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ORIGINAL ARTICLE

Bolboschoenus glaucus (Lam.) S.G. Smith, a new species in the flora of the ancient Near East

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Abstract Taxonomic advancement in the genus *Bolboschoenus* (Cyperaceae, formerly included in the genus *Scirpus*) have resulted in the re-classification of the plant previously known as *Bolboschoenus maritimus* (synonym *Scirpus maritimus*) into several closely-related but distinct *Bolboschoenus* species This improved taxonomy is of importance for archaeobotanical investigations of ancient sites within the temperate zones, where this genus frequently occurs, because it allows more precise definitions of the ecological requirements and growing habits of each species. Moreover, it details the distinct morphological and anatomical characteristics of the fruit (nutlets) of each species. Using these new nutlet classification criteria, we re-examined charred archaeological specimens which had previously been identified as *B. maritimus* (or *S. maritimus*), from five Near Eastern late Pleistocene and early Holocene village sites: Abu Hureyra, Hallan Çemi, Demirköy, Çatalhöyük and Aswad. Because three of these sites are located in Anatolia, data on the recent occurrence of *Bolboschoenus* in Turkey were also investigated. All archaeobotanical specimens were found to be *B. glaucus*. This species was also found to be the most common *Bolboschoenus* in present-day Turkey, indicating that it has a long history of occurrence in this region. The environmental, ecological and economic implications of this new information suggest that it is entirely feasible that this plant provided late Pleistocene and Holocene Near Eastern people with a dependable and possibly a staple food source.

Keywords *Bolboschoenus glaucus* · Epipalaeolithic · Near East · Neolithic · Taxonomy · Nutlet characteristics

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Introduction

Bolboschoenus maritimus (sea club-rush) is a semi-aquatic species of the Cyperaceae that produces edible nutlets, tubers and shoots (Fig. 1). This "species" inhabits saline and fresh-water wetland environments throughout the temperate latitudes. It was formerly classified as a species of the genus *Scirpus* and most frequently described as *Scirpus maritimus* L. (Norlindh 1972; DeFilipps 1980; Schultze-Motel 1980; Kantrud 1996), but taxonomists have now assigned it to its own genus, *Bolboschoenus* (Goetghebeur and Simpson 1991; Smith 1995), which describes a group of tuberous club-rushes.

Sea club-rush is of significance in the archaeobotany of the Near East because the nutlets and sometimes the tubers have been recovered in notably large numbers from Epipalaeolithic and early Neolithic archaeological sites in Anatolia, the Levant and Mesopotamia (Fig. 2; Fairbairn et al. 2002; Hillman 1975, 2000; Hillman et al. 1989a, Hillman et al. 2001; Savard et al. 2006; van Zeist and Bakker-Heeres 1982, 1984) and also from mid-Holocene Mesolithic sites in Europe (Kubiak-Martens 1999). For example, Fairbairn et al. (2002, p. 46) report that at the Neolithic Çatalhöyük East site in south-central Anatolia,

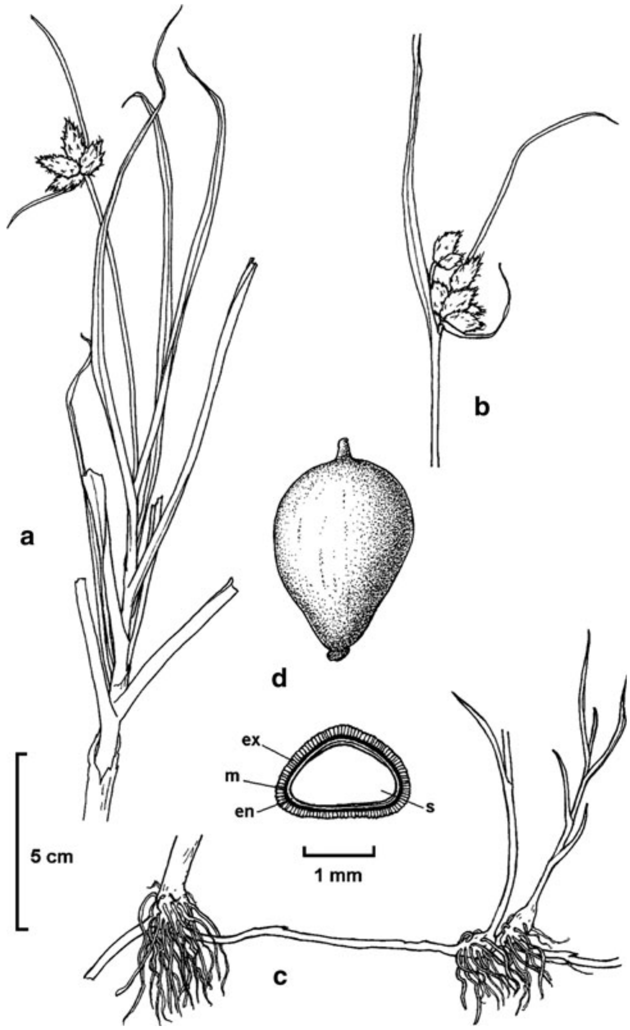


Fig. 1 *Bolboschoenus maritimus*. **a** flowering plant, **b** inflorescence with sessile spikelets and short rays, **c** underground organs (rhizome with tubers), **d** nutlet (dorsal view and cross section), *ex* exocarp, *m* mesocarp (in *black*), *en* endocarp, *s* seed. Drawn from voucher specimens from: Vilayet Konya, 1 km north Hortu, H 1548661 (**a**, **b**, **c**); Izmir: Selçuk—Pamucak, H 1203506 (**d**). Drawings by Z. Hroudová

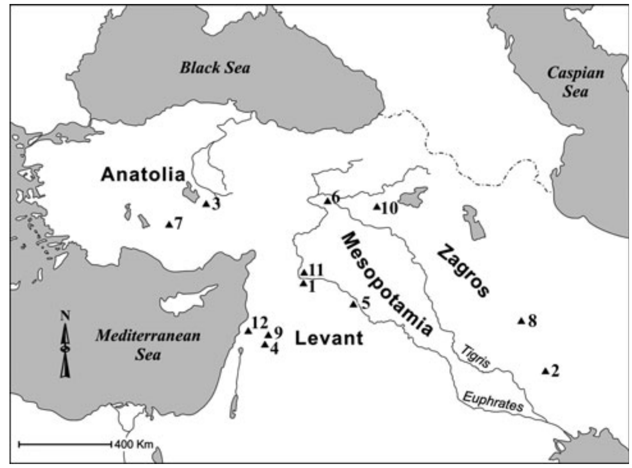


Fig. 2 Epipalaeolithic and aceramic Neolithic Near Eastern sites where sea club-rush nutlets have been found; *1* Tel Abu Hureyra (late Epipalaeolithic, PPNA & PPNB), *2* Ali Kosh (PPNB), *3* Asikli Höyük (PPNB), *4* Tel Aswad (PPNB), *5* Bourqras (PPNB), *6* Cayönü (PPNA, PPNB & PN), *7* Çatalhöyük (PPNB), *8* Ganj Dareh Tepe (PPNB), *9* Ghoraife (PPNB), *10* Hallan Çemi (Late Epipalaeolithic and PPNA), *11* Tel Mureybit (Late Epipalaeolithic, PPNA and PPNB), *12* Tel Ramad (PPNB)

sea club-rush nutlets have a ubiquity score of 59% and occur in frequencies that are greater than and/or comparable with those of other food plants found at the site such as the cereals, pulses, fruit and nuts; likewise Savard et al. (2006, pp. 186–187) report that sea club-rush nutlets dominate the seed assemblages of the Epipalaeolithic/PPNA sites of Hallan Çemi and Demirköy, in the Taurus-Zagros of present day eastern Turkey, in terms both ubiquity and proportions. Whenever sedges are found at late Pleistocene and early Holocene sites in the Near East, they are usually *Bolboschoenus*.

Bolboschoenus nutlets and tubers are energy-rich and contain substantial amounts of carbohydrate, particularly starch (Kantrud 1996; Wollstonecroft 2009). Experimental harvesting of the nutlets (Hillman in prep.) and tubers (Wollstonecroft 2009) demonstrate that the return-rates, in terms of energy (kcal/h) and carbohydrate/h, are comparable with those reported for many economically important edible wild and domesticated seeds and underground storage organs (USOs). Experimental processing of the nutlets (Hillman in prep.) and tubers (Wollstonecroft et al. 2008; Wollstonecroft and Erkal 1999) show that they can both be processed into several different forms of food; moreover, edible products can be produced from these nutlets and tubers with simple pulverising and heating methods and tools similar to those that were used by at least the late Upper Palaeolithic. Therefore it is entirely feasible that this plant was used as a food by late Pleistocene and Holocene Near Eastern people.

Initially, charred remains of sea club-rush nutlets from Near Eastern sites were identified as either "*Cyperus* spec." (van Zeist 1972, p. 13; van Zeist and Bakker-Heeres 1979, p. 162) or *"Scirpus maritimus"* (Hillman 1975, p. 71). However, during the 1980s three archaeobotanists, Gordon Hillman, Willem van Zeist and Johanna Bakker-Heeres, began to question their identifications of sea club-rush nutlets from Near Eastern sites (van Zeist and Bakker-Heeres 1982, p. 217). They observed that the Near Eastern nutlets, both modern and ancient, were proportionately smaller than those found in northwestern Europe. They inferred that the Near Eastern nutlets represented a separate species, following the French botanist Mouterde (1966), who classified Near Eastern sea club-rushes as *Scirpus tuberosus* Desf. Hillman was initially not persuaded by the differences in size, but he argued that differences in the shape and anatomy of present-day nutlets from British and Near Eastern populations of "*S. maritimus*" were so profound that at least two different species must be involved. Thereafter, he provisionally referred to the distinctive Near Eastern nutlets as *S. tuberosus* or "*Scirpus* sp. of the *Scirpus maritimus/tuberosus* type" (Hillman et al. 1989b, pp. 196–197) or else as "*Scirpus maritimus/S. tuberosus*" (Hillman et al. 1989a, p. 251, Hillman et al. 2001, p. 387). In this paper we discuss recent taxonomic research that supports the observations of Hillman, van Zeist and Bakker Heeres and clarifies the correct taxonomic identification of these nutlets.

Taxonomic reports and regional floras are important reference tools for archaeobotanical interpretation. Inaccuracies within taxonomic nomenclature and an out-of-date flora can impede archaeobotanical identifications and confound our interpretations of the plant use and land use practices of ancient peoples. In the case of the genus *Bolboschoenus*, nomenclatural problems pervade the botanical literature. Botanists attribute these taxonomic inconsistencies to disagreements over *Bolboschoenus* species boundaries, misapplication of names, probable hybridisation, the introduction of new species and infraspecific variation (Kantrud 1996). As a result, at different times and places this group of tuberous club-rushes has been assigned to any one of three separate genera: *Scirpus* (Ohwi 1944; Fernald 1950), *Schoenoplectus* (Haines and Lye 1983; Strong 1993, 1994) and *Bolboschoenus* (Browning and Gordon-Gray 1993; Hroudová and Zákravský 1995; Tatanov 2004a). Alternatively, the different species of *Bolboschoenus* have been relegated to subspecies within *B. maritimus,* for example *B. maritimus* ssp. *maritimus* and *B. maritimus* ssp. *compactus* (Casper and Krausch 1980; Kantrud 1996). To further complicate matters, *Bolboschoenus* and several other Cyperaceae have sometimes been assigned the same Latin binomial, as in southeast Asia where the name *Scirpus tuberosus* has been applied to both a *Bolboschoenus* and the edible Chinese water chestnut *Eleocharis dulcis* (Nadkarni 1954; Täckholm and Drar 1950; Tanaka 1976).

It is therefore not surprising that misidentifications of *Bolboschoenus* species are common in the ethnographic literature where the correct identification of economically or culturally important sedges is further compounded by the incompleteness of the ethnographic record, confusion over local uses of common names and linguistic errors. For example, the name "bulrush" is frequently used for semi-aquatic plants of both the Cyperaceae and Typhaceae (Mabey 1996; N. Turner personal communication) or else people simply classify sedges in a general category that includes grasses and grass-like plants (Turner 1998, p. 106).

Taxonomists have recently made great advances with *Bolboschoenus* classifications and nomenclature. Worldwide, about fourteen species of *Bolboschoenus* have now been identified (Browning and Gordon-Gray 2000; Tatanov 2007). As a result of taxonomic research by Browning et al. (1996, 1997) and Hroudová et al. (2007), encompassing the study of natural populations and cultivated plants as well as examining herbarium collections, five European *Bolboschoenus* spp. are now recognised, each with discrete botanical characteristics and distinct habitat requirements. These new *Bolboschoenus* taxonomies and nomenclature are of importance for archaeobotanical investigations in Europe and the Near East because they explain the geographical distribution of each of the five species over Eurasia as well as their individual growing habits and habitat requirements. Of particular significance for archaeobotanists is that the new taxonomies also give the morphological and anatomical characteristics of the nutlets of each species (discussed below).

In view of the ecological implications of these new taxonomies and the potential importance of *Bolboschoenus* in late Pleistocene and early Holocene Near Eastern subsistence, the UCL Institute of Archaeology in London and the Institute of Botany of the Academy of Sciences of the Czech Republic have collaborated to re-assess the identification and nomenclature of ancient *Bolboschoenus* nutlets from Near Eastern Epipalaeolithic and Neolithic sites. This paper presents the results of that collaboration, encompassing a re-classification of ancient Near Eastern *Bolboschoenus* nutlets and the introduction of *B. glaucus*, a new species in the flora of the ancient Near East.

The five European *Bolboschoenus* species: distribution, habitat preferences and fruit characteristics

In their definitive paper on the European *Bolboschoenus*, Hroudová et al. (2007) describe five species: *B. maritimus* (L.) Palla, *B. laticarpus* Marhold, Hroudová, Ducháček and Zákravský, *B. yagara* (Ohwi) Y.C. Yang and M. Zhan, B. *planiculmis* (F. Schmidt) T.V. Egorova and *B. glaucus* (Lam.) S.G. Smith. Hroudová et al. (2007) explain that these five species are distributed over three overlapping areas of Europe and Asia: *B. maritimus* and *B. laticarpus* are concentrated within Europe and only marginally extend into Asia; *B. yagara* and *B. planiculmis* are distributed within a geographical belt that stretches over Eurasia between 40° and 60° north, but have a wider north–south range in East Asia (Dai et al. 2010); *B. glaucus* which is more thermophilic and well adapted to high summer temperatures, occurs only in the southern regions, its northern border running along northern Spain, southern France, northern Italy, central Hungary and eastwards through

Romania, southern Ukraine, Russia, over central Asia to India, and in Africa along the Mediterranean seacoast and in sub-Saharan Africa (Browning et al. 1998).

With the exception of *B. maritimus*, the European *Bolboschoenus* are freshwater species. *B. maritimus* is a typical halophytic plant, inhabiting sea coasts and inland saline habitats. *B. laticarpus* and *B. planiculmis* are salt tolerant, whereas *B. glaucus* is only partially so; *B. laticarpus* has a wide ecological amplitude, and it inhabits mainly freshwater river habitats and occurs as a weed in arable land; *B. planiculmis* occurs in terrestrial habitats of warmer regions, often as a weed in arable land; *B. yagara* inhabits fishponds and lakes and is best adapted to acid, nutrient-poor habitats; *B. glaucus* frequently occurs along rivers and in river floodplains as well as in secondary habitats near villages or in rice fields; it is well-adapted to terrestrial summer-dry habitats but forms dense stands when sufficient water is available.

Bolboschoenus nutlets can be differentiated by their morphological and anatomical characteristics. The most important diagnostic features are the shape in both overall outline and cross section, pericarp structure, and size (Browning and Gordon-Gray 1993; Tatanov 2004b; Hroudová et al. 2007). Because the nutlet sizes of *Bolboschoenus* spp. vary, and frequently overlap (see below), nutlet shape and pericarp structure are considered the most diagnostic features. The following paragraphs summarise the nutlet features reported by Hroudová et al. (2007).

Bolboschoenus maritimus nutlets are elliptical, obovate to broadly obovate in outline, with a short beak on the summit (Figs. 1 and 3-1). Along with the nutlets of *B. yagara*, they are the largest of the nutlets discussed here, measuring 3–4 mm long and (1.8-) 2.1–2.7 mm wide. On the abaxial side they appear convex or with a round edge, sometimes lenticular. In cross section they are oval, flat-convex to sub-trigonous in shape. The surface is covered with a highly visible polygonal network created by depressed cell wall outlines. The distinguishing anatomical feature of this nutlet is the pericarp anatomy in which the well-developed exocarp is about twice the thickness of the sclerenchymatic mesocarp. The exocarp is composed of one layer of radially elongated and air-filled cylindrical cells. The endocarp is narrow, made up of a thin sclerenchymatic layer, like those of the other four European species.

Bolboschoenus laticarpus nutlets are obovate to broadly obovate in outline, narrow at the base and summit where they abruptly narrow into a beak (Fig. 3-2). They measure 3.1–3.7 mm (l) by 2–2.4 mm (w). In abaxial shape they are trigonous, the edge being low, sharp or nearly round, sometimes flattened. In cross-section they are obtusely trigonous to oval. The surface is smooth or else covered in a fine network pattern created by depressed anticlinal cell walls. The sclerenchymatic mesocarp is the thickest layer of the pericarp, measuring approximately three times that of the exocarp. The narrow exocarp is composed of one layer of isodiametric to slightly elongated air-filled cells. The sclerenchymatic endocarp is narrow.

Bolboschoenus planiculmis nutlets are obovate to broadly obovate in outline, with a short beak on the summit and measure 3.1–3.8 mm (l) by 2.2–2.5 mm (w) (Fig. 3-3). On the abaxial side they are concave, rarely flattened. In cross section the nutlets are biconcave to flat-concave with rounded, radially elongated edges. A highly visible polygonal network, created by depressed cell wall outlines, covers the surface. The mesocarp and endocarp are of approximate equal thicknesses, and the sclerenchymatic endocarp is thin. The exocarp is composed of one layer of cylindrical cells radially elongated and air-filled, which are thicker over the rounded edges than on the concave faces. The thickness of the sclerenchymatic mesocarp may vary in this species: *B. planiculmis* nutlets from plants from China and Germany were found to have a somewhat thicker mesocarp than exocarp, but the exocarp was nevertheless well developed (Hroudová et al. 2009; Hroudová unpublished).

Bolboschoenus yagara nutlets have a distinctive overall outline shape, being narrowly obovate to elliptic with an elongated beak on the summit (Fig. 3-4). With the nutlets of *B. maritimus*, they are the largest of the five species discussed here, measuring 3.2–4 mm (l) by 1.6–1.8 (w). The surface is smooth. The mesocarp is exceptionally thick, measuring as much as ten times that of the exocarp. The exocarp is composed of one layer of isodiametric cells that are only partly air-filled.

Bolboschoenus glaucus nutlets are noticeably smaller than those of the other four European species, measuring c. 2.2–2.5 mm (l) by 1.4–1.7 mm (w) (Figs. 3–5). They are obovate to elliptic in outline, plano-convex to sub-trigonous in cross section, and have a smooth surface. The pericarp is composed of a very narrow exocarp, made up of one layer of more or less isodiametric cells, a thick sclerenchymatic mesocarp and thin sclerenchymatic endocarp.

Methods

Nutlet species identification

The morphological and anatomical characteristics of both archaeobotanical and modern *Bolboschoenus* nutlets were examined using the identification criteria established by Hroudová et al. (2007), summarised above. At the UCL Institute of Archaeology archaeobotany laboratory, samples were subjected to a preliminary examination using a Leica Wild M3C binocular light microscope with a magnification range of 6.4–40x. Charred archaeobotanical

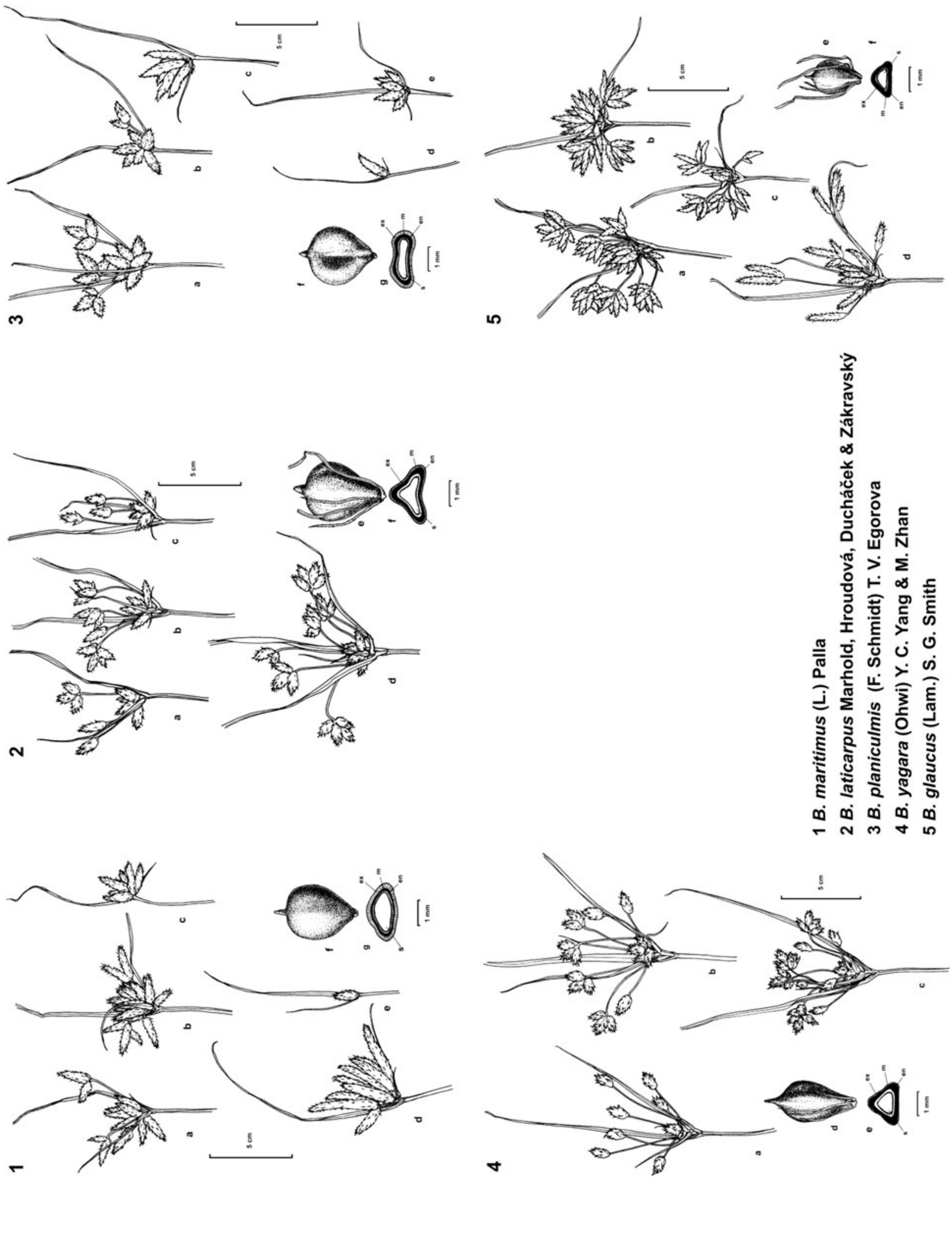
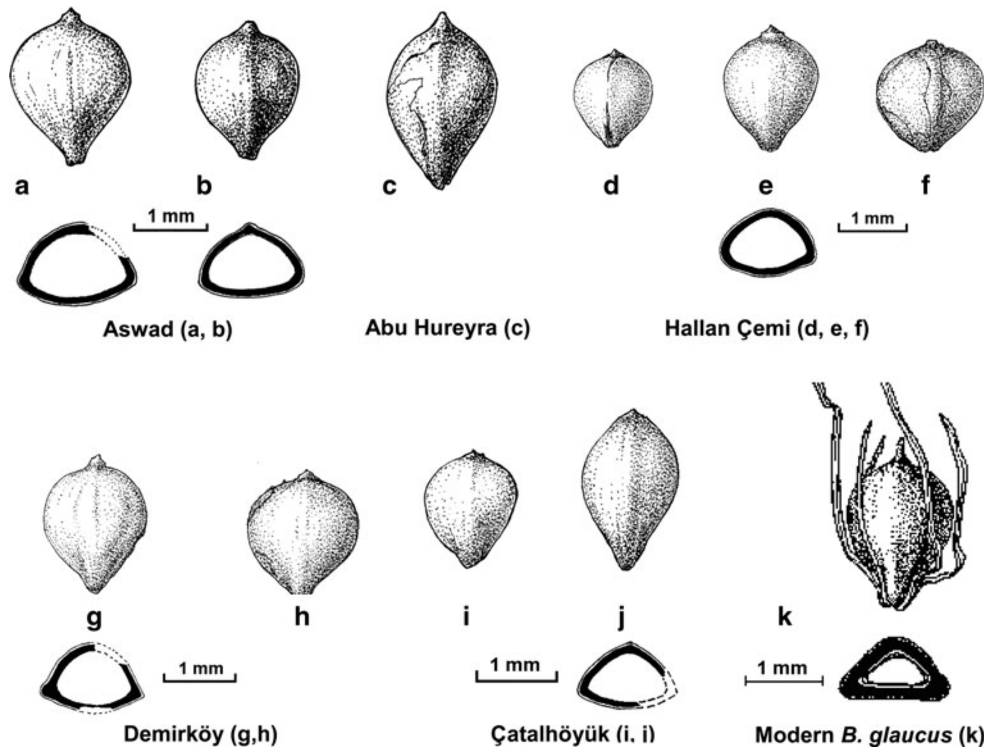


Fig. 3 The five European *Bolboschoenus* species (from Hroudová et al. 2001, with permission)

Fig. 4 Charred archaeobotanical *B. glaucus* specimens from five Near Eastern sites: **a**, **b** Tel Aswad in the Damascus Basin, **c** Abu Hureyra in the mid-Euphrates, **d**, **e**, **f** Hallan Çemi in southeastern Anatolia, **g** from Demirköy, also in southeastern Anatolia, **h**, **i**, **j** from Çatalhöyük East in south-central Anatolia, **k** modern specimen (from Hroudová et al. 2001, with permission). Drawings by Z. Hroudová



nutlets were compared to uncharred modern nutlets of both *B. maritimus* and *B. glaucus* provided by the Institute of Botany of the Academy of Sciences of the Czech Republic. Species identifications were subsequently confirmed and the nutlets drawn, at the Institute of Botany laboratories of the Academy of Sciences of the Czech Republic, using a Carl Zeiss Jena stereomicroscope with a magnification range 6.4 × 0.63–4.

Charred ancient nutlets from five prehistoric Near Eastern sites were examined: Abu Hureyra I (11150–10450 cal. B.C.; number of nutlets (n) = 100), Hallan Çemi (>9670–9300 cal. B.C.; $n = 28$), Demirköy (9440–9280 cal. B.C.; $n = 28$), Tel Aswad I (8700–8300 cal. B.C.; $n = 100$) and Çatalhöyük East (7100–6400 cal. B.C.; $n = 30$). The numbers of specimens examined were governed by the size of the sample that we were provided with. Again, notably large frequencies of the charred nutlets have been recovered from each of these archaeological sites (Fairbairn et al. 2002; Hillman 1975, 2000; Hillman et al. 1989a; Savard et al. 2006; van Zeist and Bakker-Heeres 1982, 1984). Altogether these sites span an interval of more than 4,000 years and encompass late Epipalaeolithic and aceramic Neolithic cultural complexes. The sites ring an area that stretches east–west from central Turkey to the Levant and north–south from the Taurus foothills to the southern Levant (Fig. 2).

We also examined two sets of modern *Bolboschoenus* nutlets collected by G. Hillman in Turkey in 1973 that are currently housed in the UCL Institute of Archaeology plant reference collections. The first set Hillman collected from plants along the shore of the river Murat in southeastern Anatolia; he harvested the second set in the Konya basin in south-central Anatolia, from plants in extensive freshwater marshes around Hotamış Gölü situated on calcareous marl soils which have since been drained and grazed by cattle and sheep ($n = 100$ and $n = 94$ nutlets respectively).

A third set of modern specimens, collected in England by M. Wollstonecroft in 2008 from a salt marsh habitat in the Pevensey Marshes, East Sussex, was also examined ($n = 100$ nutlets). This former wetland, which has been drained by the construction of creeks and ditches to reclaim land for agricultural purposes, is currently used as grazing areas for cattle and sheep. It is composed of grassland, salt marshes and ditches situated on a loamy substrate of sand, silt and small amounts of clay (Sussex Wildlife Trust 2002; Thompson 2001).

Data on the recent occurrence of *Bolboschoenus* species in Turkey

Data on the recent occurrence of *Bolboschoenus* species in Turkey are based on revisions of materials from herbarium collections B, (Berlin-Dahlem); BP, (Budapest); BRA, (Bratislava); BRNM, BRNU, (Brno); H, (Helsinki); JE, (Jena); LI, (Linz); M, (München); PR, PRA, PRC, (Prague); SO, (Sofia); W, WU, (Vienna). These collections cover a period spanning from the 19th century to the present day.

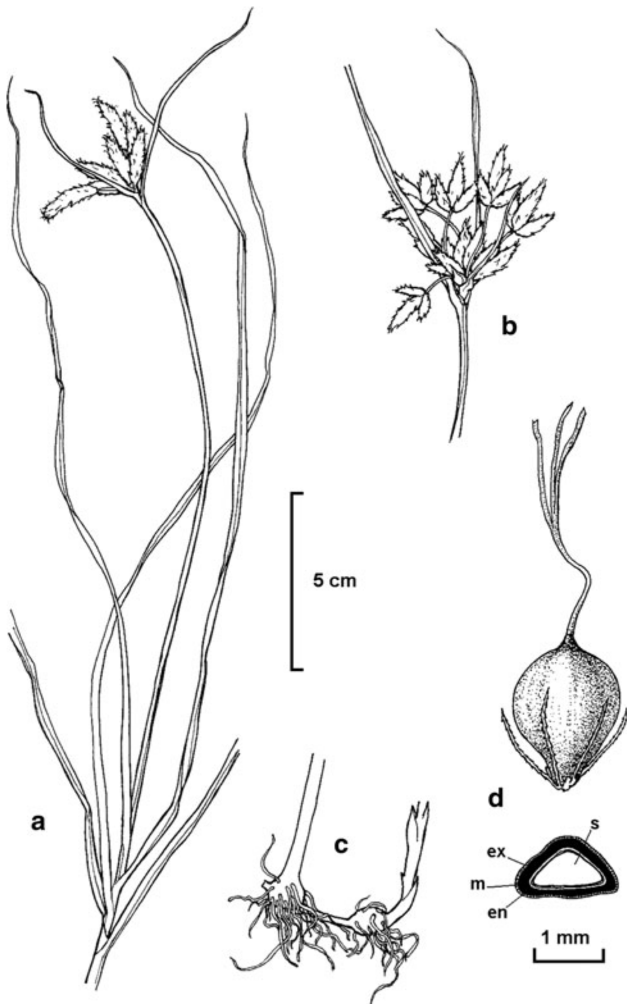


Fig. 5 *Bolboschoenus glaucus*. **a** flowering plant with mostly sessile spikelets (plant of dry habitat), **b** typical spikelet-rich inflorescence with many rays, **c** underground organs (rhizome with tubers), **d** nutlet with a remnant of trifid style (dorsal view and cross section), *ex* exocarp, *m* mesocarp (in *black*), *en* endocarp, *s* seed. Drawn from voucher specimens from: Vilayet Konya, on the road from Konya to Karapinar, 1 km east of Yarma, H 1101520 (**a**, **c**); Bursa: 35 km SW of Bandirma, near Fevzipaşa, H 1452721 (**b**); Aydin: Söke, Milet, H 1452725 (**d**). Drawings by Z. Hroudová

Results

Nutlet species identification

All charred nutlets from the five Near Eastern archaeological sites were identified as *B. glaucus.* The archaeobotanical *B. glaucus* nutlets are illustrated in Fig. 4 and the plant is shown in Fig. 5. Both sets of modern nutlets from Turkey, collected by G. Hillman in the 1970s, were also identified as *B. glaucus.* The modern nutlets from the Pevensey Marshes, UK, were identified as *B. maritimus* (Fig. 1).

Data on the recent occurrence of *Bolboschoenus* species in Turkey (Table 1)

Table 1 Frequency of habitat types inhabited recently by *Bolboschoenus glaucus* and *B. maritimus* in Turkey

Habitat type	*B. glaucus*	*B. maritimus*
Rice and crop fields with ditches	4	0
Field depressions, saline steppe, meadows	6	2
Wet ditches, irrigation channels	5	1
Stream, river and spring wetlands	9	3
Lakes and reservoirs	1	2
Swamp, marsh	6	0
Sea coast	0	2
Not given	10	1
Total	41	11

Data from labels of herbarium specimens studied (see Appendix in Supplementary Material)

1. *B. glaucus* appears to be more frequent than *B. maritimus.*
2. Both species occur most frequently along rivers.
3. *B. glaucus* inhabits a wide range of habitat types, including secondary habitats created by people (rice fields, arable land, ditches and channels); it was not found on seashores.
4. *B. maritimus* also inhabits several habitat types, but natural habitats prevail; it was never found in arable land.

Discussion

Unfortunately, the floras of the Near East, including the *Flora of Turkey* (Davis 1985), *Flora Palaestina* (Danin 2000; Feinbrun-Dothan 1981), *Flora of Iraq* (Townsend and Guest 1985), *Flora Iranica* (Rechinger 1998) and *Flora of Egypt* (Täckholm and Drar 1950) are not up to date on *Bolboschoenus*. In the *Flora of Turkey* Davis (1985) distinguished only *B. maritimus.* Kukkonen (1996) pointed out a possible occurrence of *B. glaucus* in the region covered by the *Flora Iranica*, which includes Turkey. Interestingly, recent revisions of the Iranian *Bolboschoenus* indicate that *B. glaucus* is the most frequent *Bolboschoenus* species of that country (Amini Rad et al. 2010).

Because the present-day distribution of *B. glaucus* in the Near East is yet to be studied in detail, it is not possible to make comparisons with the distributions suggested by ancient finds. The data on the recent occurrence of *Bolboschoenus* in Turkey presented here are incomplete because they are based on a limited number of available herbarium specimens, and only specimens with fruit could be included. A more detailed study is needed, especially of Turkish herbarium collections, and further field sampling.

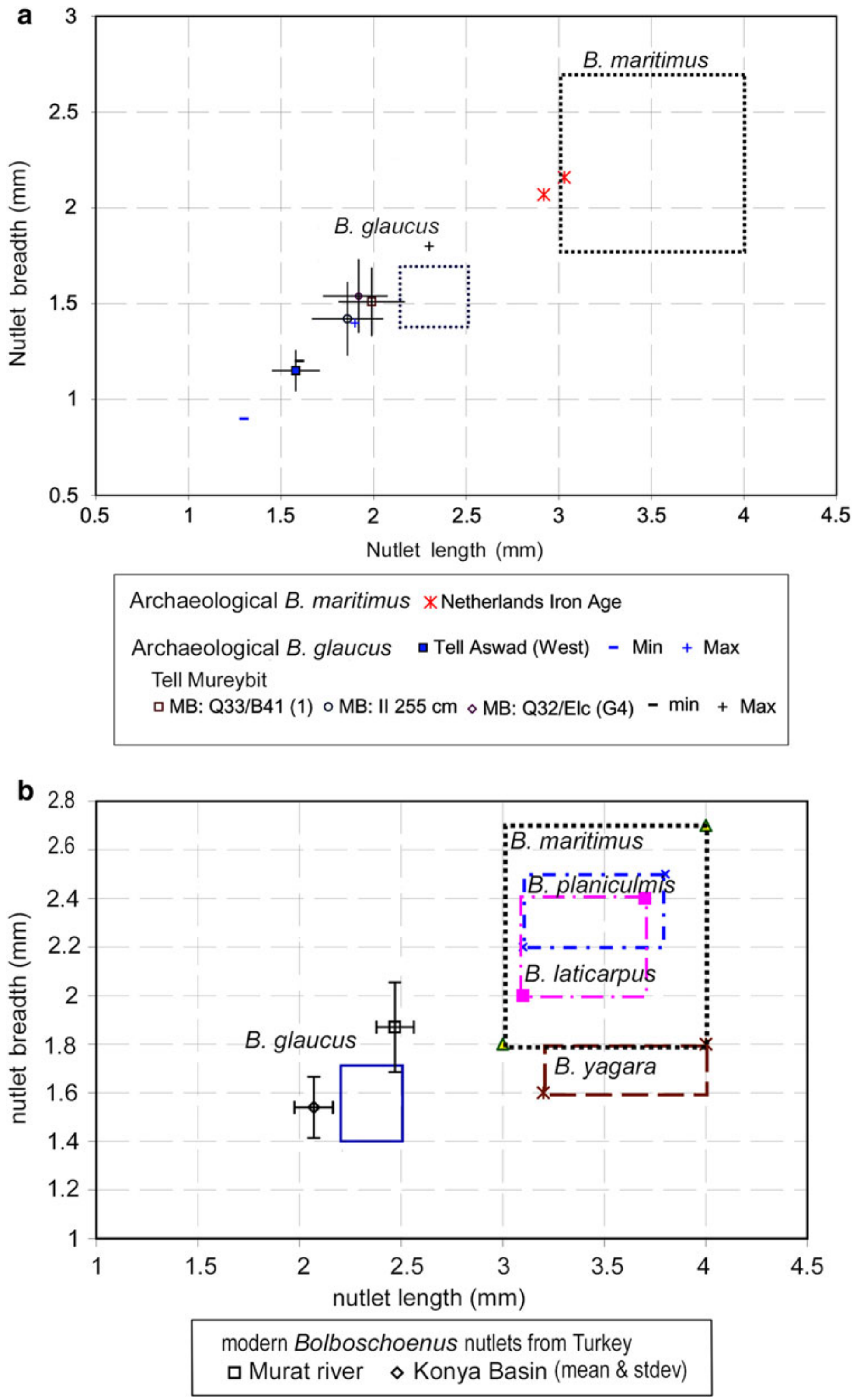


Fig. 6 Scatter plot comparing archaeological and modern nutlet measurements reported by van Zeist and Bakker-Heeres (1982, p. 214, 1984) with *Bolboschoenus* dimensions reported by Hroudová et al. (2007). **a** the boxes indicate the modern, uncarbonized range of *B. glaucus* and *B. maritimus* with the mean, standard deviation, maximum and minimum of archaeological carbonized nutlets from Aswad and Mureybit, compare with measurements of carbonized *maritimus* nutlets from two Dutch Iron Age sites also reported by van Zeist and Bakker-Heeres (1982), **b** the boxes show all the modern ranges, mean and standard deviation of the modern Turkish population collected by Hillman and measured by van Zeist

Nevertheless, some important information was obtained, including the fact that both *B. maritimus* and *B. glaucus* occur in Turkey today, that *B. glaucus* occurs more frequently than *B. maritimus,* and that there are clear ecological differences between the two species (Table 1 and Appendix in Supplementary Material). *B. maritimus* is found on the Black Sea and Mediterranean coasts, while *B. glaucus* appears to be a frequent plant in freshwater inland habitats.

Both species grow along rivers and streams, but *B. glaucus* is more associated with habitats created by people than *B. maritimus*. *B. maritimus,* as a facultative halophyte, seems to be less adapted to inhabit freshwater secondary habitats.

Our taxonomic reassessment of specimens from Epipalaeolithic and Neolithic Near Eastern contexts shows that *B. glaucus* occurred in high frequencies at sites that collectively represent a wide geographical area. Moreover, a review of the archaeobotanical literature suggests that other nutlets identified as *Scirpus maritimus/tuberosus* or *Bolboschoenus maritimus* in archaeobotanical reports from this region (specimens not examined here) are probably *B. glaucus*. For example, Fig. 6 plots the nutlet measurements reported by van Zeist and Bakker-Heeres (1982, p. 214 and 1984, p. 183) of specimens from village sites in the mid-Euphrates (Mureybit) and Damascus basin (Aswad), which show that they are closer to those of *B. glaucus* than *B. maritimus*. These measurements contrast with those of specimens from European Iron Age sites which have dimensions more similar to *B. maritimus* (Fig. 6a). Likewise, modern nutlets collected in Turkey in the 1970s by Hillman, and those reported by van Zeist and Bakker-Heeres (1982, p. 214) also fall within the size range of *B. glaucus* (Fig. 6b). While these specimens should be re-examined for anatomical confirmation of their identity, the apparent size differences between them are suggestive of smaller archaeological nutlets being *B. glaucus*.

Based on the results of the present study, Hillman is now revising his identifications of charred nutlets found embedded in remains of human (seemingly infant) faeces that were recovered from late Palaeolithic hearths at Wadi Kubbaniya in Egypt and originally identified as nutlets of *Scirpus tuberosus* or "*Scirpus* sp. of the *S. maritimus/tuberosus* type" (Hillman et al. 1989b, pp. 196–197). Given their shape, with a distinct rim running down either edge, and their very small size falling well outside the shapes and sizes of both *B. glaucus* and *B. maritimus,* they are likely to be a different member of the Cyperaceae.

The results of this study indicate that *B. glaucus* has a long history of occurrence throughout the Near East and that it was widespread over the region during the late Pleistocene and early Holocene. These results suggest several possible scenarios: (1) that only nutlets of *B. glaucus* are found in archaeological samples because no other *Bolboschoenus* species occurred in this region during the late Pleistocene and early Holocene; or else (2) that both *B. glaucus* and *B. maritimus* grew in that region but people used only *B. glaucus*; or else (3) the nutlets of both species were used by people during those periods but the nutlets of *B. maritimus* did not survive charring because of their different pericarp tissue structure, having only a thin layer of sclerenchymatic mesocarp. Preliminary results of our charring experiments on modern *B. glaucus* and *B. maritimus* nutlets (Chuenwattana et al. in prep.) suggest that the latter scenario is unlikely.

If both species were, indeed, equally abundant and equally accessible in the Epipalaeolithic and Neolithic then we need to consider the possible functional, culinary and cultural reasons that led people to prefer *B. glaucus*. Processing experiments, carried out by Hillman during the 1970s (unpublished laboratory notes, 1972) on British and Near Eastern specimens, show that once (what we now know to be) *B. glaucus* nutlets have been roasted to the point of "popping", they are more brittle and more easily crushed than those of (what we now know to be) *B. maritimus*; Hillman further observed that it is more difficult to crush *B. maritimus* nutlets with a stone pestle, similar to those found in Epipalaeolithic and Neolithic sites, probably because the large, air-filled cells cushion the impact of the implement, functioning rather like miniaturised "bubble-wrap". These differences may be due to the sclerenchymatic mesocarp of *B. glaucus*, once roasted, at least, being more brittle than the thick exocarp of *B. maritimus*.

Among the archaeological and environmental implications of the results are that during the late Epipalaeolithic and early Neolithic, people were exploiting freshwater, riverine habitats. The frequencies of *B. glaucus* nutlets in PPNA (pre-pottery Neolithic A) and PPNB sites may indicate that they continued to be of economic value even after the introduction of cultivated cereals. One potential explanation for this continuity is that *Bolboschoenus* nutlets and/or tubers may have supplemented the cereal-based diet (Wollstonecroft and Erkal 1999). Alternatively, it is possible that, with the advent of agriculture, *B. glaucus* became a weed in cultivated fields, as in Turkey today where it often occurs as a weed in rice fields (Table 1 and Appendix in Supplementary Material). This possibility is supported by Hillman's observations during fieldwork in the middle Euphrates in Syria (unpublished field notes 1983) where he witnessed *B.* cf. *glaucus* growing as a prolific weed in areas which, although adjacent to brackish backswamps, had been ploughed, sown with 6-row barley, but left unharrowed so the coarse furrows would encourage the wet soil to dry out. Here, the *B.* cf. *glaucus* grew even more abundantly than the sown barley—firstly because of partial waterlogging, and secondly because the barley seemed to have been suffering from the high salt content—visible as a powdery white efflorescence on the soil surface; there are limits to barley's ability to tolerate salt, see Harlan (1972). Thirdly, ploughing seemed to have encouraged the club rush to grow even more prolifically by fragmenting its network of rhizomes and tubers. This tendency of *B. glaucus* to inhabit human-disturbed habitats clearly raises the possibility of a mutualistic relationship between the wild plant and people.

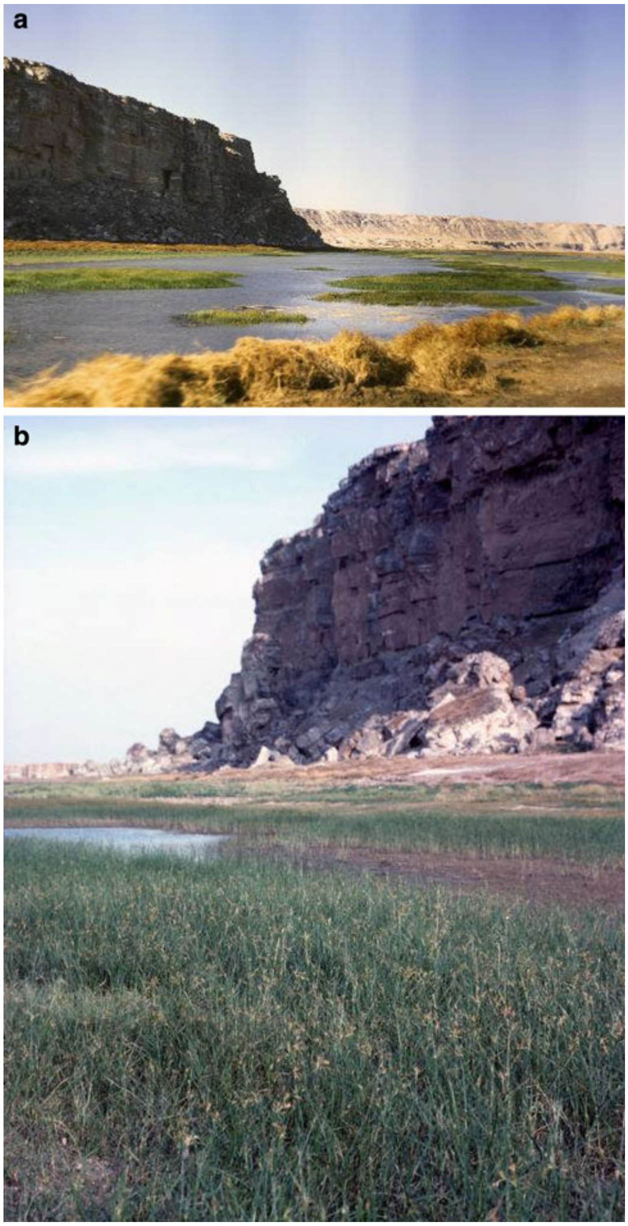


Fig. 7 Backswamp in the Euphrates valley near Raqqa, photographed by Gordon Hillman. **a** 1972; **b** 1983. Large stands of *Bolboschoenus* cf. *glaucus*, the patches of green vegetation in the centre of the backswamp, contrast with areas outside the river valley where there is nothing but arid *Artemisia*-Chenopodiaceae steppe growing

The data also suggest that throughout the late Pleistocene and early Holocene summer temperatures in the Near East must have been sufficient for *B. glaucus,* a thermophilic species, to survive. Interestingly, the abundance of *B. glaucus* nutlets found in Abu Hureyra contexts that were contemporary with the Younger Dryas stadial suggests that summer temperatures were also sufficient for *B. glaucus* during this period. Hillman et al. (2001) attribute the apparent abundance of *B. glaucus* and other river valley plants, such as *Polygonum corrigioloides*, to unusually high river water levels producing regular over-bank flooding. They cite evidence from studies of varve sediments in Lake Van undertaken by Reimbold et al. (1996), and develop the latter's argument proposing that the scarcity of vegetation on the Anatolian plateau, which was caused by the harsh climatic conditions of the Younger Dryas, led to accelerated run-off into the head-waters of the Euphrates and other rivers during the springtime snow-melt. This, in turn, produced regular springtime over-bank flooding downstream that promoted and sustained extensive backswamps favourable for the formation of dense stands of *B. glaucus*. Thus, despite the drought conditions prevailing outside the river valleys, within the valleys themselves wetland plants flourished, just as stands of *B.* cf. *glaucus* thrive in backswamps of the middle Euphrates today. This last point is illustrated by the photographs in Fig. 7, taken by G. Hillman near Raqqa in Syria of a backswamp in the Euphrates valley in 1972 and again in 1983, that show large stands of *Bolboschoenus* cf. *glaucus* growing throughout the wetland, which contrast sharply with areas outside the valley where there is nothing but arid *Artemisia*-Chenopodiaceae steppe. Riverine plant resources, such as the nutlets of *B. glaucus* could therefore have made a significant contribution to human diet. With the onset of the Younger Dryas and the reduction of plant food resources gathered from former woodland-steppe outside the river valley (Hillman 2000; Hillman et al. 2001), their role probably became increasingly central to survival.

Conclusion: overcoming the taxonomic impediment

The present study exemplifies the value of recent taxonomic revisions for archaeobotanical interpretation. Our taxonomic re-assessment of the ancient Near Eastern *Bolboschoenus* nutlets resulted in the identification of a new species for the ancient Near East. The identification of *B. glaucus* provides us with more precise information about the distinct biological characteristics, growing habits, geographic distribution and ecology of these plants. They flourish in human-disturbed habitats and form large stands when water is locally abundant, conditions that prevailed in parts of the Near East during the late Pleistocene and early Holocene. Previous studies (Hillman in prep, Wollstonecroft 2009 and Wollstonecroft et al. 2008) have also shown that, in addition to their excellent harvesting return-rates, *B. glaucus* nutlets and tubers have several potential food uses and nutritional benefits. Therefore it is entirely feasible that this plant provided a number of late Epipalaeolithic and Neolithic populations with a dependable and possibly a staple food.

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