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Macrofossil evidence of Late Holocene presence of *Aldrovanda vesiculosa* L. in Central-Eastern Europe (Poland) and East Africa (Tanzania)

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ABSTRACT

To date, the seeds of waterwheel plant (*Aldrovanda vesiculosa*) were only found in Europe, in sediments of the Eemian and Mazovian Interglacials. The absence of *A. vesiculosa* seeds in European Holocene deposits is probably due to unfavorable climatic conditions, i.e. lower temperature, during this period: in temperate zones, *A. vesiculosa* reproduces mainly in a vegetative way; it rarely blooms and only occasionally produces seeds. In this paper, subfossil seeds of *A. vesiculosa* were identified in two peat bogs: one (Sucha Kobyła) in SE Poland and another one (Kyambangunguru) in SW Tanzania. Single seeds of this plant were found in a peat layer from the Polish site formed after 1600 AD as well as in sediments accumulated around 440 AD in the Tanzanian one. To our knowledge, this is the first time that seeds of *A. vesiculosa* are found in Holocene deposits in the world. Our findings provide new data on the distribution of *A. vesiculosa* over the Late Holocene.

1. Introduction

The waterwheel plant – *Aldrovanda vesiculosa* L. (Droseraceae) – is an aquatic carnivorous plant, floating freely in water. It prefers well-insolated, mesotrophic and eutrophic water with a pH comprised between 6.0 and 6.6 (Adamec and Tichy, 1997; Kamiński, 2006). The plant has also been recorded from other water conditions ranging, from oligotrophic, through mesotrophic and eutrophic to dystrophic (Żukowski, 1963; Sokołowski, 1972; Radwan, 1976; Gramsz and Jasińska, 1986; Kamiński, 1987, 2006; Adamec, 1995). Noteworthy, the contemporary distribution range of *A. vesiculosa* in the world is dramatically decreasing (Adamec and Lev, 1999; Kamiński, 2006). Nowadays, *A. vesiculosa* occurs in Europe, Asia, Africa and Australia. Records indicate that *A. vesiculosa* is present in 295 sites in the world, among which about 220 are regarded as either historical sites or need to be checked (Kamiński, 2006). In Europe, its presence has been reported from 160 sites, among which 29 and 7 are natural and restored sites, respectively (Kamiński, 2006).

In Poland, the waterwheel plant was identified in 7 and 13 natural and restored sites respectively, whereas in Tanzania, the plant was found in 5 sites (Kamiński, 1995). Given the rapid disappearance of the plant, there have been efforts geared towards its reintroduction in various parts of the world, including Czech Republic (Adamec and Lev, 1999), Poland (Kamiński, 1995) and Japan (Nitta et al., 2003).

The oldest seeds of *Aldrovanda* date back to the Mesozoic (Yakubovskaya, 1991). In Central-Eastern (CE) Europe, the first seeds of *A. vesiculosa* were found in sediments of the Mazovian Interglacial (Velichkevich and Zastawniak, 2009). Nevertheless, the largest accumulations of these seeds were found in sediments of

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the Eemian Interglacial (e.g. Tobolski, 1991; Nita, 1998; Velichkevich and Zastawniak, 2009). So far the species have been distinguished based on their differences in shapes and dimensions of the seeds, including *A. borysthenica* Wieliczk., *A. dokturovskyi* Dorof., *A. zussii* T. V. Jakub. (Velichkevich, 1982; Yakubovskaya, 1991; Velichkevich and Zastawniak, 2009).

The post-glacial history of *Aldrovanda vesiculosa* is completely unknown, because its macrofossils (both generative and vegetative) have not been found in sediments accumulated over the last thousands of years so far. Therefore, its current origin is unknown (Berta, 1961; Adamec and Tichý, 1997). Some existing information indicates that during postglacial *A. vesiculosa* was brought into Europe from Africa (Berta, 1961; Sculthorpe, 1971), while others (e.g. Degreef, 1997) think the opposite, based on the absence of *Aldrovanda* fossil in Africa and Australia. The genus *Aldrovanda* was shown to be a Cenozoic relict (Yakubovskaya, 1991). Unfortunately, even genetic studies (Maldonado San Martin et al., 2003) could not clearly explain the origin of the European population and the post-glacial migration routes of the plant. However, some researchers linked distribution of *A. vesiculosa* with bird migration routes (Elansary et al., 2010). An example of bird is Bewick's swan which can cover a long distance from southern Japan to northern Russia (Kamiya and Ozaki, 2002) or from Siberia to Denmark, Poland and England (Klaassen et al., 2004).

This article reports the first identification of *Aldrovanda vesiculosa* seeds in Late Holocene deposits, in SE Poland and SW Tanzania. The seeds were discovered (i) in a Polish peat bog, during palaeoecological studies aiming to reconstruct the post-glacial history of *Cladium mariscus* in CE Europe and (ii) in a Tanzanian peat bog, where a core was collected to reconstruct environmental changes over the last 4000 years based on molecular proxies (Coffinet et al., unpublished data).

2. Sites of study

The peat bog "Sucha Kobyła" is located in SE Poland, between the towns of Chełm and Dorohusk (Fig. 1) and has an area of approximately 100 ha (175 m a.s.l.). Currently the peat bog, which has been drained in the past, is dominated by the vegetation build by *Carex* spp., *Cladium mariscus* and *Phragmites australis*, sometimes growing in shallow depressions with stagnant water (10–20 cm depth). The peat bog lies within moderately continental climate, with strong contrasts between the warm summer (98 days) and usually harsh winter (97 days). The growing season lasts for 210 days. Annual precipitation is 688 mm (Michalczyk and Smalisz, 1992). The average annual air temperature measured over the period 1991–1997 was 7.6 °C. The average temperature of the warmest (July) and coldest (January) months measured over the same period were 18.5 °C and −1.7 °C, respectively. *Aldrovanda* is currently present in several lakes in SE Poland.

The ombrotrophic peat bog of "Kyambangunguru" is located in the East African Rift in SW Tanzania (Fig. 1), in the center of a Quaternary maar crater at proximity of Mbambo village (660 m a.s.l.). It has no hydrological outlet and an area of approximately 4 ha. Currently, rushes, waterlilies, ferns and some scare small trees, surrounding by papyrus and reeds, dominate the peat bog vegetation. In contrast, the steep catchments crater flanks, of around 16 ha (Delalande et al., 2008a), are partially cultivated or occupied by Zambazian Miombo-type woodland. The region belongs to the humid equatorial zone of Africa and experiences alternation of a hot humid season (from November to May) and a relatively cold dry season (from June to October; Delalande et al., 2008b). Regional precipitations reach over 2000 mm/yr on average and local mean air temperature is around 24–26 °C, with low seasonal variability compared to day/night cycle. Macroscopically, ombrophic peat bog and palaeo maar-lake samples appear as no consolidated organic matter where phytoclasts such as wood, stems, and plants are visible. There are minor quantities of clay, quartz and tephra deposits.

3. Material and methods

The Polish core was collected in 2009 in the central part of the peat bog Łąka Sucha Kobyła (51°10′ N 23°38′E), densely covered by patches of *Cladium mariscus*. An Instorf peat corer (Russian corer) with a length of 50 cm and width of 5 cm was used. The water table was approximately 10 cm below the ground level. Samples of the Polish core were analysed at a resolution of 2 cm. A 4 m peat core was collected with a Wright corer in Kyambangunguru peat bog (9°22′ S 33°48′ E) in 2012. At that time, the water level reached 92 cm above the peat surface. Samples of Tanzanian core were analysed at changeable resolution, mainly 3–5 cm. The total volume of the samples was 25 cm^3. The samples were rinsed with warm water on 0.2 mm mesh sieves. Macrofossils were quantified with a stereoscopic microscope Nikon SMA 800 and a biological light microscope Olympus CX41. Species determination of individual plant macrofossils was performed using the available literature (Velichkevich and Zastawniak, 2006, 2009).

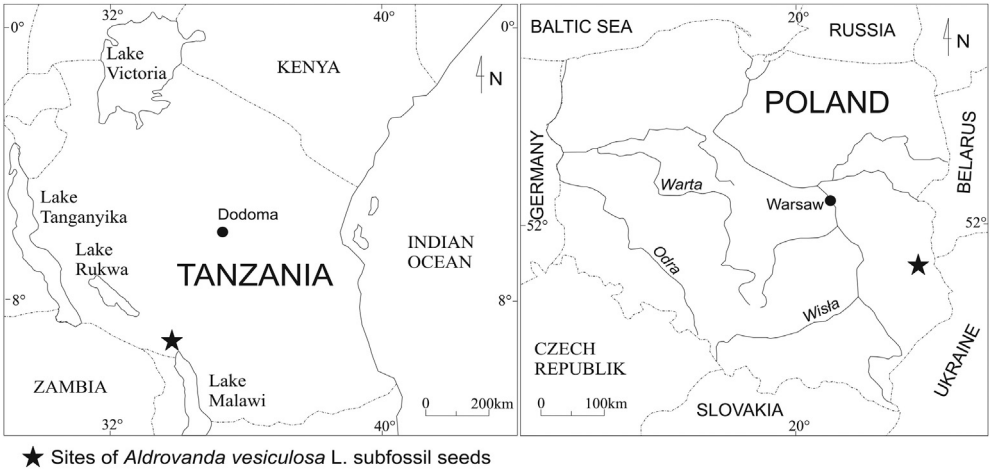

Fig. 1. Sites with subfossil seeds of *Aldrovandra vesiculosa* L.