



Environmental changes and plant use during the 5th–14th centuries in medieval Gdańsk, northern Poland

Joanna Święta-Musznicka¹ · Monika Badura¹ · Anna Pędziszewska¹ · Małgorzata Latałowa¹

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Abstract

This paper reviews the results of the many years of investigations on the ecological aspects of settlement development in the oldest districts of the city of Gdańsk, the impacts of the changing climate and growing human pressure on the local environment, as well as the question of plant use by the inhabitants during the Middle Ages. Before the settlement was established, the landscape was dominated by alder woods and shallow water bodies of the extensive wetlands in the Wisła estuary. An important factor making settlement possible was probably the lowering of the water table around the 9th–10th centuries AD, causing a reduction of wetland. Archaeobotanical results are consistent with archaeological data on the periods at which particular town districts were settled. They provide evidence of the earliest changes to the natural environment, starting in the Stare Miasto (“Old Town”) in the 11th–12th centuries, in the Główne Miasto (“Main Town”) in the 12th–13th centuries, and on Wyspa Spichrzów (“Granary Island”) during the 13th–14th centuries. The gradual expansion of the town caused a diversification of the local flora. Natural wetland communities and semi-natural wet meadows and pastures were still common within the settled area until the 14th century. On the other hand, the rapid spread of built-up areas, roads and gardens allowed the growth of ruderal vegetation there. Archaeobotanical and historical evidence shows the diverse and changing plant foods in the diet of the inhabitants during the Middle Ages.

Keywords Anthropogenic vegetation · Archaeobotany · Medieval Climate Anomaly · Medieval town development · Urban ecology · Useful plants · Wetland change

Introduction

The ecological aspects of the establishment and development of ancient towns are still poorly considered. For many years, the issues of material culture as well as the social and cultural changes were explored mainly by archaeologists and historians, while natural sciences, if involved, concentrated mainly on the economic aspects of plant and animal uses. However, especially in recent decades, there has been

a growing involvement of the natural sciences in studies of past urban societies. They offer us a better understanding of the environmental changes which took place both in the towns themselves and within their closest surroundings. The role of archaeobotany is of prime importance in this respect. It provides information on how plants were used by people (Wasylikowa 1978; Behre 1983; Märkle 2005; Mariotti Lippi et al. 2013) and on the effects of human activity upon the flora and vegetation during the stages of settlement development (Brun 2009; Pokorná 2017). Complex palaeoenvironmental studies based on different methods are also undertaken more and more often to reconstruct the ecological context of the progressing town development (Hall and Kenward 2004; Kisieliene et al. 2012; Kozáková et al. 2014; Stivrins et al. 2015). Combined results from pollen and macroscopic plant and animal remains in the natural sediments, cultural layers and other archaeological contexts make it possible to reconstruct past local ecosystems in particular periods at the urban centres (Latałowa 1999; Bosi et al. 2011; Pokorná et al. 2014). Pollen analysis also forms

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✉ Joanna Święta-Musznicka
j.musznicka@ug.edu.pl

¹ Laboratory of Palaeoecology and Archaeobotany, Department of Plant Ecology, Faculty of Biology, University of Gdańsk, ul. Wita Stwosza 59, 80-308 Gdańsk, Poland

the basis for the reconstruction of the history of regional landscape changes (Greig 1992; Bosi et al. 2015; Mercuri et al. 2015). The broadening of the range of analyses with non-pollen palynomorphs (NPPs) (van Geel 2001), geochemical analyses (Holliday and Gartner 2007; Oonk et al. 2009) and micromorphology of sediments (Macphail et al. 1990) adds to our knowledge of the conditions of the formation of cultural layers (Alexandrovskaya and Alexandrovskiy 2000; Matthews 2010; Mazurek et al. 2016), the living conditions (Florenzano et al. 2012; Brinkkemper and van Haaster 2012; Pichler et al. 2014), heavy metal pollution (Hudson-Edwards and Maclin 1999; Cook et al. 2005; Kowalska et al. 2016) and specific uses of urban space (Cook et al. 2014; Banerjea et al. 2017; Wouters et al. 2017; Borderie et al. 2020) as well as the transformation of rural areas into urban centres (Petersén et al. 2015). Unfortunately, since undisturbed sediment sequences are difficult to obtain from urban sites, high temporal resolution multiproxy studies are still relatively rare (Latałowa 1999; Beneš et al. 2002; Stančikaitė et al. 2008; Bosi et al. 2015).

In Gdańsk, archaeobotanical research dates back to the 1950s. Most of those earliest publications are short reports containing a list of plant taxa, usually without a detailed interpretation of the data. Nevertheless, they provide important information, especially on plant use (Mađalski 1952; Moldenhawer 1952, 1953; Lechnicki 1955; Klichowska 1959; Lechnicki et al. 1961). A new stage in archaeobotanical investigations in Gdańsk began in 1998, when regular research started by our team in the Laboratory of Palaeoecology and Archaeobotany at the University of Gdańsk. Cooperation with the archaeological teams from the Archaeological Museum of Gdańsk, the Historical Museum of Gdańsk, the Institute of Archaeology at the University of Warsaw (a research team in Gdańsk) and the National Heritage Board of Poland helped to obtain materials from the earliest settlement areas in the city. The vast amount of research which has been done with a coherent approach and methodology (Latałowa et al. 2007) has made it possible to gather well-structured information from many different features in several parts of the town and representing various historical periods. The abundance of the finds, the broad representation of useful plants as well as those typical of both natural communities and ones created by human activities have made it possible to study not only plant uses but also many ecological aspects of changing environment. The latter are significant in terms of the development of the town and the living conditions of its inhabitants (Latałowa et al. 2009b).

There are several papers on the use of crops as well as plants gathered from the wild in particular periods of the history of Gdańsk (Latałowa et al. 2001, 2003; Badura et al. 2005; Badura 2011; Pińska et al. 2013; Badura and Latałowa 2016, 2018). Special attention has been given to the use of plants for medical purposes (Badura and Pińska 2010) and

the role of plant products in trade, including the import of luxury commodities (Badura 2003; Latałowa et al. 2007). The information obtained from the oldest written sources has supplemented the archaeobotanical list of plants used by the citizens of Gdańsk (Badura et al. 2015; Badura and Możejko 2019). The large number of sampling sites has made it possible to compare the plant foodstuffs used by people of differing social status and in various historical periods (Badura et al. 2005; Badura 2011). An important part of the archaeobotanical research in Gdańsk was the comparison of the data on the use of plants, the importance of foodstuffs and the trade in plant products with similar records from other towns of northern Poland (Badura et al. 2004) and the Hanseatic cities of northern Europe (Latałowa et al. 2007; Karg et al. 2007; Latałowa et al. 2009a).

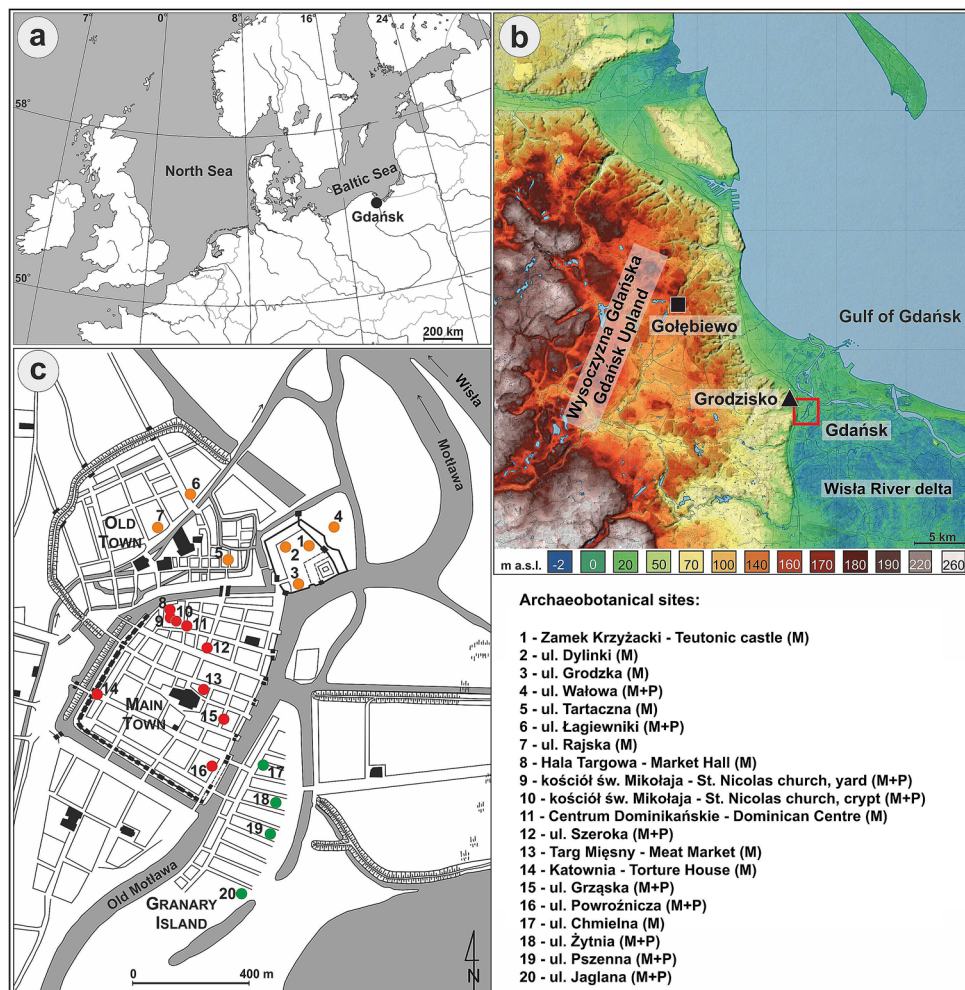
Sampling of sediment profiles including both natural and cultural layers and application of different methods (pollen analysis including NPPs, macrofossil analysis, geochemistry and radiocarbon dating), have enabled a comprehensive reconstruction of the natural history of Gdańsk. The data have allowed us to describe the natural and human environmental changes in the period preceding the foundation of the earliest medieval settlement and then during the early stages of the development of the town (Latałowa et al. 2009b; Święta-Musznicka et al. 2011; Święta-Musznicka and Latałowa 2016). Information on environmental changes around the town has been obtained from the Gołębiewo pollen site, Wysoczyzna Gdańska (“Gdańsk Upland”) (Fig. 1b) (Pędziszewska and Latałowa 2016).

The main aim of this review paper is to summarize the most important results of the research that has been done over many years on the natural conditions of settlement in the area of the oldest districts of Gdańsk from ca. the 5th until the end of the 14th centuries. The paper is based on both previously published data and new results, assembling information on local environmental diversification caused by the spatial development of the town, changes in local vegetation and the living conditions of people in the developing town and their use of plants (Table 1).

Location and development of medieval Gdańsk

Gdańsk (54° 21' 07" N; 18° 38' 46" E) developed at the river mouth of the Wisła (Vistula), near the Gulf of Gdańsk in the Baltic Sea (Fig. 1a). The area is dissected by several smaller rivers, branches of the Wisła or flowing from the morainic upland to the sea. In the past they formed a complex hydrological network which has not been fully examined to this day, mostly due to the strong changes to it over the centuries. The first settlements identified by archaeologists in the oldest parts of the town developed on sandy alluvial fans lying within the extensive wetland (Zbierski 1978a; Paner 2015).

Fig. 1 Location of the study area and sites. **a** position of Gdańsk in northern Europe; **b** location of Gołębiewo I pollen site and Grodzisko stronghold, and the area of Gdańsk covered by the archaeobotanical investigation; **c** location of archaeobotanical sites. The orange dots indicate positions of sites in Old Town, red dots in Main Town and green dots on Granary Island. M, sites with macrofossil data; M+P, sites with macrofossils, pollen and NPP data. Contour map after Niecikowski 2016; mid 16th century plan of Gdańsk after Paner 1999a



To the west, Gdańsk borders with the Pojezierze Kaszubskie (“Kashubian Lakeland”) which was the agricultural base for the town and a source of timber over the centuries. The diversity of the local environment with different kinds of natural resources, including amber, was certainly an important factor in the economic success of Gdańsk. The latest historical research shows that the origins of Gdańsk are related to the growth in economic importance of the area stretching along the Gulf of Gdańsk in the late 9th and the early 10th centuries (Śliwiński and Możejko 2017). The oldest stronghold of Gdańsk, now known as Grodzisko on Gradowa Góra, was a 10th century watchtower constructed on the hill above the low-lying floodplain of the rivers Motława and Wisła (Fig. 1b). In the mid 11th century, it was moved to the area where the Motława joined the Wisła at the time (Śliwiński and Możejko 2017). Here, on a small island, a new stronghold and settlement developed, which attracted craft workers, merchants and fishermen; it is here that the archaeological excavations were started in the 1950s (Jazdzewski 1955a, b), accompanied by the first archaeobotanical work (Lechnicki 1955; Lechnicki et al. 1961).

Stare Miasto (“Old Town”) provides scarce evidence of settlement activity in the 10th and 11th centuries, but by the 12th and 13th centuries, settlement here was already intensive (Paner 2015). Several mills were established here, with Wielki Młyn (“Great Mill”) built in AD 1350, thought to have been the largest industrial building in medieval Europe (Kochanowski 1998). Old Town was also a location for the Teutonic castle, built in the 15th century on the site of the earlier seat of the local knights and totally destroyed in the 15th century by the citizens of Gdańsk (Śliwiński and Możejko 2017).

Główne Miasto (“Main Town”) is a later part of Gdańsk, where vigorous development took place as late as the 14th century in a partly waterlogged area that needed extensive work before it was settled (Maciakowska 2011). Main Town opens to the river Motława with several gates connecting the town with the port.

Wyspa Spichrzów (“Granary Island”) is an artificial island lying between the channels of the Motława. In the 16th century, the former moat separating this area from the mainland was deepened and widened to create a new river

Table 1 Archaeobotanical sites used in the study. Site numbers as in Fig. 1

Site No.	Site name	Sediment type	Type of data	Date (century AD)	Publication(s)
1	Zamek Krzyżacki (Teutonic castle)	Limnic sediments, cultural layers	Macrofossils, historical documents	13th	Możejko 2006; Badura et al. 2015; Badura and Możejko 2019; Jarosińska unpubl.
2	ul. Dylinki	Cultural layers	Macrofossils	11/12th, 12th	Mądalski 1952; Moldenhawer 1952; Lechnicki 1955; Lechnicki et al. 1961; Badura 2011
3	ul. Grodzka	Limnic sediments, peat deposits, cultural layers	Macrofossils	10-11th, 10/11th, 11th, 11-12th	Badura 2011; Święta-Musznicka unpubl.
4	ul. Wałowa	Limnic sediments, peat deposits	Macrofossils, pollen, NPPs	12th, 13th, 14th	Święta-Musznicka and Pińska unpubl.; Święta-Musznicka unpubl.
5	ul. Tartaczna	Cultural layers	Macrofossils	12th, 12/13th, 13th	Badura unpubl.
6	ul. Łagiewniki	Limnic sediments, peat deposits	Macrofossils, pollen, NPPs	<10th, 10th, 11th	Święta-Musznicka et al. 2011; Święta-Musznicka unpubl.
7	ul. Rajska	Cultural layers	Macrofossils	14th	Badura 2010; Badura unpubl.
8	Hala Targowa (Market Hall)	Cultural layers	Macrofossils	11th, 12/13th, 11-12th, 12th, 12/13th	Badura 2011; Badura unpubl.
9	kościół św. Mikołaja (St. Nicholas church) – yard	Cultural layers	Macrofossils, pollen, NPPs	12th, 13th	Święta-Musznicka et al. 2013; Święta-Musznicka, Badura, Latałowa unpubl.
10	kościół św. Mikołaja (St. Nicolas church) – crypt	Cultural layers	Macrofossils, pollen, NPPs	13th	Święta-Musznicka et al. 2013; Święta-Musznicka, Badura, Latałowa unpubl.
11	Centrum Dominikańskie (Dominican Centre)	Cultural layers	Macrofossils	10/11th, 11th, 11/12th, 12th, 12/13th, 13th, 13/14th, 14th	Badura 2011; Badura and Jarosińska unpubl.
12	ul. Szeroka	Peat deposits	Macrofossils, pollen, NPPs	<10th, 10-12th, 13th	Święta-Musznicka unpubl.
13	Targ Mięśny (Meat Market)	Cultural layers	Macrofossil	14th	Badura and Latałowa 2018
14	Katownia (Torture House)	Cultural layers	Macrofossils	14th	Badura and Latałowa 2016
15	ul. Grząska	Limnic sediments, peat deposits, cultural layers	Macrofossils, pollen, NPPs	<10th, 10-12th, 13th, 14th	Badura 2011; Święta-Musznicka et al. 2011; Święta-Musznicka and Jarosińska unpubl.
16	ul. Powroźnicza	Peat deposits, cultural layers	Macrofossils, pollen, NPPs	13th, 13-14th, 14th	Badura 2011, Święta-Musznicka unpubl.
17	ul. Chmielna	Cultural layers	Macrofossils	14th	Badura 2011
18	ul. Żytnia	Limnic sediments, peat deposits, cultural layers	Macrofossils, pollen, NPPs	<10th, 10-12th, 13th, 14th	Święta-Musznicka et al. 2011; Święta-Musznicka and Latałowa 2016; Święta-Musznicka unpubl.
19	ul. Pszenna	Limnic sediments, peat deposits, cultural layers	Macrofossils, pollen, NPPs	<10th, 10-12th, 13th, 13-14th, 14th	Święta-Musznicka and Latałowa 2016, Święta-Musznicka unpubl.
20	ul. Jagłana	Limnic sediments	Macrofossils, pollen, NPPs	<10th	Święta-Musznicka et al. 2011; Święta-Musznicka and Latałowa 2016; Święta-Musznicka unpubl.

channel, improving the flow of traffic within the port of Gdańsk and extending access to the wharves. This floodplain wetland started to be used for granaries and as a storage area in the 13th century, but by the end of the 14th century

there were already some 120–130 granaries (Kaczyńska et al. 2005).

In the 11th–14th centuries Gdańsk was a rapidly growing centre which attracted merchants, craft workers and

Table 2 Chronological distribution of samples used in the study according to the context/feature type; “other” represents embankment fills, vessel contents or storage pits

Context/feature type	Chronology of the samples (century)										Sum
	5–10th	10/11th	11th	11/12th	10–12th	12th	12/13th	13th	13/14th	14th	
Limnic and peat sediments	92	7	4	3	20	1		13	3	9	152
Yards		1					3	2		14	20
Houses			6			4	31			2	43
Latrines										5	5
Refuse heaps			3				1				4
Granaries										25	25
Undefined useful layers		3	2	4		21	4	36	2	29	101
Leveling									1	6	7
Moat backfills										3	3
Other			8			1				2	11
Sum of samples											371

sailors of various nationalities, but also the scene of armed conflicts causing destruction of the town. Religious orders established there, building churches and monasteries together with their associated mills, gardens and other facilities. In the mid- 13th century Gdańsk received its charter as a town according to Lübeck law. In the early 14th century, Old Town was partially destroyed by the Teutonic Knights, who then established a commander’s office and built a castle here. At that time, in the area of the Main Town, a new urban centre was located according to Chełmno (Kulm) law, which defined relations between the burghers and the Teutonic Order and established the rights for shipping and river crossing on the Wisła. These regulations later covered the whole area of Gdańsk, however failing to avert fighting, which erupted periodically. In AD 1361, the town became a member of the Hanseatic League (Śliwiński and Możejko 2017).

Site locations, materials and methods

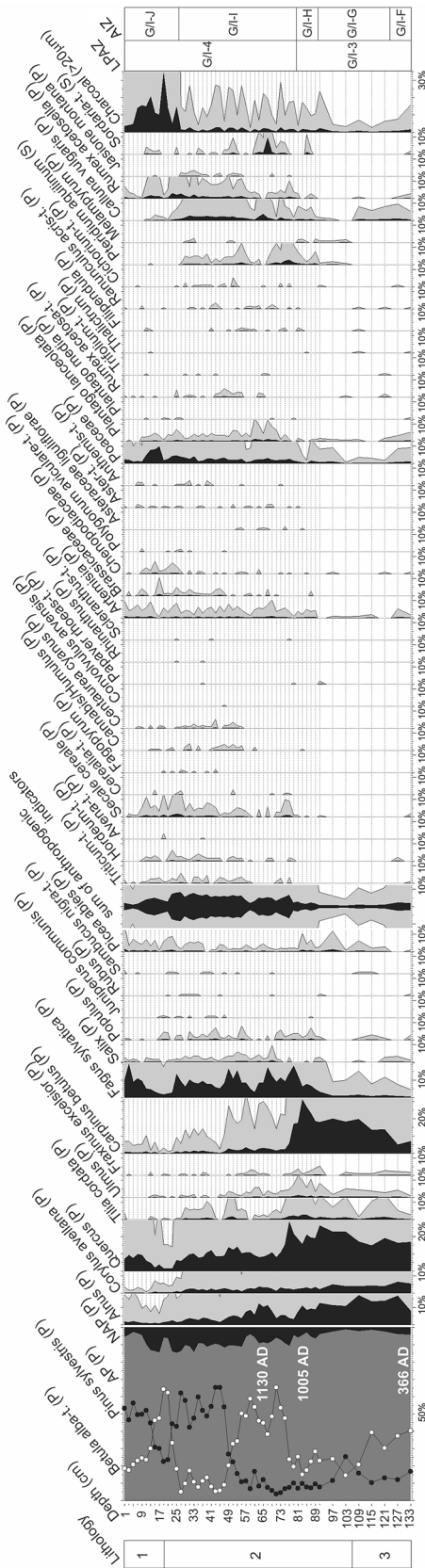
The data presented in this paper are based on the results of archaeobotanical investigations in 20 sites situated in the area of the oldest districts of Gdańsk, Old Town, Main Town and Granary Island and the Gołębiewo pollen site (Fig. 1c, b, Table 1).

Within the projects completed in 1998–2015, botanical samples were collected from various archaeological features and cultural layers within individual excavation areas or in a form of profiles taken directly from the trench walls. At ten sites, limnic sediments and peat beneath the cultural layers

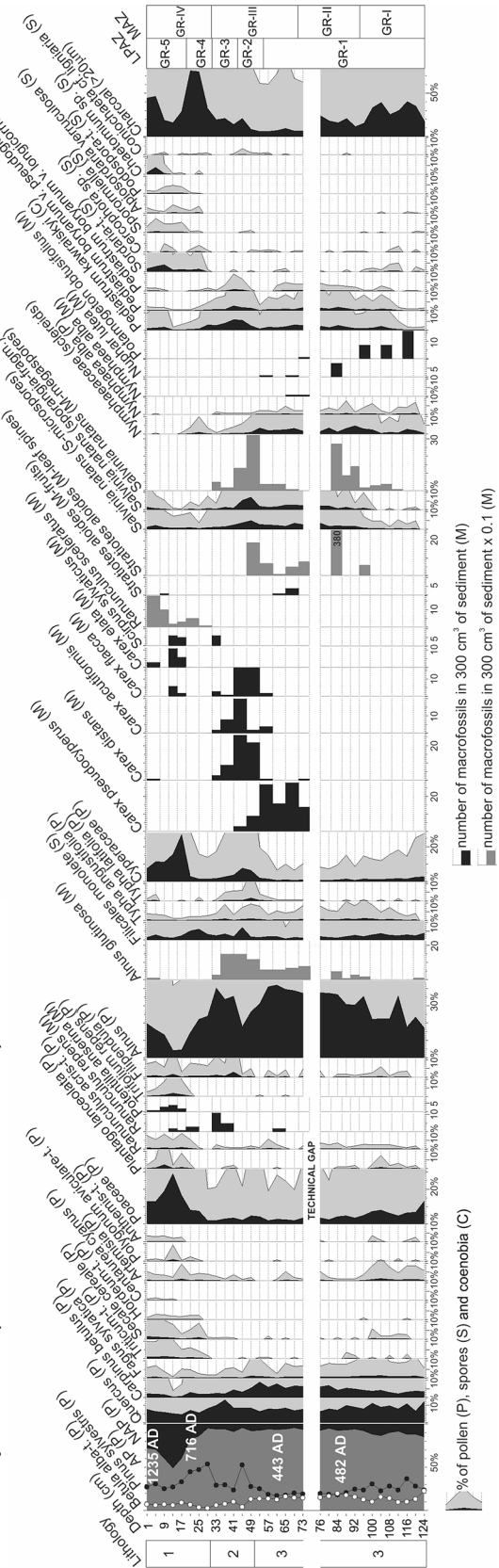
were also collected, with an Instorf sampler. Macrofossils were analysed from 371 samples, more than 40% of which (152) were limnic sediment and peat, whereas 219 samples were collected from archaeological features or cultural layers (Table 2). The plant remains were mainly waterlogged, and they were mostly very well preserved thanks to the high ground water table in the town. Mineralised remains were scarce. Purely charred material was collected only from granaries. The methodology for the sample collection strategy and laboratory preparation and treatment for macrofossil analysis have been thoroughly described in earlier publications (Latałowa et al. 2007; Badura 2011; Święta-Musznicka et al. 2013). Detailed information on the qualitative and quantitative content of the botanical samples has been archived in the ARCHBOT-UGDA DATABASE in the Laboratory of Palaeoecology and Archaeobotany, University of Gdańsk. The results presented in this paper have been supplemented with the data from extensive work on the early medieval settlement at site 2, ul. Dylinki (street) (Fig. 1c) (Mądalski 1952; Moldenhawer 1952, 1953; Lechnicki 1955; Klichowska 1959; Lechnicki et al. 1961). However, due to different methodologies applied then, the publications lack information on sample volumes and record the number of specimens and frequency of taxa inconsistently, so these data cannot be fully compared with the recent results. We use them to calculate the number of taxa in particular groups of useful plants for particular centuries.

Pollen and NPP analysis was done on 230 samples from ten sites in different parts of the town (Fig. 1c). The methods used

a - Gołębiewo I (Wysoczyzna Gdańska - Gdańsk Upland)



b - ul. Grząska, site 15 (Główne Miasto - Main Town)



■ number of macrofossils in 300 cm³ of sediment (M)
 ■ number of macrofossils in 300 cm³ of sediment x 0.1 (M)

■ % of pollen (P), spores (S) and coenobia (C)

Fig. 2 a Simplified pollen diagram from Gołębiewo I; lithology, 1, *Sphagnum* peat; 2, *Sphagnum-Eriophorum* peat; 3, *Sphagnum* peat with variable proportion of *Eriophorum* sp. and Ericaceae (after Pędziszewska and Latałowa 2016). **b** simplified pollen and macrofossil diagram from site 15; lithology, 1, herbaceous peat with high proportion of silt and charcoal; 2, herbaceous peat with detritus gyttja, silt, sand and wood; 3, silt with detritus gyttja and fine sand (after Święta-Musznicka unpubl.). LPAZ, local pollen assemblage zones; AIZ, anthropogenic indicator zones; MAZ, macrofossil assemblage zones

for pollen analysis have been described in earlier publications (Święta-Musznicka et al. 2011, 2013).

The chronostratigraphy is based on the archaeological and dendrochronological dating provided by archaeologists responsible for particular sites and AMS radiocarbon dating done on 45 samples in the Poznań Radiocarbon Laboratory and calibrated with OxCal v. 4.3.2 (Bronk Ramsey 2017). The IntCal13 age calibration curve was used for calculating the calendar age ranges and the medians used in the present paper (Reimer et al. 2013). The radiocarbon dates for particular sites have been published (Latałowa et al. 2009b; Święta-Musznicka et al. 2011, 2013; Święta-Musznicka and Latałowa 2016). The new chronology based on recent dendrochronological research (Kościński and Paner 2005) has been used for the data originally published in the 1950s and 60s from site 2.

The botanical nomenclature follows (Mirek et al. 2002).

Results and discussion

Material richness

The great diversity of the sources of the botanical material and its perfect preservation has ensured a broad representation of useful plants and taxa typical of both natural habitats and those resulting from human occupation. Full macrofossil data from Gdańsk, archived in the ARCHBOT-UGDA DATABASE, provide information on 479 plant taxa including 370 species and subspecies. Among them, 127 taxa represent weeds which would have grown in cultivated fields, gardens and in various kinds of ruderal habitats (ESM Table 1). The list of crop plants and other useful plants includes 76 taxa (ESM Table 2). At some sites, remains of plants typical of natural and semi-natural vegetation and of aquatic habitats were common. Remains of aquatic fauna, such as Porifera, Ostracoda, Cladocera (*Daphnia* sp.), Turbellaria, Hirudinea, Bryozoa (*Cristatella mucedo*, *Lophopus cristallinus*, *Plumatella* sp.), molluscs and fish occurred abundantly at several sites (Święta-Musznicka and Latałowa 2016). The palynological samples from Gdańsk are characterised by high taxonomic richness as well. We identified 182 taxa of trees, shrubs and herbs and 74 NPP taxa, mainly green algae

and coprophilous fungi (Fig. 2b; Święta-Musznicka et al. 2013; Święta-Musznicka and Latałowa 2016).

Natural conditions before the development of the town

One of the most interesting issues in studies into the origins and development of ancient urban centres is the role of environmental factors in deciding on the location of a town and their affect on its further development. Among the most important factors in determining the development of European towns in the Middle Ages was an easily defended site and a transport network for trade. Thus, the location of Gdańsk within the forks of the rivers fulfilled both these conditions.

Availability of food and other natural resources and also potential for development of the rural surroundings of a growing town were of prime importance too (Molaug 2010). In Gdańsk, besides the sea and rivers providing excellent possibilities for fishery, a variety of woodlands was another attractive factor providing game and a range of useful materials, including wood - a product of prime importance for the developing town. The pollen data (Fig. 2a) show that from around the 5th to the 10th century the upland landscape formed by moraines around Gdańsk was mainly covered by broadleaved woodlands of *Quercus* sp. and *Carpinus betulus*, with some *Corylus avellana*, *Tilia cordata*, *Ulmus* sp., *Fagus sylvatica* and *Pinus sylvestris*. In river valleys and along watercourses, patches of alder-elm woodlands were common. The low-lying areas which would later be incorporated into the expanding town were also mainly wooded. Both pollen and macrofossil data confirm that alder woods were widespread here, while small patches of mixed deciduous woods would have grown on the scattered mineral outcrops (Figs. 2b, 3).

In the pollen diagrams from Gdańsk itself, the proportions of arboreal pollen (AP) vary between 58 and 83%, but the non-arboreal pollen (NAP) represents mostly wetland environments indicating the presence of vegetation of shallow water bodies and marshes typical of a floodplain. High proportions of aquatic plant remains, like *Salvinia natans*, *Stratiotes aloides*, *Nymphaea alba*, *Lemna trisulca*, *Potamogeton perfoliatus*, *Nuphar lutea* or *Ceratophyllum demersum*, and of animal remains (Turbellaria, Porifera and *Daphnia*), are indicative of meso- or eutrophic stagnant or slow-flowing water (Figs. 2b, 3, 4). The remains of *Pediasstrum kawraiskyi*, *P. boryanum* v. *pseudoglabrum* and *Gloeotrichia* are evidence of short-lived blooms of green algae and cyanobacteria. These results, and those of geochemical analyses (Święta-Musznicka and Latałowa 2016), confirm the high trophic level and occasional oxygen depletion in the aquatic environment.

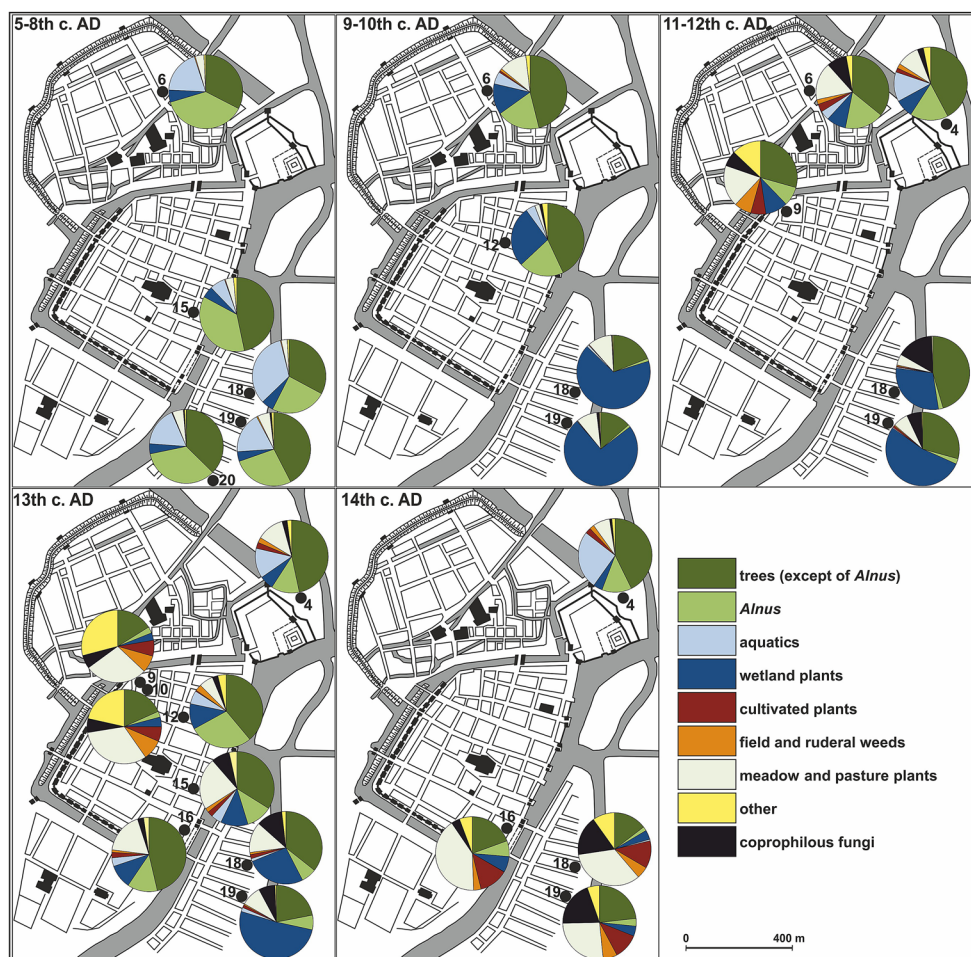


Fig. 3 Pie diagrams showing the average proportions of pollen taxa representing selected environments and cultivated plants in Gdańsk in consecutive periods from the 5th to the 14th century. Site numbers as in Fig. 1c and Table 1

A significant change in the local environment took place around the 9th–10th centuries. The palaeoecological data illustrate a considerable lowering of the water table in the wetland. In the studied profiles, the aquatic indicators are replaced by taxa typical of mires (Figs. 2b, 3, 4). This change left a distinct signature in several profiles in a form of hiatuses occurring at the transition between limnic sediments and peat (Święta-Musznicka and Latałowa 2016). A sharp decline in the proportion of *Alnus* pollen in some sites, or its distinctly lower frequency in others (Fig. 3), indicate a great reduction of the alder woods at that time. As a result, an open marsh vegetation with ferns (*Thelypteris palustris*, Filicales monoete), *Scirpus sylvaticus*, *Carex pseudocyperus*, *C. distans*, *Menyanthes trifoliata* and others spread over the area (Figs. 2b, 4). These ecological processes agree well with the data on climatic changes around the 9th–10th centuries from the Medieval Climate Anomaly, including long-lasting droughts (Helama et al. 2009; Büntgen et al. 2011) and a widespread *Alnus* decline most probably caused by a

sequence of climatic events detrimental to alder followed by a pathogen attack (Stivrins et al. 2017; Latałowa et al. 2019).

The beginnings of the medieval settlement

According to the pollen diagram from Gołębiewo, a rise in settlement activity and woodland disturbances around Gdańsk started in the 10th century (Fig. 2a; Pędziszewska and Latałowa 2016). The data suggest that especially at the edges of the upland, the loss of woodland at the time resulted mainly from the demand for oak timber, which was the basic building material for the emerging strongholds. In turn, the pollen data from the area where Gdańsk developed suggest that there was still very limited human activity there in the 10th century (Figs. 2b, 3). The results corroborate well with the archaeological and historical data (Śliwiński 2009; Paner 2015).

A significant decrease in tree pollen, mainly of *Carpinus* and *Quercus*, and a rise in herb pollen indicate a reduction of woodland around AD 1030 (Fig. 2a). The demand for

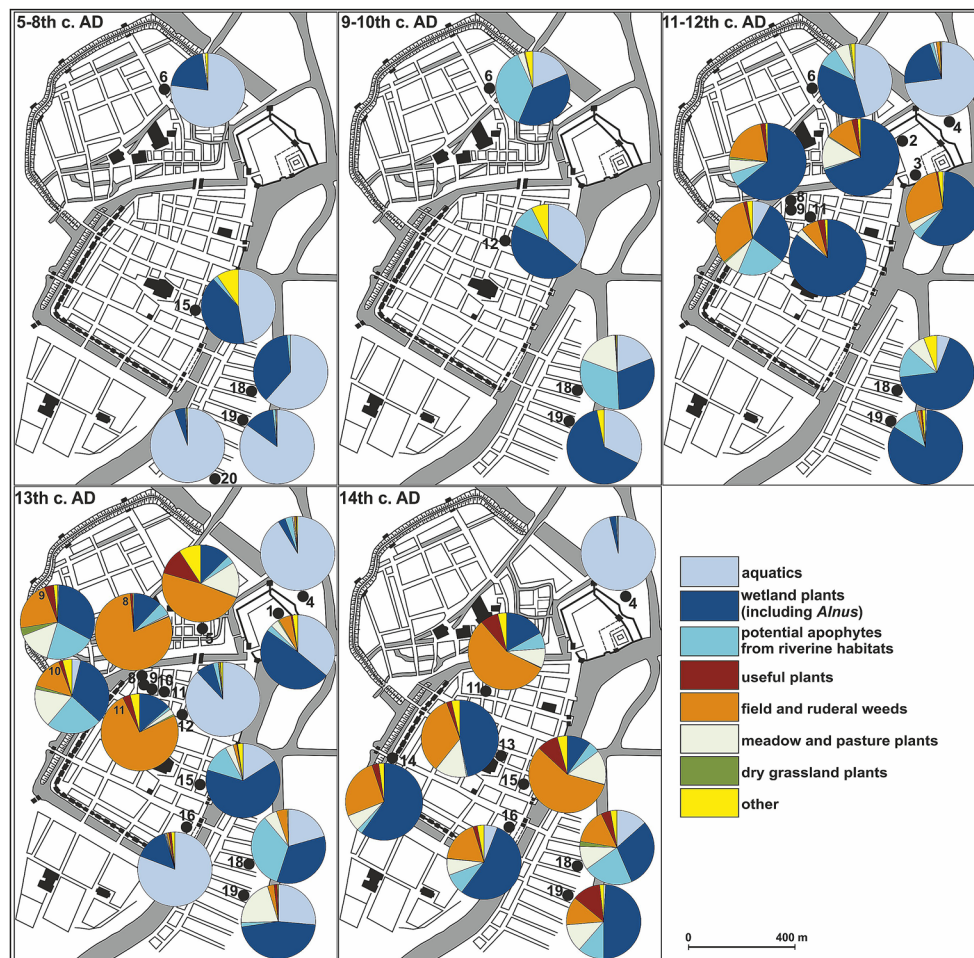


Fig. 4 Pie diagrams showing the average proportions of macrofossils representing selected environments and useful plants in Gdańsk in consecutive periods from the 5th to the 14th century. Site numbers as in Fig. 1c and Table 1

timber, especially oak, for building in the town must have increased at the time (Kościński and Paner 2005). In the woodland clearings, secondary woods with *Betula* and *Pinus* and then *Fagus* grew up where the farmland was not used. Beech, despite human pressure, expanded vigorously in the local woods and replaced hornbeam and oak. The higher land was increasingly used for farming, as demonstrated by the increase of the pollen of *Secale*, *Triticum*-type and *Hordeum*-type together with cornfield weeds and plants of meadows and pastures, like Poaceae, *Plantago lanceolata*, *P. media*, *Ranunculus acris*-type and the remains of coprophilous fungi (*Sordaria*-type).

In the 10th century, in most of the low-lying land around Gdańsk, alder wetland woods and water bodies were replaced by open fens and wet meadows (Fig. 3) with *Filipendula ulmaria*, *Potentilla anserina* and *Ranunculus repens*, which were then used for grazing (Fig. 2b) as suggested by the considerable proportion of coprophilous fungi, like *Sordaria*-type and *Sporormiella* (Davis and

Shafer 2006; Florenzano et al. 2013). The palynological data illustrate the first increase of settlement activity in this area around the early 11th century (Fig. 3), which agrees with the archaeological data (Paner 2015). The droughts which lowered the water table in wetland habitats could have been a stimulating factor for local settlement development in areas too wet to have been colonised earlier, even though there was already some settlement in the region (Śliwiński 2009). The dying wetland alder woods were probably used as a source of timber to build Gdańsk. According to Zbierski (1978b), alder wood accounted for about 19% of all the building timber used in the 11th century.

Environmental changes during the expansion of Gdańsk

The palaeoecological records suggest a very varied environment in the early period of settlement, and similar to other early medieval urban contexts (Kozáková et al. 2009), with

a mosaic of different vegetation types (Figs. 3, 4). Pollen spectra dated to the 11th–12th centuries are marked by a high proportion of *Pinus* pollen, with low values from other trees (Fig. 2b). We suggest an over-representation of pine pollen due to loss of the local alder woods which had been an effective barrier to regional pollen transport. The increasing openness of the landscape facilitated pollen transfer from pine woods growing on sandbars stretching along the sea coast and from the surrounding uplands, where at that time pine expanded rapidly in the disturbed woodlands (Fig. 2a).

In the period between the 11th and 14th centuries, although the water table became distinctly lower, at several sites spread over the Old and Main Town, at least temporary shallow water-bodies with stagnant or slow-flowing water still existed as a part of a rich hydrological network (Figs. 3, 4). Such conditions persisted until the 14th century, notably in the north-eastern part of the area (site 4) where a dense network of moats and canals surrounded the castle of the Teutonic Order (Maciakowska 2015). Our studies beneath kościół św. Mikołaja (St. Nicolas church) built in the 14th–15th centuries (sites 9 and 10) also corroborated the presence of stagnant or slow-flowing water still there in the 12th–13th centuries (Święta-Musznicka et al. 2013). Aquatic vegetation consisted of *Myriophyllum verticillatum*, *Nymphaea alba*, *Alisma plantago-aquatica*, *Lemna trisulca*, *Stratiotes aloides*, *Salvinia natans* and *Potamogeton* spp., and algae including *Pediastrum kawraiskyi*, *P. boryanum* and *Botryococcus* spp. Among the aquatic fauna, species from *Daphnia*, Ostracoda and Porifera were common (Figs. 3, 4).

Wetland alder stands as well as open fens were significant in the Gdańsk landscape until the 14th century. In the 11th–12th centuries, fragments of alder wood were still present in the surroundings of the Teutonic castle (site 1) and in both the Old and Main Town, while in the area that later became Granary Island, the proportion of alder was much lower at the time and there were mainly open fens. A relatively high content of *Alnus* pollen (28%) was recorded at site 12 in the 13th century, although contemporary samples from the nearby sites nine and ten contained very little alder pollen, indicating a difference in the local vegetation cover (Fig. 3). The macrofossil data provide evidence of the widespread, rich flora typical of floodplain habitats and a changing water-table, with *Iris pseudacorus*, *Typha* sp., various *Juncus* and *Carex* species, wet meadows with *Caltha palustris*, *Menyanthes trifoliata*, *Ranunculus sceleratus*, *R. flammula*, *R. repens*, *Filipendula ulmaria*, *Lythrum salicaria* and *Lychnis flos-cuculi*, and tall herbs typical of vegetation along river banks with *Urtica dioica*, *Bidens cernua*, *B. tripartita*, *Polygonum hydropiper* etc.

Although the main environments were wetlands, patches of dry land in the form of sandy alluvial fans occurred in a few places, as shown by both the reconstructions of the

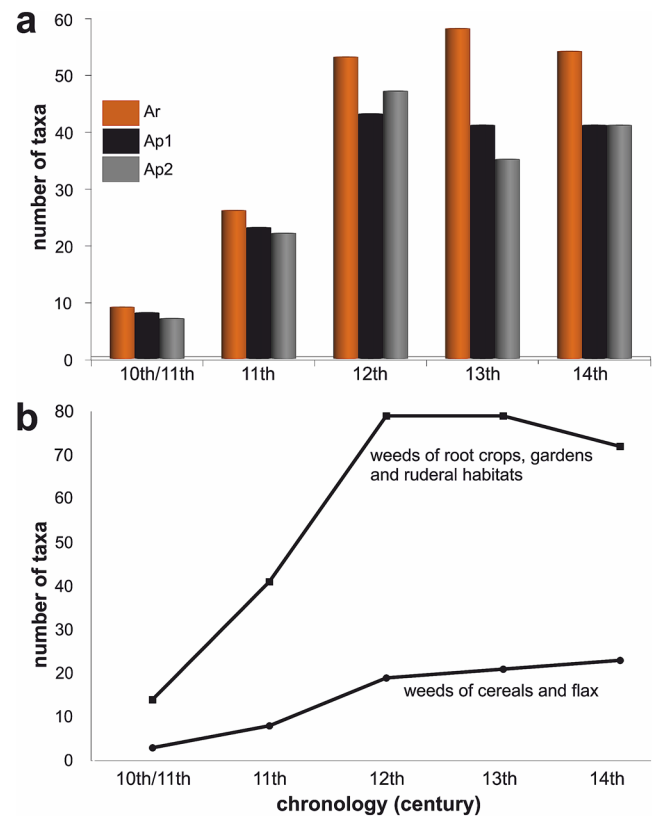
topography (Zbierski 1978a) and our study of the vegetation in the area around sites 9 and 10, where traces of the oldest settlement dated to the 10th century have been found (Gołębniak 2009). The archaeobotanical material from the area, dated to the 12th century, was rich in the pollen of crops, field and ruderal weeds as well as of meadow plants (Fig. 3). Surprisingly, the macroremains of *Calluna vulgaris*, *Jasione montana*, *Rumex acetosella*, *Hypericum perforatum*, *Potentilla argentea* and *Arenaria serpyllifolia* – species typical of dry grasslands, also occurred abundantly here, while they have been not recorded from any other site. This sandy alluvial fan next to an adjoining stream and surrounded by wetland meadows must have been favourable for settlement (Święta-Musznicka et al. 2013).

As the urban area expanded, a number of indigenous plants typical of riverside habitats rich in nutrients, such as *Urtica dioica*, *Chenopodium album*, *Artemisia* sp., *Polygonum* spp., *Bidens cernua*, *B. tripartita* and *Galium aparine*, spread there and formed the local ruderal vegetation of apophytes (native plants growing in anthropogenic habitats). The ruderal plant communities were also enriched by several nitrophilous archaeophytes (alien wild plants introduced up to the end of the 15th century) by then already established in the regional flora, like *Chenopodium hybridum*, *Conium maculatum*, *Urtica urens* and *Descurainia sophia* (Fig. 5, ESM Table 1). The pollen data demonstrate an increasing share of plants typical of trampled pathways like *Polygonum aviculare* and *Plantago major* as well (Fig. 2b). The list of various groups of weeds is substantial (ESM Table 1). The increasing number of weed taxa from the 10th/11th century transition to the 12th century (Fig. 5) reflects not only the spread of the local ruderal flora but also increasing transport of crops to the port and town (cf. Paner 1999b) and most probably the development of local gardening, as shown by records of archaeophytes (Ar) and apophytes (Ap1) in Fig. 5a. In turn, the many ruderal weeds (Fig. 5b) including apophytes typical of meadows and pastures (Ap2 in Fig. 5a) in the 12th century and their subsequent decline, might reflect changes in the layout of the town as it developed, causing alterations to the character of the local flora due to the expansion and higher density of the built-up area.

Living conditions in the developing town

The location of Gdańsk in a large wetland, in the fork between the rivers Wisła and Motława, with only a few drier places on alluvial fans, was a major challenge for the developing town. As already mentioned above, and as has been argued in earlier papers (Święta-Musznicka and Latałowa 2016; Latałowa et al. 2019), we suggest that the persistent droughts which occurred in the 9th–10th centuries finally made the wetland accessible for the local settlement. The

Fig. 5 Changes in the anthropogenic flora in medieval Gdańsk. **a** number of archaeophytes (Ar), apophytes growing mainly as crop weeds (Ap1) and other apophytes (Ap2); **b** number of weed taxa most typical of cereal and flax crops and those of root crops, gardens and ruderal habitats. For the list of taxa and classifications, see ESM Table 1

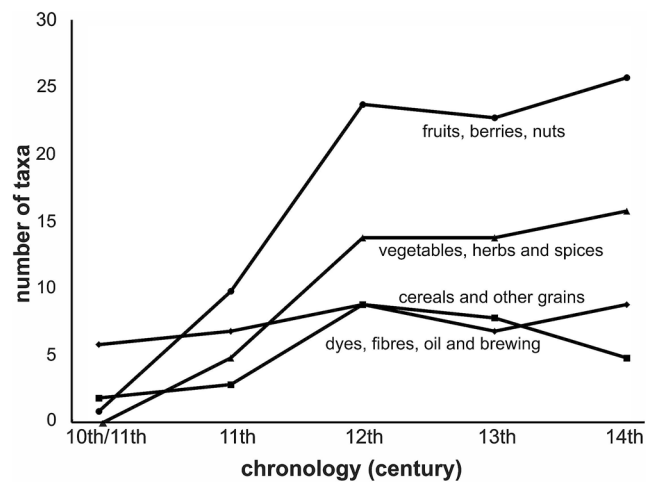


earliest settlements developed on small patches of mineral soil from the alluvial fans, but then gradually spread on to muddy and peaty ground. This is well illustrated by the archaeobotanical data which still show a large proportion of wetland vegetation and aquatic environments in the 13th century in the northeast of the city (Fig. 4). Notably, the political and economic pressure at the beginning of the 14th century resulted in a vigorous expansion of the town (Paner 2015; Śliwiński and Możejko 2017). The builders had to contend with a high water table and unstable ground (Maciakowska 2011). The archaeological investigations have uncovered levelling and insulation layers up to 2 m deep built up of reeds, tree branches and chopped wood fragments on Granary Island (Kaczyńska et al. 2005) and even thicker in other parts of the town (Maciakowska 2011). In some houses parts of old boats were also used as packing material beneath the floors of buildings (Krzywdziński 2009). The rising ground surface made frequent rebuilding necessary (Polak 2009). For example, in ul. Chlebnicka, the early medieval structures lie as much as 6.8 m below the present-day street level (Paner 2001). Most wooden houses and also the later ones of brick were built upon large wooden piles, mostly of oak, driven into the ground to stabilise them (Paner 2001; Krzywdziński 2009). Such a solution was even used for the foundations of the huge kościół Mariacki (St. Mary's church), the largest brick built church in medieval Europe. All the building works as well as large-scale drainage,

regulation of watercourses and moats, and construction of a water supply system, resulted in a gradual decrease of the ground moisture in most of the city as shown by our archaeobotanical data (Figs. 3, 4; Maciakowska 2005).

The waterlogging favoured accumulation of organic waste. The gravity of the situation then is illustrated by one of the earliest known civil codes in Gdańsk from around AD 1460, listing various regulations for the maintenance of cleanliness and forbidding pollution of the waterway to the port, which was punishable by death (Paner 2004). Our geochemical data confirm enrichment of the local aquatic habitats with phosphorus and nitrogen, indicating a significant increase of these elements, especially phosphorus, since the 13th century (Święta-Musznicka and Latałowa 2016). A high phosphorus content in archaeological deposits is regarded as one of the most important indicators of human activities, including food processing and storage, waste disposal and burning of organic matter. It is also evidence of human and animal faeces at the sites (Wilson et al. 2008; Mercuri et al. 2010; Cook et al. 2014). In Gdańsk, abundance of dung is confirmed by the many remains of coprophilous fungi (including *Sordaria*-type, *Sporormiella* and *Chaetomium* sp.) and intestinal parasite eggs of *Trichuris* and *Ascaris* in the sediments dated to the 11th century and later (Święta-Musznicka et al. 2013; Święta-Musznicka and Latałowa 2016; Figs. 2b, 3). Insanitary conditions were a general problem in medieval towns in Europe (Ewert 2007).

Fig. 6 Number of taxa in particular groups of useful plants known from medieval Gdańsk. The data are based on macroscopic plant remains, pollen and historical sources. The list of taxa and classification are in ESM Table 2



In Gdańsk, pollution of the local environment with heavy metals began to grow around AD 1200 (Święta-Musznicka and Latałowa 2016). The significant increase of copper, zinc and lead in the sediments reflects the development of local metalworking and processing (Zbierski 1978b) distinctly accelerating in the 14th century (Biskup 1978).

Plant use

The information on plant use by past societies, whether it is based on archaeobotanical materials or historical sources, is never complete. The problem has been thoroughly discussed by many authors (for example, Green 1984; Greig 1996; Karg 2007) and has been also considered in the interpretations of the data from Gdańsk (Latałowa et al. 2007; Badura et al. 2015). In general, archaeobotanical data depend on the potential of a plant material to fossilize and the way in which a given plant was used. It is easier to find remains of widely used plants and those producing large number of fruits/seeds, while the chance of recording rare taxa or those producing few diaspores is much lower (Hondelink and Schepers 2020). In the case of pollen analysis, pollen production, dispersal and potential for identification to species level are important issues (Behre 1981). Besides, the archaeobotanical information is strongly dependent on the archaeological features from which the samples are analysed. Cautious interpretation is necessary for many wild plants, especially edible ones, while they may also have grown wild within and around the settlement, such as *Chenopodium album*, *Urtica dioica* and *Valeriana officinalis*. In turn, historical sources are usually limited to plant products being traded, lists of products bought for convents and courts, or for occasional meals for wealthy people (Karg 2007).

In spite of these reservations, the plant macrofossil finds supplemented by the pollen and historical data offer some interesting hints on the use of plants, mainly as food, in Gdańsk in the 11th–14th centuries. The data from the

periods earlier than the 11th century are too scarce to be used for any conclusion. In general, the numbers of plant taxa used in Gdańsk gradually increased through time, with distinct peaks in the 12th and 14th centuries (ESM Table 2, Fig. 6). This must have been caused by the introduction of new products to the local market, following the development of the port and town in the 12th century enabling broader trade contacts (Paner 1999b) and then by the accession of Gdańsk to the Hanseatic League in the 14th century (Śliwiński and Możejko 2017). Another factor stimulating development of farming, gardening and introduction of new plant foods was the local establishment of the Cistercian and the Dominican monastic orders in the 12th and the 13th centuries respectively and then the foundation of the commander's office of the Teutonic Knights in the 14th century (Śliwiński and Możejko 2017).

The staple plant foods in medieval Gdańsk must have been cereals. The earliest, occasional finds of *Panicum miliaceum*, *Secale cereale*, *Triticum aestivum* and *Hordeum vulgare* were recorded in the samples dated to the 10th/11th century transition, collected from site 11. *Avena sativa* was recorded at two sites in the layers dated to the 12th century. The most exhaustive data come from the settlement at site 2 (Lechnicki 1955; Lechnicki et al. 1961; Badura 2011), where in the samples dated from the 11th century to the 12th/13th century transition charred and uncharred remains of millet distinctly outnumbered those of other cereals, both in number of remains and frequency. This seems to be in line with other results from north-western Poland, suggesting that millet was a major crop in the region during the early medieval period (Jarosińska 1994; Latałowa 1999; Badura et al. 2018). In the 13th century gradual development of Granary Island began and by the end of the 14th century 120–130 granaries already existed there (Paner 1999b). Historical and archaeobotanical data suggest that rye at that time was one of the most important crops delivered to Gdańsk from the region and

from more distant areas in central and southern Poland (Zbierski 1978c; Latałowa et al. 2007; Badura et al. 2015). It was then sold to European markets, however some consignments from inland reached the local market. This is shown by the occurrence of cereal weeds such as *Galium tricornutum* which are typical of warm rendzina soils in southern Poland, seeds of which have been found not only at Granary Island, but also at other sites in Gdańsk (Latałowa et al. 2007; Badura 2011).

Apart from the remains of the main cereals, some other grain crops were also recorded. A few uncharred glumes of *Setaria italica* were found in the 12th century cultural layers at site 2 and from the 14th century samples at site 16, however, it is not clear if we are dealing here with the remains of a cultivated plant or a weed (Latałowa et al. 2007). The earliest scattered finds of *Fagopyrum esculentum* were found from a layer dated to the 12th/13th century transition at site 8 and then at two other sites dated to the 14th century (Badura 2011). *Oryza sativa* appears on a list of goods in the 14th century inventory books of the Teutonic castle (Możejko 2006; Badura et al. 2015).

The use of some starchy wild plants in early medieval Gdańsk seems to be shown by the archaeobotanical data from site 2, where large concentrations of crushed *Chenopodium album* seeds in the settlement layers dated to the 12th–13th centuries must be remains from processing the seeds for food (Lechnicki 1955). There is ample data on the use of *C. album* as a food plant in prehistoric and early historic periods (Helbæk 1958, 1960; Behre 2008; Mueller-Bieniek et al. 2019) up to recent times (Poonia and Upadhyay 2015). In a layer dated to the 12th century, a pot filled with *Quercus* sp. (acorns) was found. The use of acorns as food for people or animals has a long tradition as well (Kluk 1808; Ayerdi et al. 2016). In two layers dated to the 11th and 12th centuries, large numbers of *Trapa natans* nuts occurred. Considering the situation of early medieval Gdańsk, it must have had excellent conditions to grow there in pools and oxbows. The inhabitants of the settlement certainly made use of this very nutritious plant to feed both themselves and their livestock (cf. Karg 2006).

The staple foods of medieval Gdańsk certainly included pulses and charred *Vicia faba*, *V. faba* var. *minor*, *Lens culinaris* and *Pisum sativum* were found in the settlement layers dated to the 11th–12th centuries at site 2. *Cicer arietinum* appears in the 14th century inventory books of the Teutonic castle (Możejko 2006; Badura et al. 2015). Pulses could have been grown in local gardens as suggested by *V. faba* pollen in the layers from the 12th–13th centuries in the town (Święta-Musznicka et al. 2013). Their popularity might have been increased by the arrival of monks at the time, whose monastic rules included eating food based on pulses (Dembińska 1987; Wyrwa 2004).

Vegetables are, in general, highly underrepresented in archaeobotanical materials because they are mostly eaten as bulbs, leaves or shoots which have low potential for being fossilized (Greig 1996). It is also true for Gdańsk, where finds of this group of plants are rather scarce. Our data indicate that *Cucumis sativus* (cucumber) was eaten in the 11th and 12th century by the people living at site 2 and *Allium cepa* (onion) was used by Teutonic monks in the 14th century (Możejko 2006). It is not clear if the few remains of other plants of this group represent plants used as vegetables or wild plants which would have been common in meadows and on fallow land, such as *Daucus carota* (carrot) (ESM Table 2; cf. Mueller-Bieniek 2010).

Plants used as herbs and spices were probably gathered in the wild as well as being grown in local gardens, but exotic imports were limited in this study period. According to our data, *Origanum vulgare* and *Coriandrum sativum* were certainly used in the 11th century, then *Brassica nigra* and *Carum carvi* appeared in the cultural layers from the 11th/12th century transition and the 12th century. The number and frequency of such remains increased in the later archaeobotanical material, in which *Betonica officinalis* and *Juniperus communis* appeared in the 12th century, *Verbena officinalis* in the 12th–13th century, *Levisticum officinale* in the 13th century and *Apium graveolens* and *Petroselinum crispum* in the 14th century. All these were used in various foods for their flavour as well as preserving and healing properties and they were believed to have various therapeutic powers, so for example, *C. sativum* was used to relieve indigestion and against gut parasites (Lonicerus 1679) and *B. nigra* as a flavouring and medicine (Kluk 1811; Grieve 1971) was regularly listed in the Teutonic Order inventory books (Możejko 2006). The wealthier people had access to more exotic spices, traces of which are, however, generally rare in archaeobotanical samples. The evidence is more often provided by historical sources. The use of *Crocus sativus* (saffron) and *Piper nigrum* in the 14th century is confirmed by entries in Teutonic inventory books and by the ledger of the Main Town treasury (Możejko 2006; Badura et al. 2015; Grulkowski 2016). Powdered stigmas of saffron flowers were considered to be a prized addition to food and also an aphrodisiac (Toussaint-Samat 2009). Pepper, on the other hand, was not only valued as a spice, but also used by apothecaries as a basic unit of weight (Wojciechowska 2000) and as a means of payment (Długokęcki 1984).

In the cultural layers of medieval Gdańsk a significant number of remains of fruits and nuts have been preserved. Some of the fruit trees could have been cultivated in local gardens and orchards. Numerous *Prunus* fruitstones, including *P. domestica* and *P. domestica* ssp. *insititia*, were found in the 11th and 12th century samples from site 2, while other sites showed the presence of *Malus* sp., *Pyrus* sp., *Cerasus vulgaris* and *C. avium*. *Ribes rubrum* appeared in the 14th

century. Remains of *Vitis vinifera* and *Ficus carica* have been found in the features dated to the 12th century and *Persica vulgaris* to the 12th/13th century transition. It is difficult to decide whether the grape pips are the remains of imported raisins (Gade 2018) or perhaps of locally grown grapes used to make the wine needed by the church. The historical sources tell us that the Cistercians, who settled in Oliwa (now part of Gdańsk) in AD 1178 were obliged to grow vines (Badowicz 2017) and then in the 13th and 14th centuries several vineyards were established in the region, mainly due to the activity of the Teutonic Order (Tandecki 1997). The relatively warm climate in the Baltic region in that period made viticulture possible (Niedźwiedz et al. 2015). *Ficus carica* reached Gdańsk thanks to the development of long-distance trade and the supply to the local market subsequently grew (Badura et al. 2015). Figs were not only eaten as a delicacy, but were also used to make a medicinal syrup with numerous uses (Compendium 1767; Rosenblum 1855). Fruit and nuts were also collected from the wild. Remains of *Vaccinium myrtillus*, *Fragaria vesca*, *Rubus idaeus* and *C. avellana* were found in the cultural layers of site 2 dated to the 11th/12th century transition and to the 12th century and in the 11th century living quarters of site 8. The excavation of site 3 revealed a foundation offering placed at the base of the stronghold rampart which included the skeleton of a dog and a large accumulation of *Fragaria vesca* and *V. myrtillus* seeds (Badura 2011). Scattered remains of *Rubus saxatilis*, *R. caesius*, *R. fruticosus*, *Oxycoccus palustris*, *Prunus spinosa*, *Sambucus nigra*, *Sorbus aucuparia* and *Viburnum opulus* occurred in the layers dated from the 11th to 14th centuries at several sites (ESM Table 2).

Gdańsk has a long tradition of brewing and drinking beer (Bogucka 1962). Historical documents from the beginning of the fifteenth century mention 378 brewers there (Maciakowska 2011) indicating the already long tradition of the local craft. Fruits of *Humulus lupulus* occurred regularly and abundantly in the archaeobotanical material. The oldest finds, from the 10th/11th century transition, may have come from wild hops growing in the woods on the Wisła floodplain, where they must have been common. It is not unlikely, however, that hops were already cultivated at the time, as suggested by A. Alsleben (1995) for early medieval Wolin. Hop cultivation was widespread in later periods and they were an important trade item as demonstrated by documents about Granary Island mentioning the job of a hop sorter in the 14th century (Biskup 1978). Significant amounts of hops, malt and beer were listed in the 14th century inventory books of the Teutonic castle (Możejko 2006). A plant which may have been used to make ale in Gdańsk was *Myrica gale*. Its numerous leaves and buds were found in the 12th century cultural layers at site 2 and a fruit has been found in a 13th century sample from site 9. In the medieval period, sweet gale was an important ale plant in parts of western and

northern Europe (Behre 1999), but we may suspect that in Gdańsk its use was rather limited to brewing traditional ales for Germans and Scandinavians who settled there. Gdańsk lies at the southern limit of the geographical range of *M. gale* (Hegi 1957) and even if it was certainly more frequent in the region in medieval times than today (Herbichowa 1979), it was probably still not common enough to be used as a major brewing ingredient (Latałowa et al. 2007).

Six oilseed taxa are among the useful plants listed for medieval Gdańsk (ESM Table 2). Seeds of *Linum usitatissimum* and *Cannabis sativa* were certainly used as food and for various medicinal purposes (Kluk 1805, 1808), but both were grown mainly for their fibre. Numerous remains of shives (stem fragments) and fibres found along with textile tools in the 12th–13th century cultural layers at site 2 indicate local development of textile and rope production (Kamińska and Nahlik 1958; Lechnicki et al. 1961). Large amounts of seeds of *Iris pseudacorus* from the 12th century, a plant used to make dyes, may be a sign of textile production as well. There is also 14th century historical evidence for the development of such crafts and locations of the workshops in Gdańsk (Maciakowska 2011). Seeds of *Papaver somniferum* dated to the 11th–14th centuries were a source of oil, but were also used for a “poppy soup” and as a spice and a medicine (Zemanek et al. 2009). Oil could also be obtained from *Camelina sativa* (12th/13th century transition) and *Brassica napus* (13th/14th century transition). A few 12th century samples from site 2 contained *Cornus sanguinea* seeds which are known as a source of oil used for lighting and medical purposes (Kluk 1805).

Conclusions

The archaeobotanical data from medieval archaeological contexts and sediments in Gdańsk provide unique information on environmental aspects of the town as it developed, the shrinking of natural vegetation and spread of anthropogenic plant communities, changes of hydrological conditions, soil and water pollution and other issues important for the people living in the growing city.

We suggest that the climate change around the 9th–10th centuries was an important factor which enabled local settlement to develop, when alder wetland woods and oxbows began to shrink because of long droughts. Our data are a perfect complement to the existing archaeological and historical information on the beginnings of Gdańsk. They confirm that it was only in the 11th and 12th centuries when significant settlement development started there and that the spatial development of the town was particularly fast in the 14th century.

A comparison of the data from the sites in different parts of Gdańsk indicates that the initially dispersed settlement

provided habitats for a rich mosaic of vegetation with mostly natural and semi-natural plant communities typical of wet habitats which continued to exist in the town throughout the whole study period. The increasing human activity resulted in the spread of ruderal vegetation rich in plants of moist, nutrient-rich habitats. The pressure from economic and demographic growth resulted in the rising eutrophication of aquatic and land habitats and since the beginning of the 13th century, heavy metal pollution too.

The inhabitants of the growing town created a considerable demand for plants for food and other purposes. The archaeobotanical results suggest an important change in the use of cereals around the 13th century, when the amount of rye increased, which may reflect more consumption of food such as bread. The choice of vegetables and flavourings as well as fruits eaten in Gdańsk distinctly grew in the 12th and 14th centuries following local establishment of religious orders which brought new agricultural practices. Development of regional and long-distance trade was also a factor, which enabled import of exotic goods.

The environmental issues are far less studied by archaeobotanists than those concerning plant use. Gdańsk, with its large network of archaeological sites which have been systematically studied by both pollen and macrofossil analyses supplemented by geochemical data, is certainly one of the leading urban centres in the Baltic region in terms of the knowledge of its past environment. The present review focuses on the oldest history of the city until the end of the 14th century, when demographic and economic development led to increasingly rapid changes in the many aspects of urban structure and function (Maciakowska 2011). The ARCHBOT-UGDA DATABASE contains data from 32 archaeological sites spread over the historical part of Gdańsk, extending into modern times. While discussion of plant use also including the post-medieval period has mostly been summarized (Latałowa et al. 2007; Badura 2011), there is still material in the database providing potential for further research on various aspects of the environmental history of the city.

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