement activities in the vicinity of Lake Iznik (Bottema et al., 2001; Gerritsen et al., 2013a, b; Fig. 7). Also Bottema et al. (2001) postulated the relationship of these settlements and a deforestation in the Yenişehir area.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



According to Mayewski et al. (2004), there is evidence for a RCC at 4.2–3.8 ka cal BP in some paleorecords on global scale (the so-called 4.2 ka event). A pronounced aridity prevailed in the Eastern Mediterranean around 4.2 ka cal BP, although timing and magnitude of changes varies considerably among different records (Finné et al., 2011). The forest retreat around ca. 4.1 ka cal BP in the Iznik area might also be associated with this dry period. However, an extensive cultural network across Anatolia was already established by the end of the Early Bronze Age (Sagona and Zimansky, 2009). Therefore, persistent anthropogenic influences on the vegetation are also possible.

4.7 Late Bronze Age to Classical Period: ca. 3.5–2.2 ka cal BP (LPAZ 2)

During the Late Bronze Age, at ca. 3.5 ka cal BP, an enormous change in the vegetation took place in the catchment of Lake Iznik (Fig. 7). At least since that time, the vegetation development was overprinted by human impacts and the detection of climate influences on the vegetation is hardly possible. Natural forests got cleared, from which mainly deciduous oaks and pines were affected. People probably cleared the low altitude forests, where *Quercus* and *Pinus* were most likely common as they are today (Atalay et al., 2014). Cereal cropping was an important form of land use, while fruit cultivation played a minor role. Open land vegetation like Asteraceae (mainly Liguliflorae) and grasses benefited from the retreat of forests and from agricultural use. But also Mediterranean species like Ericaceae and evergreen oaks became rapidly more abundant. The abundance of the *Plantago lanceolata* pollen type and the rapid increase of *Pteridium* indicate a stronger human activity in the catchment of Lake Iznik (van Zeist et al., 1975; Bottema and Woldring, 1990). *Platanus orientalis* (oriental plane) pollen are continuously present since ca. 3.9 ka cal BP. The oriental plane is a natural component of the local vegetation and is especially abundant in riparian habitats (van Zeist et al., 1975). It was probably planted to provide shade like it is still done today in Anatolian villages (Eastwood et al., 1998).

A conspicuous palynologically identifiable settlement period firstly described from southwestern Turkey, the Beyşehir occupation phase (BOP), started at ca. 3.4 ka cal BP

nian Kingdom. Antigoneia (later Nicaea and finally Iznik) was founded at the eastern shore of Lake Iznik (Abbasoğlu and Delemen, 2003).

The maximal percentages of *Olea europaea* and minimal percentages of natural forest elements are found during the Roman Period (ca. 2.05–1.65 ka cal BP). Apparently, the general anthropogenic influence on the vegetation increased (higher amounts of *Pteridium* and lower pollen concentrations probably due to increased erosion), and olive cultivation expanded. In 74 BC (2024 BP), the Iznik area became incorporated into the Roman Empire. Iznik developed very quickly (Abbasoğlu and Delemen, 2003) and was one of the largest cities in the region. Furthermore, the city became famous for hosting a large ecumenical council in 325 AD (1625 BP; Şahin, 2003). Settlement activities are also described for other archaeological sites close to Lake Iznik (Bottema et al., 2001; Gerritsen et al., 2013a, b; Fig. 7).

Olea europaea pollen percentages retreat at ca. 1.3 ka cal BP, which indicates that many olive orchards were abandoned. Percentages of other human indicator taxa decrease as well. Concurrently *Pinus* pollen rise significantly, which suggests the recolonization of abandoned agricultural land by pine forests. Pines probably also benefited from human induced soil degradation (Roberts, 1990). The AP ratio and pollen concentration reach magnitudes comparable to the mid-Holocene, which indicates that the vegetation still had the ability to recover despite the preceding disturbances. This was also the case at other forested sites in the Eastern Mediterranean (e.g., Ionnania, NW Greece). In contrast, in some drier areas (e.g., Central Anatolia) the anthropogenic forest loss was irreversible (Roberts et al., 2011 and references therein).

During the Byzantine Period (1.15–0.8 ka cal BP), a repeated foray of humans is documented in Lake Iznik's pollen record. The cultivation of olives and cereals increased once more, although it did not reach dimensions comparable to earlier times. Pines retreated quickly and strongly again, while deciduous oaks were not affected by the probable forest clearing. Simultaneously, in 787 AD (1163 BP), a second famous ecumenical council took place in Iznik (Şahin, 2003).

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



impacts at least since the Late Bronze Age, which makes it hardly possible to detect climate-induced vegetation changes.

6. Cereals, olives, and walnuts were among the most important cultivars in the Iznik area. Oriental planes were probably planted to provide shade in settlements. Grape vines, mamma-ashes, stone fruit trees of the rose family (*Sorbus* group), pistachios, cruciferous crops (Brassicaceae), hop and/or hemp (*Humulus/Cannabis*) may have been cultivated.
7. Phases of different agricultural use alternated with phases of forest regeneration. A strong coincidence of vegetation changes and the regional archaeological history becomes apparent. Rapid fluctuations in pollen concentrations since the mid-Holocene might indicate rapid changes of Lake Iznik's sedimentation rates caused by catchment erosion.

Data availability

The complete pollen and NPP dataset is available on the PANGAEA database (www.pangaea.de).

The Supplement related to this article is available online at [doi:10.5194/cpd-11-5157-2015-supplement](https://doi.org/10.5194/cpd-11-5157-2015-supplement).

Acknowledgements. A part of this work is based on the unpublished master theses of Andrea Miebach and Phoebe Nistrath carried out at the Steinmann Institute at the University of Bonn under the supervision of Thomas Litt and Jens Mutke, and Thomas Litt and Georg Heumann, respectively. We thank the teams of the coring campaigns at Lake Iznik in 2005 and 2009. We acknowledge Karen Schmeling for her technical support. We are very grateful for useful discussions with Nadine Pickarski and her improvements of the manuscript. Furthermore, we thank Verushka Valsecchi, Maria Fernanda Sanchez Goñi, and Umut Barış Ülgen for providing

CPD

11, 5157–5201, 2015

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Bond, G., Heinrich, H., Broecker, W., Labeyrie, L., Mcmanus, J., Andrews, J., Huon, S., Jantschik, R., Clasen, S., Simet, C., Tedesco, K., Klas, M., Bonani, G., and Ivy, S.: Evidence for massive discharges of icebergs into the North-Atlantic Ocean during the Last Glacial Period, *Nature*, 360, 245–249, doi:10.1038/360245a0, 1992.

Bottema, S.: The Younger Dryas in the Eastern Mediterranean, *Quaternary Sci. Rev.*, 14, 883–891, doi:10.1016/0277-3791(95)00069-0, 1995.

Bottema, S.: The Holocene history of walnut, sweet-chestnut, manna-ash and plane tree in the Eastern Mediterranean, *Pallas*, 52, 35–59, 2000.

Bottema, S. and Woldring, H.: Anthropogenic indicators in pollen diagrams of the Eastern Mediterranean, in: *Man's Role in the Shaping of the Eastern Mediterranean Landscape*, edited by: Bottema, S., Entjes-Nieborg, G., and van Zeist, W., Balkema, Rotterdam, 231–264, 1990.

Bottema, S., Woldring, H., and Kayan, I.: The Late Quaternary vegetation history of Western Turkey, in: *The Ilipinar Excavations II*, edited by: Roodenberg, J. J. and Thissen, L. C., Nederlands Instituut voor het Nabije Oosten, Leiden, 327–354, 2001.

Chester, P. I. and Raine, J. I.: Pollen and spore keys for Quaternary deposits in the northern Pindos Mountains, Greece, *Grana*, 40, 299–387, doi:10.1080/00173130152987535, 2001.

Dansgaard, W., Clausen, H. B., Gundestrup, N., Hammer, C. U., Johnsen, S. F., Kristinsdottir, P. M., and Reeh, N.: A new Greenland deep ice core, *Science*, 218, 1273–1277, doi:10.1126/science.218.4579.1273, 1982.

Eastwood, W. J., Roberts, N., and Lamb, H. F.: Palaeoecological and archaeological evidence for human occupancy in Southwest Turkey: the Beyşehir Occupation Phase, *Anatolian Studies*, 48, 69–86, doi:10.2307/3643048, 1998.

Eriksen, U., Friedrich, W. L., Buchardt, B., Tauber, H., and Thomsen, M. S.: The Stronghyle Caldera: geological, palaeontological and stable isotope evidence from radiocarbon dated stromatolites from Santorini, in: *Thera and the Aegean World III. Proceedings of the Third International Congress, Santorini, Greece, 1989, vol. 2.*, edited by: Hardy, D. A., Keller, J., Galanopoulos, V. P., Flemming, N. C., and Druitt, T. H., Thera Foundation, London, 139–150, 1990.

Fægri, K. and Iversen, J.: *Textbook of Pollen Analysis*, 4th edn., John Wiley & Sons, Chichester, New York, Brisbane, Toronto, Singapore, 1989.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



- Finné, M., Holmgren, K., Sundqvist, H. S., Weiberg, E., and Lindblom, M.: Climate in the eastern Mediterranean, and adjacent regions, during the past 6000 years – a review, *J. Archaeol. Sci.*, 38, 3153–3173, doi:10.1016/j.jas.2011.05.007, 2011.
- Fleitmann, D., Cheng, H., Badertscher, S., Edwards, R. L., Mudelsee, M., Göktürk, O. M., Fankhauser, A., Pickering, R., Raible, C. C., Matter, A., Kramers, J., and Tüysüz, O.: Timing and climatic impact of Greenland interstadials recorded in stalagmites from northern Turkey, *Geophys. Res. Lett.*, 36, L19707, doi:10.1029/2009gl040050, 2009.
- Fletcher, W. J., Sánchez Goñi, M. F., Allen, J. R. M., Cheddadi, R., Combourieu-Nebout, N., Huntley, B., Lawson, I., Londeix, L., Magri, D., Margari, V., Müller, U. C., Naughton, F., Novenko, E., Roucoux, K., and Tzedakis, P. C.: Millennial-scale variability during the last glacial in vegetation records from Europe, *Quaternary Sci. Rev.*, 29, 2839–2864, doi:10.1016/j.jas.2011.05.007, 2010.
- Franz, S. O., Schwark, L., Brüchmann, C., Scharf, B., Klingel, R., Van Alstine, J. D., Çagatay, N., and Ülgen, U. B.: Results from a multi-disciplinary sedimentary pilot study of tectonic Lake Iznik (NW Turkey) – geochemistry and paleolimnology of the recent past, *J. Paleolimnol.*, 35, 715–736, doi:10.1007/s10933-005-5015-3, 2006.
- Gerritsen, F., Fokke, A., Özbal, R., and Thissen, L. C.: The Earliest Neolithic Levels at Barcin Höyük, Northwestern Turkey, *Anatolica*, 39, 53–92, doi:10.2143/ANA.39.0.2990784, 2013a.
- Gerritsen, F., Özbal, R., Thissen, L., Özdoğan, M., Başgelen, N., and Kuniholm, P.: Barcin Höyük: the beginnings of farming in the Marmara region, in: *The Neolithic in Turkey: New Excavations and New Research. Vol. 5 Northwestern Turkey and Istanbul*, edited by: Özdoğan, M., Başgelen, N., and Kuniholm, P., Archaeology and Art Publications, Istanbul, 93–112, 2013b.
- Göktürk, O. M., Fleitmann, D., Badertscher, S., Cheng, H., Edwards, R. L., Leuenberger, M., Fankhauser, A., Tüysüz, O., and Kramers, J.: Climate on the southern Black Sea coast during the Holocene: implications from the Sofular Cave record, *Quaternary Sci. Rev.*, 30, 2433–2445, doi:10.1016/j.quascirev.2011.05.007, 2011.
- Grimm, E. C.: CONISS: a FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares, *Comput. Geosci.*, 13, 13–35, doi:10.1016/0098-3004(87)90022-7, 1987.
- Heinrich, H.: Origin and consequences of cyclic ice rafting in the Northeast Atlantic Ocean during the past 130,000 years, *Quaternary Res.*, 29, 142–152, doi:10.1016/0033-5894(88)90057-9, 1988.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Hemming, S. R.: Heinrich events: massive late Pleistocene detritus layers of the North Atlantic and their global climate imprint, *Rev. Geophys.*, 42, RG1005, doi:10.1029/2003rg000128, 2004.

Higham, T., Compton, T., Stringer, C., Jacobi, R., Shapiro, B., Trinkaus, E., Chandler, B., Groning, F., Collins, C., Hillson, S., O'Higgins, P., FitzGerald, C., and Fagan, M.: The earliest evidence for anatomically modern humans in northwestern Europe, *Nature*, 479, 521–524, doi:10.1038/nature10484, 2011.

Jankovská, V. and Komárek, J.: Indicative value of *Pediastrum* and other coccal green algae in palaeoecology, *Folia Geobot.*, 35, 59–82, doi:10.1007/BF02803087, 2000.

Johnsen, S. J., Dahl-Jensen, D., Gundestrup, N., Steffensen, J. P., Clausen, H. B., Miller, H., Masson-Delmotte, V., Sveinbjörnsdottir, A. E., and White, J.: Oxygen isotope and palaeotemperature records from six Greenland ice-core stations: Camp Century, Dye-3, GRIP, GISP2, Renland and NorthGRIP, *J. Quaternary Sci.*, 16, 299–307, doi:10.1002/jqs.622, 2001.

Köppen, W.: Versuch einer Klassifikation der Klimate, vorzugsweise nach ihren Beziehungen zur Pflanzenwelt, *Geogr. Z.*, 6, 593–611, 1900.

Kotthoff, U., Müller, U. C., Pross, J., Schmiedl, G., Lawson, I. T., van de Schootbrugge, B., and Schulz, H.: Lateglacial and Holocene vegetation dynamics in the Aegean region: an integrated view based on pollen data from marine and terrestrial archives, *Holocene*, 18, 1019–1032, doi:10.1177/0959683608095573, 2008.

Kouli, K., Brinkhuis, H., and Dale, B.: *Spiniferites cruciformis*: a fresh water dinoflagellate cyst?, *Rev. Palaeobot. Palyno.*, 113, 273–286, doi:10.1016/S0034-6667(00)00064-6, 2001.

Kürschner, H., Raus, T., and Venter, J.: *Pflanzen der Türkei*, 2nd edn., Quelle & Meyer, Wiesbaden, 1997.

Kwiecien, O., Arz, H. W., Lamy, F., Plessen, B., Bahr, A., and Haug, G. H.: North Atlantic control on precipitation pattern in the eastern Mediterranean/Black Sea region during the last glacial, *Quaternary Res.*, 71, 375–384, doi:10.1016/j.yqres.2008.12.004, 2009.

Lawson, I., Frogley, M., Bryant, C., Preece, R., and Tzedakis, P.: The Lateglacial and Holocene environmental history of the Ioannina basin, north-west Greece, *Quaternary Sci. Rev.*, 23, 1599–1625, doi:10.1016/j.quascirev.2004.02.003, 2004.

Le Houërou, H. N.: Impacts of man and his animals on Mediterranean vegetation, in: *Mediterranean Type Shrublands*, edited by: Di Castri, F., Goodall, D. W., and Specht, R. L., Elsevier, Amsterdam, 523–535, 1981.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

▶

▶

[Back](#)

Close

Full Screen / Esc

[Printer-friendly Version](#)

Interactive Discussion



- Lisiecki, L. E. and Raymo, M. E.: A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}\text{O}$ records, *Paleoceanography*, 20, PA1003, doi:10.1029/2004PA001071, 2005.
- Litt, T., Brauer, A., Goslar, T., Merkt, J., Bałaga, K., Müller, H., Ralska-Jasiewiczowa, M., Stebich, M., and Negendank, J. F. W.: Correlation and synchronisation of Lateglacial continental sequences in northern central Europe based on annually laminated lacustrine sediments, *Quaternary Sci. Rev.*, 20, 1233–1249, doi:10.1016/S0277-3791(00)00149-9, 2001.
- Litt, T., Krastel, S., Sturm, M., Kipfer, R., Örcen, S., Heumann, G., Franz, S. O., Ülggen, U. B., and Niessen, F.: “PALEOVAN”, International Continental Scientific Drilling Program (ICDP): site survey results and perspectives, *Quaternary Sci. Rev.*, 28, 1555–1567, doi:10.1016/j.quascirev.2009.03.002, 2009.
- Litt, T., Ohlwein, C., Neumann, F. H., Hense, A., and Stein, M.: Holocene climate variability in the Levant from the Dead Sea pollen record, *Quaternary Sci. Rev.*, 49, 95–105, doi:10.1016/j.quascirev.2012.06.012, 2012.
- Louis, H.: Das natürliche Pflanzenkleid Anatoliens, J. Engelhorn's Nachf. Adolf Spemann, Stuttgart, 1939.
- Mayer, H. and Aksoy, H.: Wälder der Türkei, Gustav Fischer Verlag, Stuttgart, New York, 1986.
- Mayewski, P. A., Rohling, E. E., Curt Stager, J., Karlén, W., Maasch, K. A., David Meeker, L., Meyerson, E. A., Gasse, F., van Kreveland, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R. R., and Steig, E. J.: Holocene climate variability, *Quaternary Res.*, 62, 243–255, doi:10.1016/j.yqres.2004.07.001, 2004.
- Moore, P. D., Webb, J. A., and Collinson, M. E.: Pollen Analysis, 2nd edn., Blackwell Scientific Publications, Oxford, 1991.
- Mudie, P. J., Rochon, A., and Aksu, A. E.: Pollen stratigraphy of Late Quaternary cores from Marmara Sea: land–sea correlation and paleoclimatic history, *Mar. Geol.*, 190, 233–260, doi:10.1016/S0025-3227(02)00349-3, 2002.
- Müller, U. C., Pross, J., Tzedakis, P. C., Gamble, C., and Kotthoff, U.: The role of climate in the spread of modern humans into Europe, *Quaternary Sci. Rev.*, 30, 273–279, doi:10.1016/j.quascirev.2010.11.016, 2011.
- NGRIP members: High-resolution record of Northern Hemisphere climate extending into the last interglacial period, *Nature*, 431, 147–151, doi:10.1038/nature02805, 2004.
- Öztürk, K., Yaltırak, C., and Alpar, B.: The relationship between the tectonic setting of the Lake İznik Basin and the Middle Strand of the North Anatolian Fault, *Turk. J. Earth Sci.*, 18, 209–224, doi:10.3906/yer-0803-4, 2009.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Panagiotopoulos, K., Böhm, A., Leng, M. J., Wagner, B., and Schäbitz, F.: Climate variability over the last 92 ka in SW Balkans from analysis of sediments from Lake Prespa, *Clim. Past*, 10, 643–660, doi:10.5194/cp-10-643-2014, 2014.

Pichler, H. and Friedrich, W.: Radiocarbon dates of Santorini volcanics, *Nature*, 262, 373–374, doi:10.1038/262373a0, 1976.

Pickarski, N., Kwiecień, O., Langgut, D., and Litt, T.: Abrupt climate variability of eastern Anatolia vegetation during the last glacial, *Clim. Past Discuss.*, 11, 3341–3373, doi:10.5194/cpd-11-3341-2015, 2015.

Prentice, I. C., Guiot, J., Huntley, B., Jolly, D., and Cheddadi, R.: Reconstructing biomes from palaeoecological data: a general method and its application to European pollen data at 0 and 6 ka, *Clim. Dynam.*, 12, 185–194, doi:10.1007/s003820050102, 1996.

Rasmussen, S. O., Bigler, M., Blockley, S. P., Blunier, T., Buchardt, S. L., Clausen, H. B., Cvi-
janovic, I., Dahl-Jensen, D., Johnsen, S. J., Fischer, H., Gkinis, V., Guillevic, M., Hoek, W. Z.,
Lowe, J. J., Pedro, J. B., Popp, T., Seierstad, I. K., Steffensen, J. P., Svensson, A. M., Valle-
longa, P., Vinther, B. M., Walker, M. J. C., Wheatley, J. J., and Winstrup, M.: A stratigraphic
framework for abrupt climatic changes during the Last Glacial period based on three synchro-
nized Greenland ice-core records: refining and extending the INTIMATE event stratigraphy,
Quaternary Sci. Rev., 106, 14–28, doi:10.1016/j.quascirev.2014.09.007, 2014.

Reille, M.: Pollen et spores d'Europe et d'Afrique du Nord: supplement 1, Laboratoire de
Botanique Historique et Palynologie, Marseille, 1995.

Reille, M.: Pollen et spores d'Europe et d'Afrique du Nord: supplement 2, Laboratoire de
Botanique Historique et Palynologie, Marseille, 1998.

Reille, M.: Pollen et spores d'Europe et d'Afrique du Nord, 2nd edn., Laboratoire de Botanique
Historique et Palynologie, Marseille, 1999.

Richter, J., Melles, M., and Schäbitz, F.: Temporal and spatial corridors of *Homo sapiens sapiens*
population dynamics during the Late Pleistocene and early Holocene, *Quatern. Int.*, 274,
1–4, doi:10.1016/j.quaint.2012.06.009, 2012.

Roberts, N.: Human-induced landscape change in South and Southwest Turkey during the later
Holocene, in: *Man's Role in the Shaping of the Eastern Mediterranean Landscape*, edited by:
Bottema, S., Entjes-Nieborg, G., and van Zeist, W., Balkema, Rotterdam, 53–66, 1990.

Roberts, N. and Wright, H. E.: Vegetational, lake-level, and climatic history of near East and
Southwest Asia, in: *Global Climates since the Last Glacial Maximum*, edited by: Wright, H. E.,

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

▶

▶

[Back](#)

Close

Full Screen / Esc

[Printer-friendly Version](#)

Interactive Discussion



- Kutzbach, J. E., Webb, T., Ruddiman, W. F., Street-Perrott, F. A., and Bartlein, P. J., University of Minnesota Press, Minneapolis, London, 194–220, 1993.
- Roberts, N., Eastwood, W. J., Kuzucuoğlu, C., Fiorentino, G., and Caracuta, V.: Climatic, vegetation and cultural change in the eastern Mediterranean during the mid-Holocene environmental transition, *Holocene*, 21, 147–162, doi:10.1177/0959683610386819, 2011.
- Robinson, S. A., Black, S., Sellwood, B. W., and Valdes, P. J.: A review of palaeoclimates and palaeoenvironments in the Levant and Eastern Mediterranean from 25,000 to 5000 years BP: setting the environmental background for the evolution of human civilisation, *Quaternary Sci. Rev.*, 25, 1517–1541, doi:10.1016/j.quascirev.2006.02.006, 2006.
- Roeser, P.: Paleolimnology of Lake Iznik (NW Turkey) during the past ~ 31 kcal BP, PhD thesis, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, 202 pp., 2014.
- Roeser, P. A., Franz, S. O., Litt, T., Ülgen, U. B., Hilgers, A., Wulf, S., Wennrich, V., Ön, S. A., Viehberg, F. A., Çağatay, M. N., and Melles, M.: Lithostratigraphic and geochronological framework for the paleoenvironmental reconstruction of the last ~ 36 kcal BP from a sediment record from Lake Iznik (NW Turkey), *Quatern. Int.*, 274, 73–87, doi:10.1016/j.quaint.2012.06.006, 2012.
- Roeser, P., Franz, S. O., and Litt, T.: Aragonite and calcite preservation in lacustrine sediments related to bottom lake oxygenation and water column depth, in preparation, 2015.
- Rosignol-Strick, M.: Sea–land correlation of pollen records in the eastern Mediterranean for the glacial–interglacial transition, *Quaternary Sci. Rev.*, 14, 893–915, doi:10.1016/0277-3791(95)00070-4, 1995.
- Sagona, A. and Zimansky, P.: *Ancient Turkey*, Routledge World Archaeology, Routledge, Abingdon, New York, 2009.
- Şahin, S.: İznik (Nicaea) in the Hellenistic and Roman Periods, in: *İznik Throughout History*, edited by: Akbaygil, I., İnalçık, H., and Aslanapa, O., Türkiye İş Bankası Kültür Yayınları, İstanbul, 3–23, 2003.
- Sanchez Goñi, M. F. and Harrison, S. P.: Millennial-scale climate variability and vegetation changes during the Last Glacial: concepts and terminology, *Quaternary Sci. Rev.*, 29, 2823–2827, doi:10.1016/j.quascirev.2009.11.014, 2010.
- Şenkul, Ç. and Doğan, U.: Vegetation and climate of Anatolia and adjacent regions during the Last Glacial period, *Quatern. Int.*, 302, 110–122, doi:10.1016/j.quaint.2012.04.006, 2013.
- Shumilovskikh, L. S., Tarasov, P., Arz, H. W., Fleitmann, D., Marret, F., Nowaczyk, N., Plessen, B., Schlütz, F., and Behling, H.: Vegetation and environmental dynamics in the

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



southern Black Sea region since 18 kyr BP derived from the marine core 22-GC3, *Palaeogeogr. Palaeoclimatol.*, 337–338, 177–193, doi:10.1016/j.palaeo.2012.04.015, 2012.

Shumilovskikh, L. S., Fleitmann, D., Nowaczyk, N. R., Behling, H., Marret, F., Wegwerth, A., and Arz, H. W.: Orbital- and millennial-scale environmental changes between 64 and 20 ka BP recorded in Black Sea sediments, *Clim. Past*, 10, 939–954, doi:10.5194/cp-10-939-2014, 2014.

Staubwasser, M. and Weiss, H.: Holocene climate and cultural evolution in late prehistoric–early historic West Asia, *Quaternary Res.*, 66, 372–387, doi:10.1016/j.yqres.2006.09.001, 2006.

Stockmarr, J.: Tablets with spores used in absolute pollen analysis, *Pollen et Spores*, 13, 615–621, 1971.

Tarasov, P. E., Cheddadi, R., Guiot, J., Bottema, S., Peyron, O., Belmonte, J., Ruiz-Sanchez, V., Saad, F., and Brewer, S.: A method to determine warm and cool steppe biomes from pollen data; application to the Mediterranean and Kazakhstan regions, *J. Quaternary Sci.*, 13, 335–344, 1998.

Torfstein, A., Goldstein, S. L., Stein, M., and Enzel, Y.: Impacts of abrupt climate changes in the Levant from Last Glacial Dead Sea levels, *Quaternary Sci. Rev.*, 69, 1–7, doi:10.1016/j.quascirev.2013.02.015, 2013.

Tzedakis, P. C., Frogley, M. R., Lawson, I. T., Preece, R. C., Cacho, I., and de Abreu, L.: Ecological thresholds and patterns of millennial-scale climate variability: the response of vegetation in Greece during the last glacial period, *Geology*, 32, 109–112, doi:10.1130/G20118.1, 2004.

Tzedakis, P. C.: Seven ambiguities in the Mediterranean palaeoenvironmental narrative, *Quaternary Sci. Rev.*, 26, 2042–2066, doi:10.1016/j.quascirev.2007.03.014, 2007.

Ülgen, U. B., Franz, S. O., Biltekin, D., Çagatay, M. N., Roeser, P. A., Doner, L., and Thein, J.: Climatic and environmental evolution of Lake Iznik (NW Turkey) over the last ~ 4700 years, *Quatern. Int.*, 274, 88–101, doi:10.1016/j.quaint.2012.06.016, 2012.

Valsecchi, V., Sanchez Goñi, M. F., and Londeix, L.: Vegetation dynamics in the Northeastern Mediterranean region during the past 23 000 yr: insights from a new pollen record from the Sea of Marmara, *Clim. Past*, 8, 1941–1956, doi:10.5194/cp-8-1941-2012, 2012.

van Zeist, W. and Bottema, S.: Late Quaternary vegetational and climatic history of southwest Asia, *Proc. Indian Nat. Sci. Acad.*, 54, 461–480, 1988.

van Zeist, W. and Bottema, S.: Late Quaternary Vegetation of the Near East, *Beihefte zum Tübinger Atlas des Vorderen Orients*, Dr. Ludwig Reichert, Wiesbaden, 1991.

- van Zeist, W., Woldring, H., and Stapert, D.: Late Quaternary vegetation and climate of south-western Turkey, *Palaeohistoria*, 17, 55–143, 1975.
- Viehberg, F. A., Ülgen, U. B., Damcı, E., Franz, S. O., Ön, S. A., Roeser, P. A., Çağatay, M. N., Litt, T., and Melles, M.: Seasonal hydrochemical changes and spatial sedimentological variations in Lake Iznik (NW Turkey), *Quatern. Int.*, 274, 102–111, doi:10.1016/j.quaint.2012.05.038, 2012.
- Walker, M., Johnsen, S., Rasmussen, S. O., Steffensen, J.-P., Popp, T., Gibbard, P., Hoek, W. Z., Lowe, J. J., Andrews, J., Björck, S., Cwynar, L. C., Hughen, K. A., Kershaw, P., Kromer, B., Litt, T., Lowe, D. J., Nakagawa, T., Newnham, R. M., and Schwander, J.: The Global Stratotype Section and Point (GSSP) for the base of the Holocene Series/Epoch (Quaternary System/Period) in the NGRIP ice core, *Episodes*, 31, 264–267, 2008.
- Weninger, B., Clare, L., Rohling, E. J., Bar-Yosef, O., Böhner, U., Budja, M., Bundschuh, M., Feurdean, A., Gebel, H.-G., and Jöris, O.: The impact of rapid climate change on prehistoric societies during the Holocene in the Eastern Mediterranean, *Documenta Praehistorica*, 36, 7–59, doi:10.4312/dp.36.2, 2009.
- Wester, R.: Wasserwirtschaftlicher Rahmenplan für das Izniksee-Gebiet/Türkei, Diploma thesis, Fachhochschule Mainz, Mainz, 1989.
- Wick, L., Lemcke, G., and Sturm, M.: Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: high-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey, *Holocene*, 13, 665–675, doi:10.1191/0959683603hl653rp, 2003.
- Yokoyama, Y., Lambeck, K., Deckker, P., Johnston, P., and Fifield, L. K.: Timing of the Last Glacial Maximum from observed sea-level minima, *Nature*, 406, 713–716, doi:10.1038/35021035, 2000.
- Zohary, D. and Hopf, M.: *Domestication of Plants in the Old World*, Oxford University Press, Oxfordshire, 2000.
- Zohary, M.: *Geobotanical Foundations of the Middle East*, Gustav Fischer Verlag, Stuttgart, 1973.

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 1. Average climate data and elevation of Iznik and Orhangazi (Wester, 1989; see Fig. 2 for the locations).

	Elevation (m a.s.l.)	Air temperature (°C)			Precipitation (mm)			Evaporation (mm)
		year	Jan	Jul	year	Nov–Apr	May–Oct	
Iznik	88	14.4	6.9	23.8	552	351	201	718
Orhangazi	95	14.4	5.2	24.2	743	507	236	648

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Table 2. Local pollen assemblage zones (LPAZ) with composite depths, ages, the number of pollen samples, the temporal resolution, main components of the pollen assemblage (AP: arboreal pollen, NAP: non-arboreal pollen, percentages refer to the total pollen sum and give minimal and maximal values for the respective LPAZ), pollen concentrations (PC), definitions of lower boundaries (LB), and the inferred dominant vegetation type.

LPAZ	Depth (m)	Age (ka cal BP)	No. of pollen samples/temporal resolution (years)	Pollen assemblage	Dominant vegetation type
1: <i>Olea europaea</i> LPAZ	0.51–2.65	0.6–2.2	17/102	AP: predominance with increasing trend: 71.4–91.6%, high amounts of deciduous <i>Quercus</i> and <i>Pinus</i> , maximum of <i>Olea europaea</i> (0.6–28.3%), plateau of <i>Juglans regia</i> NAP: Poaceae (2.2–7.8%) and Cerealia type (0.5–5.9%) are most abundant PC: moderate to high LB: increase of <i>Olea europaea</i> and <i>Juglans regia</i> , decrease of deciduous <i>Quercus</i>	Mixed forest with some Mediterranean elements; strong anthropogenic exploitation on the natural vegetation and fruit and cereal cropping
2: Cerealia type LPAZ	2.65–3.97	2.2–3.5	11/116	AP: predominance with rapid decrease followed by an increasing trend: 54.5–77%, mainly deciduous <i>Quercus</i> , <i>Pinus</i> , and <i>Fagus</i> NAP: Poaceae (4–16.5%) and Cerealia type (2.4–11%) are most abundant PC: low to moderate LB: increase of NAP, Poaceae, Cerealia type, Liguliflorae, Tubuliflorae, and Ericaceae, decrease of AP, deciduous <i>Quercus</i> , <i>Pinus</i>	Mixed forest with some Mediterranean elements; strong anthropogenic exploitation on the natural vegetation and cereal cropping
3: deciduous <i>Quercus</i> LPAZ	3.97–9.16	3.5–9.0	32/179	AP: predominance: 63.2–93.1%, mainly deciduous <i>Quercus</i> , <i>Fagus</i> , and <i>Carpinus/Ostrya</i> , increasing but unstable values of <i>Pinus</i> , peak of <i>Olea europaea</i> (0–6.9%) NAP: Poaceae (1.5–16.3%) is most abundant, peak of Liguliflorae (0–5.9%) PC: rapid fluctuations between low and high LB: increase of <i>Juniperus</i> type, decrease of <i>Sanguisorba minor</i> type, <i>Ulmus/Zelkova</i> , and <i>Alnus</i>	Diverse deciduous and mixed forest dominated by oaks with an increasing influence of pines
4: <i>Sanguisorba minor</i> type LPAZ	9.16–10.27	9.0–12.1	5/664	AP: predominance with increasing trend: 67.5–82.2%, mainly deciduous <i>Quercus</i> , plateau of <i>Ulmus/Zelkova</i> NAP: Poaceae (9.8–17.1%) and <i>Sanguisorba minor</i> type (0.2–4.5%) are most abundant PC: high LB: increase of AP and deciduous <i>Quercus</i> , decrease of <i>Artemisia</i>	Full development of deciduous forest dominated by oaks, which get successively accompanied by cool temperate and warm-temperate species
5: Poaceae-deciduous <i>Quercus</i>	10.27–11.13	12.1–15.0	10/314	AP: strong increase up to predominance: 33.7–67.1%, mainly due to strong increase of deciduous <i>Quercus</i> (9.7–51.8%), peak of <i>Pinus</i> , increase of <i>Alnus</i> NAP: initial predominance but with rapid decrease, two peaks of Poaceae (13.5–40.6%), weak peak of Chenopodiaceae (2–7%) PC: moderate to high with one peak LB: increase of AP, deciduous <i>Quercus</i> , and <i>Pinus</i> , decrease of NAP and Chenopodiaceae	Establishment of oak dominated woodland (with one weak and one stronger setback) and an decreasing influence of steppe
6: <i>Artemisia-Juniperus</i> type LPAZ	11.13–12.91	15.0–18.4	8/428	AP: <i>Pinus</i> , <i>Juniperus</i> type, <i>Betula</i> , and deciduous <i>Quercus</i> are most abundant, maximum of <i>Ephedra</i> (0.2–2.6%) NAP: predominance: 77.4–82.3%, mainly <i>Artemisia</i> , Poaceae, and Chenopodiaceae PC: moderate LB: increase of <i>Artemisia</i> , <i>Juniperus</i> type, and <i>Betula</i> , decrease of Tubuliflorae, Liguliflorae, <i>Hippophaë rhamnoides</i> , and <i>Pinus</i>	More productive dwarf shrub steppe with scattered stands of pioneer trees
7: <i>Hippophaë rhamnoides</i> -Tubuliflorae LPAZ	12.91–16.55	18.4–28.4	18/554	AP: high amounts of <i>Pinus</i> (6.5–26.4%), maximum of <i>Hippophaë rhamnoides</i> (1.7–18.9%) NAP: predominance with stable assemblage and abundance: 52.1–83.9%, mainly <i>Artemisia</i> , Tubuliflorae, Poaceae, Chenopodiaceae, and Liguliflorae PC: very low LB: increase of NAP, <i>Artemisia</i> , and Tubuliflorae, decrease of AP and deciduous <i>Quercus</i>	Open steppe with very low vegetation cover
8: <i>Artemisia</i> -deciduous <i>Quercus</i> LPAZ	16.55–18.14	28.4–31.1	11/259	AP: <i>Pinus</i> (4.2–26.3%) and deciduous <i>Quercus</i> (0.6–12.5%) are most abundant and peak twice NAP: predominance with rapid fluctuations: 56–90.6%, mainly <i>Artemisia</i> , Poaceae, Chenopodiaceae, and Tubuliflorae PC: low to moderate LB: not defined (end of record)	Fluctuation between open dwarf shrub steppe and forest steppe with scattered trees and shrubs

Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

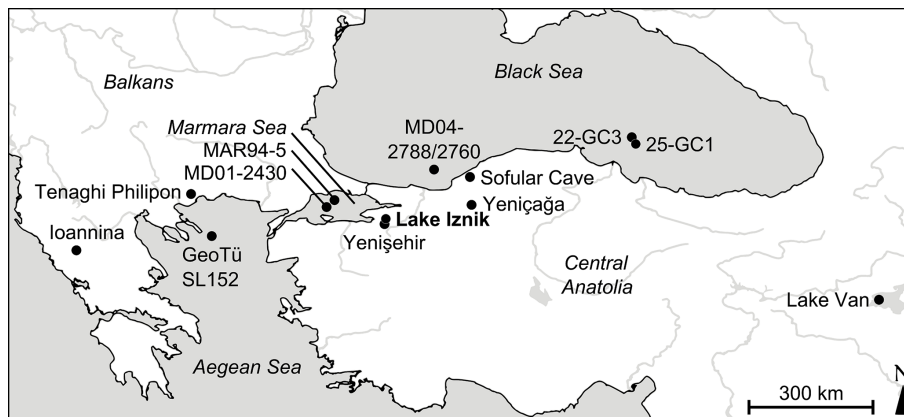


Figure 1. Regional overview modified from Roeser et al. (2012). Dots indicate Lake Iznik (this study) and paleorecords mentioned in the discussion: loannina (Lawson et al., 2004), Tenaghi Philippon (Tzedakis et al., 2004; Müller et al., 2011), GeoTü SL152 (Kotthoff et al., 2008), MAR94-5 (Mudie et al., 2002), MD01-2430 (Valsecchi et al., 2012), Yenişehir (Bottema et al., 2001), MD04-2788/2760 (Kwiecien et al., 2009), Sofular Cave (Fleitmann et al., 2009; Göktürk et al., 2011), Yeniçağa (van Zeist and Bottema, 1991), 22-GC3 (Shumilovskikh et al., 2012), 25-GC1 (Shumilovskikh et al., 2014), and Lake Van (Wick et al., 2003; Litt et al., 2009).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

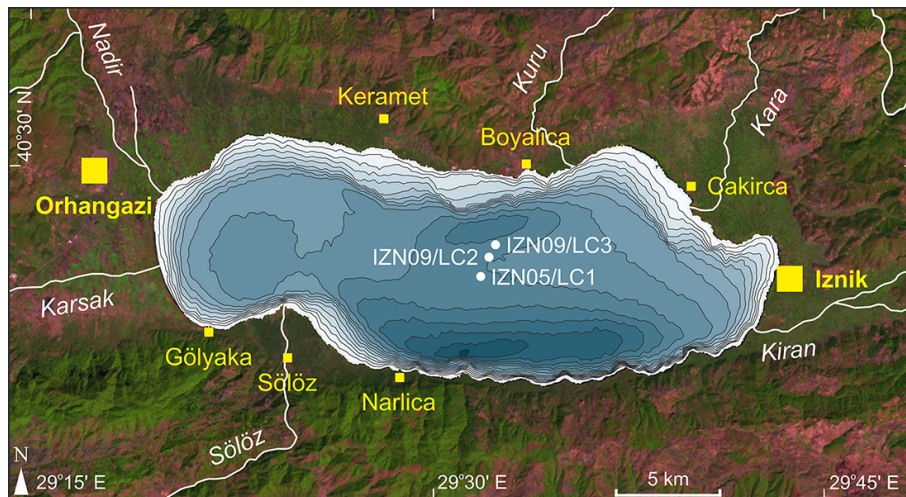


Figure 2. Lake Iznik with bathymetric curves in 5 m intervals modified from Roeser et al. (2012). Dots indicate the coring locations, and squares indicate settlements.





Impacts of climate and humans on the vegetation in NW Turkey

A. Miebach et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures

◀

▶

◀

▶

Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

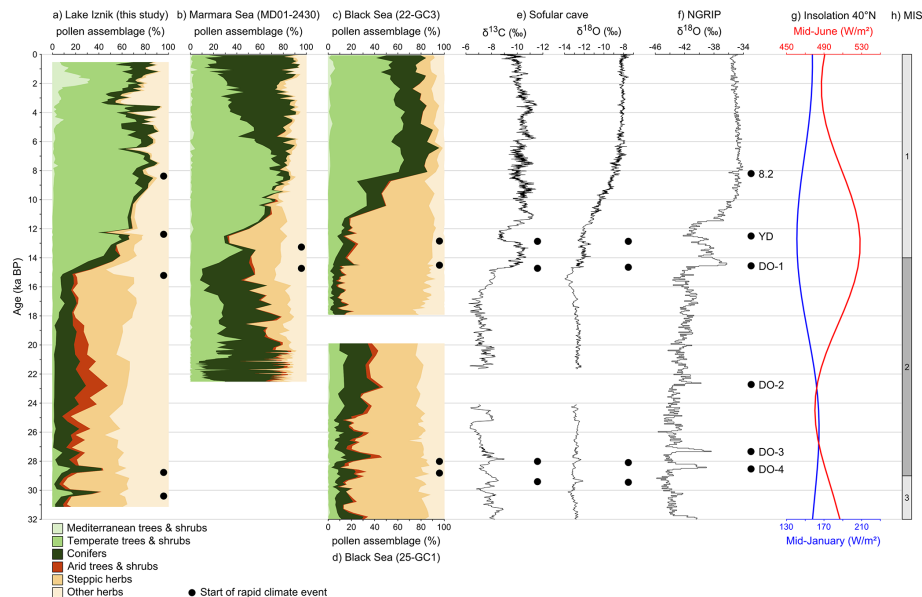


Figure 6. Comparison of pollen assemblages from **(a)** Lake Iznik (this study), **(b)** Marmara Sea, core MD01-2430 (Valsecchi et al., 2012), **(c)** Black Sea, core 22-GC3 (Shumilovskikh et al., 2012), and **(d)** Black Sea, core 25-GC1 (Shumilovskikh et al., 2014) with **(e)** isotope data from Sofular cave (Fleitmann et al., 2009), **(f)** isotope data from Greenland (NGRIP members, 2004), **(g)** mid-June and mid-January insolation (Berger, 1978; Berger et al., 2007), and **(h)** marine isotope stages (MIS; Lisiecki and Raymo, 2005). Dots mark Dansgaard–Oeschger events (DO), the Younger Dryas (YD), and the 8.2 event.

