Quaternary Research 70 (2008) 392–397

Contents lists available at ScienceDirect

Quaternary Research

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

Short Paper

Holocene environment and subsistence patterns near the Tree Shelter, Red Sea Mountains, Egypt

Elena Marinova [a,*], Veerle Linseele [a], Pierre Vermeersch [b]

[a] Center for Archaeological Sciences, Katholieke Universiteit Leuven, Celestijnenlaan 200E, 3001 Leuven, Belgium
[b] Physical and Regional Geography Research Group, Katholieke Universiteit Leuven, Celestijnenlaan 200E, 3001 Leuven, Belgium

ARTICLE INFO

Article history:
Received 28 February 2008
Available online 1 October 2008

Keywords:
Eastern Desert
Neolithic Egypt
Arid environments
Wood charcoal
Domestic ovicaprines

ABSTRACT

The Tree Shelter site dates to the Early to Mid-Holocene (8000 to 4900 ^{14}C yr BP). Present conditions around the site are hyperarid, but charcoal remains indicate less severe aridity at the time of its occupation. The environment around the site then supported a rich wadi vegetation, which allowed hunting during the Epipaleolithic and herding during the Neolithic occupation. Although more favorable than today, the environmental conditions also displayed a desert character and seem to have limited the range of domestic herbivores introduced in the area.

© 2008 University of Washington. All rights reserved.

Introduction

During the Early to Mid-Holocene changes of the precipitation patterns, connected with an intensification of monsoon activities, shaped the climate and vegetation of the arid and sub-arid belt of the Sahara, Sahel and Arabian Peninsula (Hoelzmann et al., 2004). They led to the wetter climate of the so called "African Humid Period" (de Menocal et al., 2000), which supported denser and more diverse vegetation during this period. Palaeoecological and anthracological studies from the Sahara west of the Nile and the Nile Valley itself revealed vegetation responses to these patterns and the human impact on the vegetation in the period (Barakat, 2001; Neumann, 1989; Newton, 2005; Newton and Midant-Reynes, 2007; Vermeersch et al., 1992). Such information is still scarce for the Sahara east of the Nile and in general little is known about the Early to Middle Holocene paleoenvironment of the Red Sea Mountains. Valuable clues on the desert environment in the past might be provided by proxy data (e.g., faunal remains, plant macrofossils, phytoliths, etc.) from archaeological cave sites where preservation is better, than in most sediments of desert regions, where due to low primary production, usually oxygen rich conditions and lack of anoxic deposits fossils are not easily preserved (Scott, 2005). The recent analyses carried out on wood charcoal and animal bones, collected at the site Tree Shelter, give a possibility, rare for the region, to get information on the prehistoric environment and its use by humans during their visits there.

Site description and natural environment

At the Tree Shelter site (26°16.332′ N; 33°57.379′ E), excavated between 1995 and 1996, several habitation levels were recognized; they could not be individualised and have been attributed to five different archaeological horizons (AH), defined and described by Vermeersch et al. (2008). Their division is based on field data (measured XYZ-coordinates of artifacts) and lithostratigraphic members (Fig. 1). This division, combined with careful sampling allowed minimizing the potential biases, which the bioturbation typical for cave and shelter sites could cause. Available radiocarbon dates are summarized in Table 1. AH 1 is considered as subrecent, AH 2 and AH 3 are comparable to the Late and Middle Neolithic from the Egyptian Western Desert (Wendorf et al., 1984). The lowermost AH5 has been attributed to the Elkabian (Vermeersch, 1978). For all periods, repeated and short occupations of the site are likely (Vermeersch et al., 2008).

The Tree Shelter site is located in a tributary wadi of the Wadi Sodmein in the Gebel Umm Hammad, running parallel to the Egyptian Red Sea coast for a distance of about 30 km and 25 km inland from Quseir (Fig. 1). The climate is hyper-arid. At inland locations like the surroundings of the Tree Shelter site, winter rains occasionally occur (Moeyersons et al., 1996, 1999).

The arboreal vegetation of the wadi is limited nowadays to a lonely *Acacia* tree at its entrance. The modern vegetation in the broad area of the Red Sea coastal land between Wadi Qena and the Nubian desert (lat. 26°–24°N) in the main wadis is dominated by associations of *Acacia raddiana*, *A. tortilis* and *A. ehrenbergiana*. There are also associations of *Salvadora persica* and *Leptadenia pyrotechnica*, and more limited communities of *Balanites aegyptiaca*.

* Corresponding author. Fax: +32 0 16 32 29 00.
E-mail address: elena.marinova@bio.kuleuven.be (E. Marinova).

0033-5894/$ – see front matter © 2008 University of Washington. All rights reserved.
doi:10.1016/j.yqres.2008.08.002

https://doi.org/10.1016/j.yqres.2008.08.002 Published online by Cambridge University Press

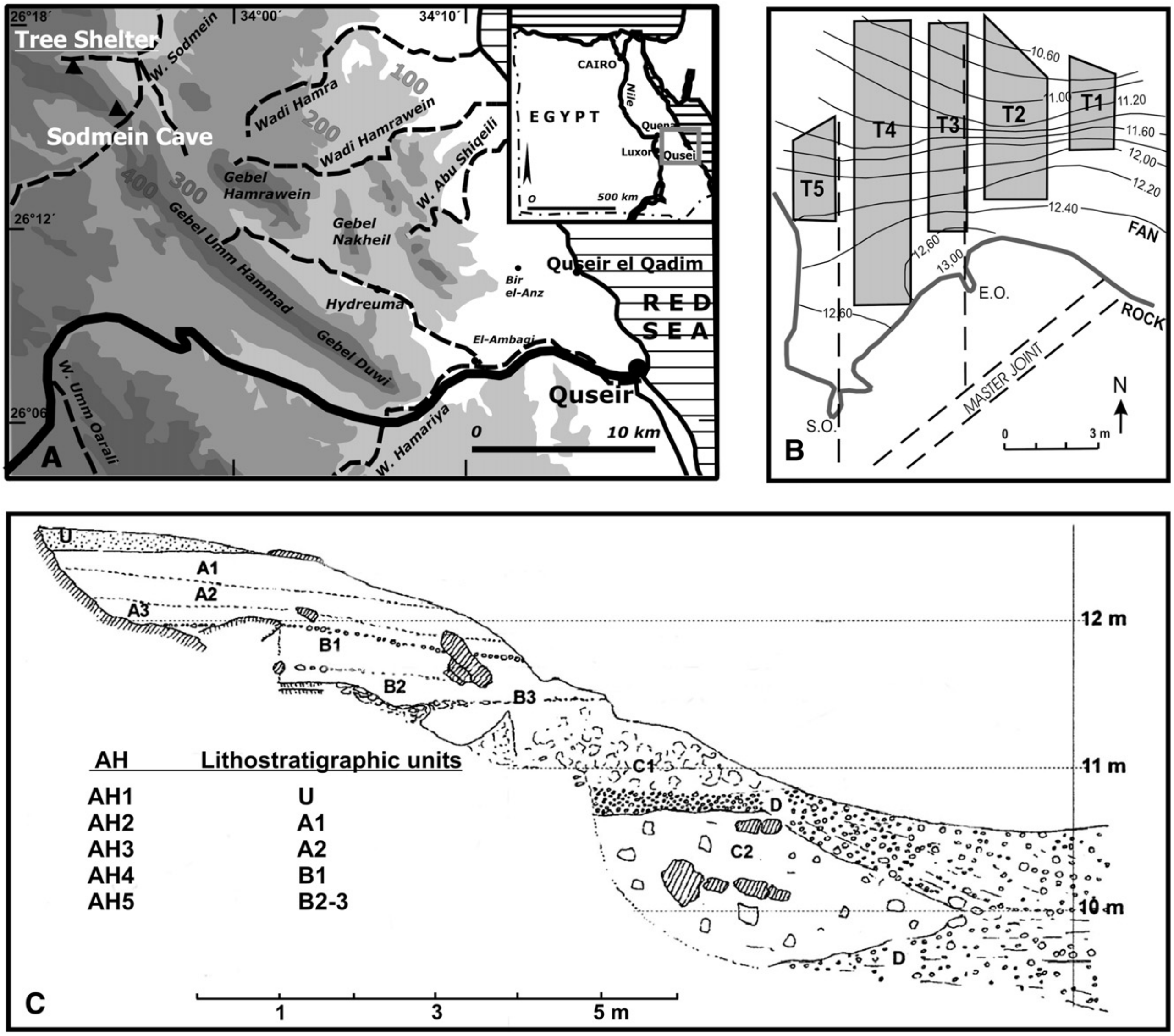

Figure 1. (A) Geographical position of the site; (B) Topographic plan of the shelter with excavation trenches (T), joints — interrupted line, the orifices (S.O. and E.O.) and the delimitation of the shelter roof (thick dark grey line), after Vermeersch et al 2008; (C) Generalised lithostratigraphic sequence of the Tree Shelter deposits, according to Trench 4 (after Vermeersch et al., 2008).

In wadis with higher groundwater *Tamarix* communities occur (Kassas and Girgis, 1970; Zahran and Willis, 1992). Over-exploitation and partial extinction of the tree vegetation in the area was apparent by the beginning of the 20th century AD, increasing after further cutting of the perennial vegetation in the 1950–60s AD (Hobbs, 1989) and continuing to the present day (Andersen and

Table 1

Radiocarbon dates from the Tree Shelter site based on dating of wood charcoal (after Vermeersch et al., 2008); calibration carried out with the program CALIB 5.0.2. (Stuiver and Reimer, 1993); calibration data set according to Reimer et al. (2004)

	Lab nr.	^{14}C yr BP	Cal yr BP (2 σ age ranges)	Relative area under distribution	Method
AH 1	GrN-22559	200±35	137–223	0.54	Conv.
			256–306	0.27	
AH 3	GrN-22561	4930±30	5600–5720	1.00	Conv.
	Lv-2185	5330±60	5947–5967	0.03	Conv
			5988–6222	0.88	
			6230–6277	0.09	
	UtC-5390	5835±30	6560–6734	1.00	AMS
	GrN-22510	6630±45	7438–7575	1.00	Conv.
	GrN-22562	6770±60	7510–7543	0.05	Conv.
			7557–7718	0.95	
AH 4	Beta-229537	7630±50	8369–8540	1.00	AMS
AH 5	UtC-5388	7790±70	8411–8776	0.99	AMS
			8837–8851	0.01	
	UtC-4193	7910±90	8546–9004	1.00	AMS
	UtC-5389	8120±45	8988–9144	0.90	AMS
			9169–9252	0.10	

https://doi.org/10.1016/j.yqres.2008.08.002 Published online by Cambridge University Press

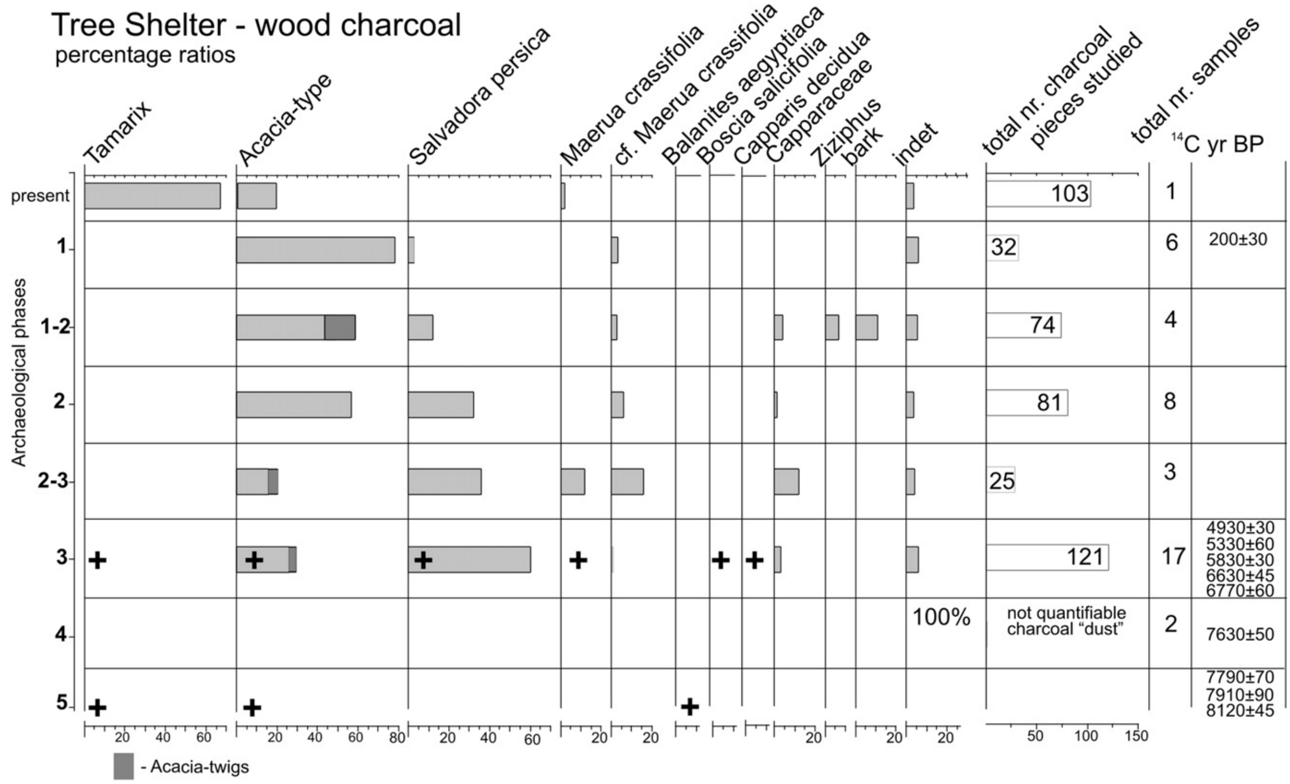

Figure 2. Diagram showing the percentage abundance of the wood charcoals found in each horizon, Results of previous wood charcoal determinations published by Moeyersons et al (1999) are given as presence/absence indicated by "+".

Krzywinski, 2007). This has also affected the wildlife population of the Eastern Desert. The clearance of *Acacia* has, for example, caused a decline of rock dassie (*Procavia capensis*) populations (Osborn and Helmy, 1980). Intensive hunting furthermore has much reduced wildlife in the Eastern Desert, including Barbary sheep (*Ammotragus lervia*) and ibex (*Capra ibex nubiana*) populations, both typical species of mountainous desert areas (Osborn and Helmy, 1980). Dorcas gazelle (*Gazella dorcas*), an inhabitant of vegetated wadis, is still widely spread in the Eastern Desert, although populations of this animal have also declined under anthropogenic pressure (Osborn and Helmy, 1980). Domestic stock in the Eastern Desert consists of dromedary (*Camelus thomasi* f. dromedarius), goat (*Capra aegagrus* f. hircus) and sheep (*Ovis ammon* f. aries), and is kept by nomadic groups (Cappers, 2006).

Methods and material

Available for analyses were 54 samples of wood charcoal from the Tree Shelter, with a total number of 436 charcoal fragments. The wood charcoal originates mainly from hearths, but also occasionally from stray finds outside hearths. There is considerable variation between the different archaeological horizons in the available number of wood charcoal fragments and samples. Altogether about 1000 faunal remains, mostly bones, were collected from AH 5-1. The archaeobiological remains were retrieved by handpicking and dry sieving of sediment on 2 or 6 mm meshes, depending on the context. The laboratory study of the wood charcoals (>2 mm) was carried out with reflected light microscopy in three anatomical views (transverse, tangential and radial). Identification literature (Fahn et al., 1986; Schweingruber, 1990; Neumann et al., 2001) was used in combination with the reference collection of modern wood housed at the Laboratory of the Archaeobotany of Africa, University of Frankfurt. The animal remains were identified mainly through comparisons with recent skeletons of reference specimens housed at the Royal Belgian Institute for Natural Sciences. In addition also identification literature was consulted, mainly for the distinction between the different possible bovid species (Boessneck et al., 1964; Gabler, 1985; Peters, 1986).

Results

For the studied AH 4-1, the counts of charcoal fragments of each taxon are presented as percentage ratios of abundance, based on the total number of charcoal fragments studied in each of them (Fig. 2). In

Table 2
Animal remains found at the Tree Shelter site (numbers of identified specimens)

	Archaeological horizon					
	1	2	3	4	5	Sum
Red Sea shells	1	–	3	1	5	10
Terrestrial snail (*Zootecus insularis*)	–	–	–	41	77	118
Large freshwater bivalve	–	–	–	–	1	1
Red Sea fish	3	2	11	–	–	16
Small lizard (Agamidae?)	1	–	2	–	–	3
Small snake	3	–	1	–	–	4
Small bird	–	–	1	–	–	1
Ostrich eggshell	–	1	–	3	30	34
Gerbil (*Tatera* sp.)	–	–	1	–	–	1
Small rodent	1	–	4	–	–	5
Rock dassie (*Procavia capensis*)	–	–	–	–	1	1
Dorcas gazelle (*Gazella dorcas*)	–	3	3	–	–	6
cf. Sheep (cf. *Ovis ammon* f. aries)	1	–	–	–	–	1
Goat (*Capra aegagrus* f. hircus)	1	–	2	–	–	3
Sheep (*Ovis ammon* f. aries) or goat (*Capra aegagrus* f. hircus)	–	1	–	–	–	1
Sheep, goat, Barbary sheep (*Ammotragus lervia*) or ibex (*Capra ibex*)	–	3	1	1	1	6
Small bovid	4	12	36	3	5	60
Small or large bovid	1	1	1	–	–	3
Unidentified mammal	52	92	428	12	61	645

https://doi.org/10.1016/j.yqres.2008.08.002 Published online by Cambridge University Press

addition, the results of the wood charcoal determinations mentioned in Moeyersons et al (1999) are integrated in the diagram. Because of the morphological resemblance of the various species, the identifications of *Acacia* wood are indicated as "*Acacia*-type." In the area under consideration the most probable *Acacia*-species are *Acacia tortilis*, *A. raddiana* and *A. ehrenbergiana* (Kassas and Girgis, 1970). The charcoal assemblages from AH 3-1 are more or less homogenous in their composition, with a predominance of *Acacia* and *Salvadora persica*. In the AH 2-1 (the period after 5000 ^{14}C yr BP to subrecent) wood of *Ziziphus* also appears.

Despite poor preservation, 17 different taxa, including mollusk shells, fish, reptiles and mammals, could be identified among the faunal remains (Table 2). Most animals were probably obtained locally, while the marine shells and marine fish, found only in the Neolithic and subrecent horizons, must have been brought in from the Red Sea. The animal remains of the Elkabian occupation (AH 5) at the Tree Shelter site are mainly connected with hunting. In the Neolithic horizons (AH3 and AH2) bones of domestic ovicaprines appear and herding continued in the subsequent horizons. In the former only goat could be identified, while the subrecent horizon (AH 1) yielded one bone that is possibly of sheep.

Discussion

Reconstruction of the vegetation around the site

In general the plant material found represents the typical contracted desert vegetation of wadis and depressions where water accumulation allows growing of perennials with a deep root system (Walter, 1990). This group, particularly *Acacia* and *Salvadora*, dominates the charcoal assemblage. Other evidence shows that after 8.0 ka more stable conditions with regular and less heavy rains – compared to the Early Holocene torrential rains – occurred near the site (Moeyersons et al., 1999). During the occupation of AH 3-1 at the Tree Shelter, most probably stands of *Acacia* and *Salvadora* developed at the wadi edges (*A. radiana* dominates today in the main wadis, *A. tortilis* and *A. ehrenbergiana* in the tributaries). The *Acacia* trees grow usually on more coarse sediment (Kassas and Girgis, 1970). Modern communities of *Salvadora persica* are associated with silt deposits of the principal wadis. The wood charcoal found at the Tree Shelter from *Maerua crassifolia* and *Ziziphus* might originate from specimens, which grew as shrubs or as trees in the *Acacia* stands. Today only sporadic trees of *Salvadora* and few specimens of *Maerua crassifolia* can be found in the area of the Red Sea Hills, roughly between 28–26°N (Hobbs, 1989).

Earlier identifications of wood charcoal from AH 3, from samples given for ^{14}C analysis, showed the presence of *Acacia*-type, *Salvadora persica, Cadaba farinosa, Maerua crassifolia, Capparis decidua* and *Tamarix* sp. (Moeyersons et al., 1999). The charcoal from the contemporaneous layers of the nearby cave of Sodmein (ca. 7152–7435 BP cal yr BP) gave a similar picture of the wadi vegetation, with a predominance of *Acacia* cf. *tortilis, Cadaba farinosa* and *Salvadora persica* (Moeyersons et al., 2002). These wood charcoal assemblages resemble those of the current study. *Tamarix* is absent in the samples analysed in the present study, except in the uppermost levels of the site (Fig. 2). The wood charcoal from AH 3, analysed prior to ^{14}C dating (Moeyersons et al., 1999), contains *Tamarix* identifications, which are absent in the newly studied samples. A possible explanation for this is limited availability of *Tamarix* in the surrounding of the Tree Shelter as it predominantly grows in oases and along the Nile River.

Some idea of the vegetation prior to AH 3-1 at the Tree Shelter is given by the previously done wood charcoal analyses from the ^{14}C sample from AH 5 which consist of *Tamarix*, *Acacia*-type, *Celtis* type and *Balanites aegyptiaca* (Moeyersons et al., 1999). However, the identifications published by Moeyersons et al (1999) are not precisely quantified, hampering their integration with the new data from Tree Shelter. From AH 5 at the Tree Shelter a humerus of a rock dassie (*Procavia capensis*) was identified. This animal can still be found in the Red Sea Mountains. Its habitat is restricted to rocky areas with cliffs, where acacia trees are available (Osborn and Helmy, 1980). Such habitats were presumably present in the surroundings of the site.

Paleoenvironmental and paleoeconomic implications

The wood charcoals from AH 5 and AH 3 at the Tree Shelter, used for radiocarbon dating (Moeyersons et al., 1999), and from contemporary layers at Sodmein Cave (Moeyersons et al., 2002), give a picture quite similar to that established for AH 3 by the present study. In both AH 4 and 3 Sahelian elements, like *Salvadora persica* and *Maerua crassifolia*, are present. The appearance of such vegetation in the Eastern Sahara during the period around 8000–7300 cal yr BP was interpreted as a consequence of increased precipitation and temperatures in the region (Neumann, 1989), and in addition to less anthropogenic pressure than in later periods (see above). This small tree is less tolerant of soil drought and is confined to localities where the topographic and climatic conditions lead to increased moisture and higher temperatures (Kassas and Girgis, 1970). This corresponds well with the more humid climatic conditions for the period roughly between 9252–8988 to 5720–5600 cal yr BP documented by previous studies at the Tree Shelter site (Moeyersons et al., 1999) and at the nearby Sodmein Cave (Moeyersons et al., 2002), the Red Sea Hills (Butzer, 1999) and in regional correlations (Neumann, 1989; Gasse, 2000; Hoelzmann et al., 2001; Kuper and Kröpelin, 2006; Bubenzer and Riemer, 2007). This tendency is observed also in marine sediments from the northern Red Sea. There a humid interval was recorded for the period between approximately 9.25 and 7.25 ka, which was finally terminated at about 6.25 ka (Seeberg-Elverfeldt et al., 2004). This humid period can be explained by enhancement and southward extension of rainfall from Mediterranean sources (Arz et al., 2003).

The predominance of *Salvadora persica* in the wood charcoal assemblage from the period 7718–7510 to 5720–5600 cal yr BP or AH 3 is consistent with the sedimentological evidence from the site surroundings, pointing to a higher humic content of the valley slopes, proving more frequent, but less heavy rains (Moeyersons et al., 2002). *Salvadora persica* prefers areas where groundwater is readily available, for example in seasonally wet sites and along drainage lines in arid zones. The tree is able to tolerate a very dry environment with mean annual rainfall of less than 100 mm. Highly salt tolerant, it can grow on coastal regions and inland saline soil (Kassas and Girgis, 1970). *Salvadora*'s abundance in the wood charcoal assemblages from fifth millennium BC of Makhadma 4 (Vermeersch et al., 1992) and third millennium BC (period contemporaneous with the final phases of AH 3) from Adaïma (Newton, 2005) indicates that its distribution in the region was extensive during the Middle Holocene.

The decreasing number of *Salvadora persica* finds during the Neolithic occupation at the Tree Shelter (AH 3-2) could be connected with a more intense use of the plant as both fuel and fodder, but the small number of samples do not allow to draw reliable conclusions about this. The Neolithic economy with the presence of domesticated ovicaprines (Vermeersch et al., 2002) may have had a greater impact on the plant ecosystem, than that of the earlier AH 4 and 5. Large amounts of dung found in the Neolithic layers of nearby Sodmein Cave site indicate that herds of domestic stock were probably larger than suggested by the sparse ovicaprine bones collected (Linseele et al., in press).

Another useful plant in the charcoal assemblage is *Ziziphus* sp. The presence of *Ziziphus spina-christi* in the Sahara is considered as an anthropogenic introduction during the Neolithic, due to its fruits

https://doi.org/10.1016/j.yqres.2008.08.002 Published online by Cambridge University Press

which could be eaten and transported by humans and animals (Barakat, 2001). The appearance of *Ziziphus* sp. at Tree Shelter site in the final occupation phases (AH 1-2) might be an indication of such an anthropogenic introduction.

Wadi vegetation, especially *Acacia*, is attractive for human groups as fuel wood and animal fodder. Most probably the wood charcoal assemblage derives from such uses. Leaves of young trees of *Acacia tortilis* are eaten by goats and sheep, but the main value of this species is in its pods, which can be eaten by all African livestock. At the time when pods are mature, they are often the main source of food for sheep and goats (Briggs et al., 1999). *Salvadora* fruits are sweet and edible. The pulp contains glucose, fructose and sucrose. It is a rich source of calcium containing about 15 times the amount present in wheat (von Maydell, 1986). The use of *Salvadora* as fodder plant at the site is quite plausible too. Leaves and young shoots are browsed by all stock, but normally cattle do not occur in the driest part of the *S. persica* distribution range and it tends to be valued more as a camel, sheep and goat forage.

The scarce animal remains from AH 3 at the Tree Shelter, did not yield evidence for more humid conditions in the area than today. This horizon (AH3) displays the remains of several occupation periods dating from ca 7718–7510 to 5720–5600 cal yr BP, with a large number of hearths and dense horizontal scatter of lithic and faunal remains. Among them bones of domestic ovicaprines appear. They are between the oldest finds of domesticated animals on the African continent, together with finds from Sodmein (Vermeersch et al., 1994, 1996) and, in the Western desert, the Middle and Late Neolithic of the Bir Kiseiba and Nabta Playa area (Gautier, 2001) and from the Bashendi B period in Dakhla Oasis (McDonald, 1991). As at the Tree Shelter site, only ovicaprines have been identified at Sodmein and only goat is certainly present. In the Bir Kiseiba and Nabta Playa area, on the other hand, goat was found accompanied by remains of cattle as well as sheep (Gautier, 2002). In fact, sheep are predominant among the small livestock remains from the Middle and Late Neolithic period there. In the Bashendi B phase, contemporary with the Late Neolithic, at Dakhla Oasis only cattle bones have been reported together with goat remains (McDonald, 1991). The faunas from Sodmein and the Tree Shelter suggest that Neolithic herds in the Eastern Desert only consisted of small livestock, and perhaps only of goat. Cattle need more drinking water and better pasture than ovicaprines (Dahl and Hjort, 1976). They could be kept successfully in the Western Desert thanks to the available playas, which provided sufficient surface water and pasture (Bolten and Bubenzer, 2007). The absence of such features in the Eastern Desert may have made cattle keeping there impossible. The lack of sheep remains is possibly also related to environmental circumstances. Goat is much better adapted to living in arid areas which lack good pasture (Dahl and Hjort, 1976).

Conclusion

The charcoal assemblages from Tree Shelter do not differ greatly throughout the studied sequence, indicating more or less stable and probably more favorable conditions than today throughout the period 7718–7510 to 5720–5600 cal yr BP. They show that during the so called "African Humid Period" in the Red Sea Mountain area similar to the Egyptian Western Desert well-developed wadi vegetation dominated by *Acacia* and *Salvadora persica* was present and used by the prehistoric population. Most probably the humans visited the area after occasional rains that are characteristic for the study area. After such rains, which have shown to be rather recurrent in the Early to Middle Holocene of the arid and sub-arid belt of the Sahara, Sahel and Arabian Peninsula, the area around the site became attractive for nomadic groups, practicing pasture. The archaeozoological data indicate that small livestock had reached the Eastern Desert by 7718–7510 to 5720–5600 cal yr BP. Cattle could probably not spread to the area because of unsuitable environmental conditions.

Acknowledgments

Charcoal analyses were partly done at the Laboratory of the Archaeobotany of Africa, University of Frankfurt with the friendly support of A. Höhn and K. Neumann. We are grateful to W. Van Neer (Royal Belgian Institute for Natural Sciences) for discussion on an early version of the manuscript and to M. Nesbitt for language improvement. We would like to thank to the editor A. Gillespie, the reviewer P. Hoelzmann and one anonymous reviewer for the valuable remarks and suggestions, which generally improved the paper.

References

Andersen, G.L., Krzywinski, K., 2007. Mortality, recruitment and change of desert tree populations in a hyperarid environment. PLoSONE 2 (2), e208.

Arz, H.W., Lamy, F., Pätzold, J., Müller, P.J., Prins, M., 2003. Mediterranean moisture source for an early-Holocene humid period in the northern Red Sea. Science 300, 118–122.

Barakat, H., 2001. Anthracological studies in the Neolithic sites of Nabta Playa, South Egypt. In: Wendorf, F., Schild, R., Associates (Eds.), Holocene settlement of the Egyptian Sahara—Vol. I : The archaeology of Nabta Playa. Kluwer Press, New York, pp. 592–600.

Boessneck, J., Müller, H., Teichert, M., 1964. Osteologische Unterscheidungsmerkmale zwischen Schaf (*Ovis aries* Linne) und Ziege (*Capra hircus* Linne). Kühn-Archiv 78 (1–2), 1–129.

Bolten, A., Bubenzer, O., 2007. Watershed analysis in the Western Desert of Egypt. In: Bubenzer, O., Bolten, A., Darius, F. (Eds.), Atlas of Cultural and Environmental Change in Arid Africa. . Africa Praehistorica, Volume 21. Köln, pp. 22–23.

Briggs, J., Badri, M., Mekki, A-M., 1999. Indigenous knowledges and vegetation use among bedouin in the Eastern Desert of Egypt. Applied Geography 19, 87–103.

Bubenzer, O., Riemer, H., 2007. Holocene climatic change and human settlement between the Central Sahara and the Nile Valley: Archaeological and geomorphological results. Geoarchaeology 22, 607–620.

Butzer, K., 1999. Climatic history. In: Bard, K. (Ed.), Encyclopedia of the Archaeology of Egypt. Routledge, London, pp. 195–198.

Cappers, R.T.J., 2006. Roman foodprints at Berenike. Archaeobotanical evidence of trade and subsistence in the Eastern Desert of Egypt. Monograph 55. Cotsen Institute of Archaeology, UCLA.

Dahl, G., Hjort, A., 1976. Having herds: Pastoral herd growth and household economy. Stockholm Studies in Social Anthropology, Volume 2. University of Stockholm, Sweden.

De Menocal, P., Ortiz, J., Guilderson, Sarnthein, M., 2000. Cocherent high and low-latitude climate variability during the Holocene Warm Period. Science 288, 2198–2202.

Fahn, A., Werker, E., Baas, P., 1986. Wood Anatomy and Identification of Trees and Shrubs from Israel and Adjacent Regions. Israel Academy of Sciences, Jerusalem, Israel.

Gabler, K.-O., 1985. Osteologische Unterscheidungsmerkmale am postkranialen Skelett zwischen Mähnenspringer (*Ammotragus lervia*), Hausschaf (*Ovis aries*) und Hausziege (*Capra hircus*). München Univ., Diss.

Gasse, F., 2000. Hydrological changes in the African tropics since the Last Glacial Maximum. Quaternary Science Reviews 19, 189–211.

Gautier, A., 2001. The Early to Late Neolithic archaeofaunas from Nabta and Bir Kiseiba. In: Wendorf, F., Schild, R., Associates (Eds.), Holocene settlement of the Egyptian Sahara. Volume 1. The Archaeology of Nabta Playa. Kluwer Academic / Plenum Publishers, New York, pp. 609–635.

Gautier, A., 2002. The evidence for the earliest livestock in North Africa: or adventures with large bovids, ovicaprids, dogs and pigs. In: Hassan, F.A. (Ed.), Droughts, food and culture. Ecological change and food security in Africa's later prehistory. Kluwer Academic / Plenum Publishers, New York / Boston / Dordrecht / London / Moscow, pp. 195–207.

Hobbs, J.J., 1989. Bedouin life in the Egyptian wilderness. University of Texas Press, Austin.

Hoelzmann, Ph., Keding, B., Berke, H., Kröpelin, S., Kruse, H.-J., 2001. Environmental change and archaeology: lake evolution and human occupation in the Eastern Sahara during the Holocene. Paleogeography, Paleoclimatology, Paleoecology 169, 193–217.

Hoelzmann, Ph., Gasse, F., Dupont, L., Salzmann, U., Schtaubwasser, M., Leuschner, D., Siroko, F., 2004. Paleoenvironmental changes in the arid and subarid belt (Sahara–Sahel–Arabian peninsula) from 150 kyr to present. In: Battarbee, R., Gasse, F., Stickley, C. (Eds.), Past Climate Variability Through Europe and Africa. . Developments in Paleoenvironmental Research, Volume 6. Springer, Dordrecht, pp. 219–256.

Kassas, M., Girgis, W.A., 1970. Habitat and plant communities in the Egyptian Desert: VII. Geographical facies of plant communities. The Journal of Ecology 58, 335–350.

Kuper, R., Kröpelin, S., 2006. Climate-controlled Holocene occupation in the Sahara: motor of Africa's evolution. Science 313, 803–807.

Linseele, V., Marinova, E., Van Neer, W., Vermeersch, P., in press. Sites with Holocene dung deposits in the Eastern Desert of Egypt: visited by herders? Journal of Arid Environments.

https://doi.org/10.1016/j.yqres.2008.08.002 Published online by Cambridge University Press

McDonald, M.M.A., 1991. Origins of the Neolithic in the Nile Valley as seen from Dakhleh Oasis in the Egyptian Western Desert. Sahara 4, 41–52.
Moeyersons, J., Vermeersch, P., Van Peer, P., Van Neer, W., Beeckman, H., De Coninck, E., 1996. Sodmein Cave Site, Red Sea Mountains, Egypt: development, stratigraphy and palaeoenvironment. In: Pwiti, G., Soper, R. (Eds.), Aspects of African archaeology. Papers 10th congr. PanAfrican Ass. Prehistory and Related Studies. Harare, pp. 53–62.
Moeyersons, J., Vermeersch, P.M., Beeckman, H., Van Peer, P., 1999. Holocene environmental changes in the Gebel Umm Hammad, Eastern Desert, Egypt. Geomorphology 26, 297–312.
Moeyersons, J., Vermeersch, P.M., Van Peer, P., 2002. Dry cave deposits and their palaeoenvironmental significance during the last 115 ka, Sodmein Cave, Red Sea Mountains, Egypt. Quaternary Science Reviews 21, 837–851.
Neumann, K., 1989. Vegetationsgeschichte der Ostsahara im Holozän. Holzkohlen aus prähistorischen Fundstellen. In: Kuper, R. (Ed.), Forschungen zur Umweltgeschichte der Ostsahara. . Africa Praehistorica, Volume 2. Köln, pp. 13–181.
Neumann, K., Schweingruber, F., Schoch, W., Détienne, P., 2001. Woods of the Sahara and the Sahel / Bois du Sahara et du Sahel / Hölzer der Sahara und des Sahel. Haupt, Bern.
Newton, C., 2005. Upper Egypt: vegetation at the beginning of the third millennium BC inferred from charcoal analysis at Adaı¨ma and Elkab. Journal of Archaeological Science 32, 355–367.
Newton, C., Midant-Reynes, B., 2007. Environmental change and settlement shifts in Upper Egypt during the Predinastic: charcoal analysis at Adaïma. The Holocene 18, 1109–1118.
Osborn, D.J., Helmy, I., 1980. The contemporary land mammals of Egypt (Including Sinai). Fieldiana Zoology, New Ser., Volume 5. Chicago.
Peters, J., 1986.Osteomorphology and osteometry of the appendicular skeleton of Grant's Gazelle, *Gazella granti* (Brooke, 1872), Bohor Reedbuck, *Redunca redunca* (Pallas, 1767) and Bushbuck, *Tragelaphus scriptus* (Pallas, 1766), Occasional papers 2, Laboratorium voor Paleontologie, Ghent University, Ghent.
Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, G., Manning, S., Ramsey, C.B., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., Weyhenmeyer, C.E., 2004. IntCal04 Terrestrial Radiocarbon Age Calibration, 0–26 cal kyr BP. Radiocarbon 46 (3), 1029–1059.
Schweingruber, F.H., 1990. Anatomy of European woods. Verlag Paul Haupt, Bern/ Stuttgart.
Scott, L., 2005. The Holocene of middle altitude arid areas. In: Mackay, A., Battarbee, R., Birks, J., Oldfield, F. (Eds.), Global Change in the Holocene. Hodder Arnold, London, pp. 396–405.
Seeberg-Elverfeldt, I.A., Lange, C.B., Arz, H.W., Pätzold, J., Pike, J., 2004. The significance of diatoms in the formation of laminated sediments of the Shaban Deep, Northern Red Sea. Marine Geology 209, 279–301.
Stuiver, M., Reimer, P.J., 1993. Radiocarbon 35, 215–230.
Vermeersch, P.M., 1978. L'Elkabien, Epipaléolithique de la vallée du Nil égyptien. Universitaire Pers and Bruxelles Fondation égyptologique reine Elisabeth, Leuven.
Vermeersch, P.M., Paulissen, E., Huyge, D., Neumann, K., Van Neer, W., Van Peer, P., 1992. Predynastic Hearths in Upper Egypt. In: Friedman, R., Adams, B. (Eds.), The Followers of Horus. . Oxbow Monograph, Volume 20. Oxford, pp. 163–172.
Vermeersch, P.M., Van Peer, P., Moeyersons, J., Van Neer, W., 1994. Sodmein Cave Site, Red Sea Mountains (Egypt). Sahara 31–40.
Vermeersch, P.M., Van Peer, P., Moeyersons, J., Van Neer, W., 1996. Neolithic occupation of the Sodmein area, Red Sea Mountains, Egypt. In: Pwiti, G., Soper, R. (Eds.), Aspects of African archaeology. Papers 10th congr. PanAfrican Ass. Prehistory and Related Studies. Harare, pp. 411–420.
Vermeersch, P., Van Peer, P., Moeyersons, J., Van Neer, W., 2002. The Tree Shelter, a Holocene Site in the Red Sea Mountains. Archéo-Nil 12, 123–136.
Vermeersch, P.M., Moeyersons, J., Van Peer, P., Rots, V., Vanmontfort, B., 2008. Field work. In: Vermeersch, P.M. (Ed.), A Holocene prehistoric sequence in the Egyptian Red Sea area. The Tree Shelter. Egyptian Prehistory Monographs. Leuven University Press, pp. 11–61.
von Maydell, H.J., 1986. Trees and shrubs of the Sahel — their characteristics and uses. GTZ 6MBH, Eschborn
Walter, H., 1990. Vegetation und Klimazonen. 6. Auflage. 382 S. Ulmer UTB 14.
Wendorf, F., Schild, R., Close, A.E., 1984. Cattle-keepers of the Eastern Sahara. The Neolithic of Bir Kiseiba. Southern Methodist University, Dallas.
Zahran, M., Willis, A., 1992. The Vegetation of Egypt. Chapman and Hall, London.

https://doi.org/10.1016/j.yqres.2008.08.002 Published online by Cambridge University Press