Summary of professional accomplishments

Joanna Święta-Musznicka, PhD

University of Gdańsk
Faculty of Biology, Department of Plant Ecology
Laboratory of Palaeoecology and Archaeobotany

Gdańsk, 2022

Attachment 3b

1. **Name**

   Joanna Święta-Musznicka

2. **Diplomas, degrees conferred in specific areas of science, including the name of the institution which conferred the degree, year of degree conferment, title of the PhD dissertation**

Master of Science in biology – Faculty of Biology, Geography and Oceanology, University of Gdańsk, 2000, title of master thesis: *Fossil flora of the archaeological site at the junction of Piwna and Kaletnicza streets in Gdańsk with particular consideration to the useful plants,* supervisor Małgorzata Latałowa, PhD, DSc, ProfTit.

PhD in biology – Institute of Biology, Faculty of Biology, Geography and Oceanology, University of Gdańsk, 2005, title of PhD thesis: *Palaeoecological reconstruction of the Late Holocene history of selected lobelia lakes in the light of changes in their catchments*, supervisor Małgorzata Latałowa, PhD, DSc, ProfTit.

3. **Information on employment in research institutes**

01.10.2004-31.10.2005: technician, Department of Plant Ecology, Faculty of Biology UG
since 01.11.2005: assistant professor, Department of Plant Ecology, Faculty of Biology UG

4. **Description of the achievements, set out in art. 219 para 1 point 2 of the Act**

4.1. The title of the scientific achievement

As an achievement, in agreement with art. 219, para 1 point 2b of the above-mentioned Act, I point out a series of five thematically related scientific articles entitled:

Natural conditions and environmental consequences of the settlement development in the area of Gdańsk (5-15th centuries) based on palaeoecological data from urban archaeological sites.

4.2. The publications included in the scientific achievement

1. **Święta-Musznicka J.**, Latałowa M.[*], Szmeja J., Badura M. 2011. *Salvinia natans* – an invasive plant in water currents in early medieval Gdańsk (N. Poland) – some consideration on past hydrologic and climate condition. Journal of Paleolimnology 45: 369-383.

   IF_{2011}: 1.898, $IF_{5\text{-}years}$: 2.198; quartile (JIF): Q1; MNiSW scoring[1]: 35; number of citations: 16 (Web of Science); 26 (Scopus), 31 (Google Scholar)

   My contribution to the publication involved working on the concept of the article, performing pollen and non-pollen palynomorphs analysis in two profiles, performing macrofossil analysis in two profiles and contributing to macrofossil analysis of samples in two more, segregating materials for dating, compiling data for the article, performing statistical analyses and their interpretation, preparing figures, table and the part of manuscript in terms of site and sediment description, as well as preliminary versions of the results description and discussion.

*corresponding author

2. **Święta-Musznicka J.**[*], Latałowa M., Badura M., Gołembnik A. 2013. Combined pollen and macrofossil data as a source for reconstructing mosaic patterns of the early medieval urban habitats a case study from Gdańsk, N. Poland. Journal of Archaeological Science 40 (1): 637-648.

   IF_{2013}: 2.139, $IF_{5\text{-}years}$: 2.369; quartile (JIF): Q1; MNiSW scoring[1]: 35; number of citations: 13 (Web of Science); 25 (Scopus); 26 (Google Scholar)

   My contribution to the publication involved leading the UG-funded project through which the pollen analysis in profile PIII was completed, participating in developing the concept of the article, performing pollen and non-pollen palynomorphs analysis in the three profiles discussed in the article, performing some of the analyses of macroremains in profile PIII, segregating materials for dating, compiling data for the article, preparing figures and tables, interpreting the results, performing literature review, preparing the structure of the article and the final version of the manuscript, and preparing responses to reviews.

3. **Święta-Musznicka J.**[*], Latałowa M. 2016. From wetland to commercial centre: the natural history of Wyspa Spichrzów (''Granary Island'') in medieval Gdańsk, northern Poland. Vegetation History and Archaeobotany 25: 583–599.

   IF_{2016}: 1.908, $IF_{5\text{-}years}$: 2.004; quartile (JIF): Q1; MNiSW scoring[1]: 35; number of citations: 1 (Web of Science); 3 (Scopus); 5 (Google Scholar)

   My contribution to the publication included the management of a project funded by NCN and related to the research described in this paper, participation in developing the concept of the article, preparation of pollen and non-pollen palynomorphs analyses in three profiles, analysis of macroremains (2 profiles) and verification of some determinations (upper part of the profile from Jaglana St.), segregation of materials for dating, compilation of data for the article, preparation of figures and tables, statistical analyses, interpretation of results, literature review, drafting the structure of the article and final version of the manuscript, preparation of responses to reviews.

4. **Święta-Musznicka J.**[*], Badura M., Pędziszewska A., Latałowa M. 2021. Environmental changes and plant use during 5th-14th centuries in medieval Gdańsk, northern Poland. Vegetation History and Archaeobotany 25: 583–599.

   IF_{2021}: 2.375, $IF_{5\text{-}years}$: 2.669; quartile (JIF): Q1; MEiN scoring[2]: 100; number of citations: 2 (Google Scholar)

   My contribution to the publication involved managing the NCN-funded project that included the research described in this paper, performing pollen and non-pollen palynomorphs analysis at all sites, performing macrofossil analysis (sites 3, 6, 12, 18, 19; Table 1 in the article) or participating in the preparation and verification of determinations (sites 4, 9, 10, 15, 16, 20; Table 1 in the article), segregating materials for dating, developing the concept of review paper, compiling data for the article and interpreting the results, reviewing literature, preparing figures and tables, preparing the structure of article and the final version of manuscript, preparing responses to reviews.

5. **Święta-Musznicka J.**[*], Badura M., Jarosińska J., Latałowa M. 2021. Naturalne uwarunkowania i konsekwencje przyrodnicze rozwoju osadnictwa na terenie Gdańska (V-XV w.). Archeologia Gdańska 8: 11-38.

   IF: -; quartile: -; MEiN scoring[2]: 5; number of citations: 0

   My contribution to the publication included the management of the scientific project involving the research described in this paper, performance of pollen and non-pollen palynomorphs analysis at all sites, performance of macrofossil analysis (sites 3, 7, 13, 21, 22, 24; Table 1 in the article), or

participation in the preparation and verification of determinations (sites 4, 10, 11, 16, 17, 19, 23; Table 1 in the article), development of the review paper concept, compilation of data for the article, literature review, preparation of figures and tables, preparation of the final manuscript and responses to reviews.

The presented series of five thematically related articles includes papers that were prepared and published after the Conferment of Doctoral Degree. Four articles were published in journals from the JCR list (quartile Q1), one as a peer-reviewed scientific publication in Polish. I am the first author of all papers; in four of them I am a corresponding author.

The publications total Impact Factor that constitutes the achievement, according to the specific year of publication amounts to 8.32 (9.24 $IF_{5\text{-year}}$). Their total number of citations: 30 (Web of Science), 54 (Scopus), 64 (Google Scholar). The total bibliometric value of publications amounts to 210 points according to the unified lists of 26.01.2017 and 9.02.2021.

The publications listed above are enclosed in Attachment 6. Declarations of the co-authors of papers that form the scientific achievement along with their individual contributions are enclosed in Attachment 5.

4.3. Aim of the above publications and description of obtained results, including the description of their potential use

The series of papers entitled **Natural conditions and environmental consequences of the settlement development in the area of Gdańsk (5-15th c.) based on palaeoecological data from urban archaeological sites** contains the results of palaeoecological studies carried out at sites situated in the oldest districts of the town. This is the result of my long-term research, which I carried out after the Conferment of Doctoral Degree, first as a principal contractor in the MNiSW project *The natural environment of Gdańsk in the Middle Ages and in Modern Times*, and then as a manager and the main contractor in NCN project *From wetlands to urban vegetation - using palaeoecological data to reconstruct environmental changes in the area of Gdańsk from 5th to 17th century*.

The palaeoecological research conducted on urban sites accompanies archaeological investigations which, in accordance with the law on the protection of cultural heritage, precedes investments in areas of special value from the viewpoint of knowledge of the past. These have been undertaken on sites located in the historic centres of many European cities, e.g., in England (e.g., Woolgar et al. 2006; Hall, Huntley 2007), Germany (e.g., Märkle 2005; Alsleben 2007), Lithuania (Stančikaitė et al. 2008) and Belgium (Vrydaghs et al. 2015; Crabtree et al. 2017; Devos 2018). Intensive studies have been carried out in Prague (Beneš et al. 2002; Kozáková, Pokorný 2007; Kozáková et al. 2009; Pokorná et al. 2014) and several cities in Italy (e.g., Ferrara - Bandini Mazzanti et al. 2005; Florence - Mariotti Lippi et al. 2009; Pisa - Bertacchi et al. 2008; Rome - Sadori et al. 2010a; Parma - Bosi et al. 2011). In Poland, analyses of botanical remains have been used in studies on sites located, among others, in the centre of historic Kraków (Wieserowa 1979; Wasylikowa 1991; Sokołowski et al. 2008; Wasylikowa et al. 2009; Mueller-Bieniek 2012), Wolin (Latałowa 1999), Elbląg and Kołobrzeg (Latałowa et al. 2003), and Poznań (Okuniewska-Nowaczyk 2005; Koszałka 2005). These studies made it possible to reconstruct the environmental context of the developing settlement and its changes along with the formation of urban system, as well as to

provide data on the use of natural resources by humans at the successive stages of urban development. The archaeobotanical studies undertaken also provided data on the processes of synanthrophization of flora and vegetation in the study areas in terms of long-term changes.

In the five papers included in the scientific achievement I focused on the detailed characteristics of natural conditions that prevailed in the area of the western edge of the Wisła delta before Gdańsk was established and on the description of the following stages of local flora and vegetation transformations against the background of the city spatial development in the Middle Ages. The presented series of publications is the first study of natural consequences of the formation of medieval agglomeration of Gdańsk, thanks to the integration of results based on palynological studies, macroscopic remains of plants and animals, geochemical analyses and their confrontation with the historical, archaeological and paleoclimate data.

The archaeological and historical research into the beginning of settlement in Gdańsk and its spatial development has a long tradition (i.e., Jażdżewski 1955, 1958; Zbierski 1978a) and is still ongoing (i.e., Kościński, Paner 2005; Paner 2015; Śliwiński, Możejko 2017). It indicated that the oldest stronghold of Gdańsk was a 10th century watchtower, situated on the Gradowa Mountain, a natural hill in the region the low-lying floodplain of the rivers Motława and Wisła. In the mid-11th century, it was moved to the area where Motława joined Wisła at the time (Kościński, Paner 2005; Śliwiński, Możejko 2017), which provided defensive functions, enabled the development of port, as well as the control over water-borne and land communication and trade. In the 14th century Gdańsk was already a town with several districts, forming its historical centre today. The north-western part of the agglomeration was taken by the Old Town, located near the stronghold on the so-called Zamczysko, and the central part by the Main Town, the largest commercial centre with access to the harbours on the Motława River. To the east of it, Granary Island was developed, surrounded by the waters of the Motława River (Maciakowska 2011; Lipiński, Lorens 2016; Śliwiński, Możejko 2017). At that time, the largest undeveloped areas were located to the north-east of the Old Town, in the direct vicinity of the Wisła riverbed where, as late as at the end of the 14th century, the Young Town was established - still the poorest studied district of medieval Gdańsk. On the one hand, the differences in the rate of settlement development in various parts of the town must have been related to natural conditions, on the other, they certainly influenced the disproportions in the transformation of local environment under the influence of anthropopression. Therefore, the long-term team works conducted by the Gdańsk University Laboratory of Palaeoecology and Archaeobotany aimed e.g., to collect as much materials as possible from sites located in various parts of the city and representing subsequent chronological periods, which would provide grounds not only for reconstructing the fossil flora of the sites, but also for describing the natural history of the town.

Due to the intensive archaeological surveys conducted in Gdańsk in relation to the modernisation of the city's infrastructure, materials were collected from 24 sites located within the historical districts, providing information on the natural conditions in subsequent stages of the city's development. Taking into account the sources of materials, their chronological and spatial variation, the aim of palaeoecological studies undertaken in the Gdańsk included:

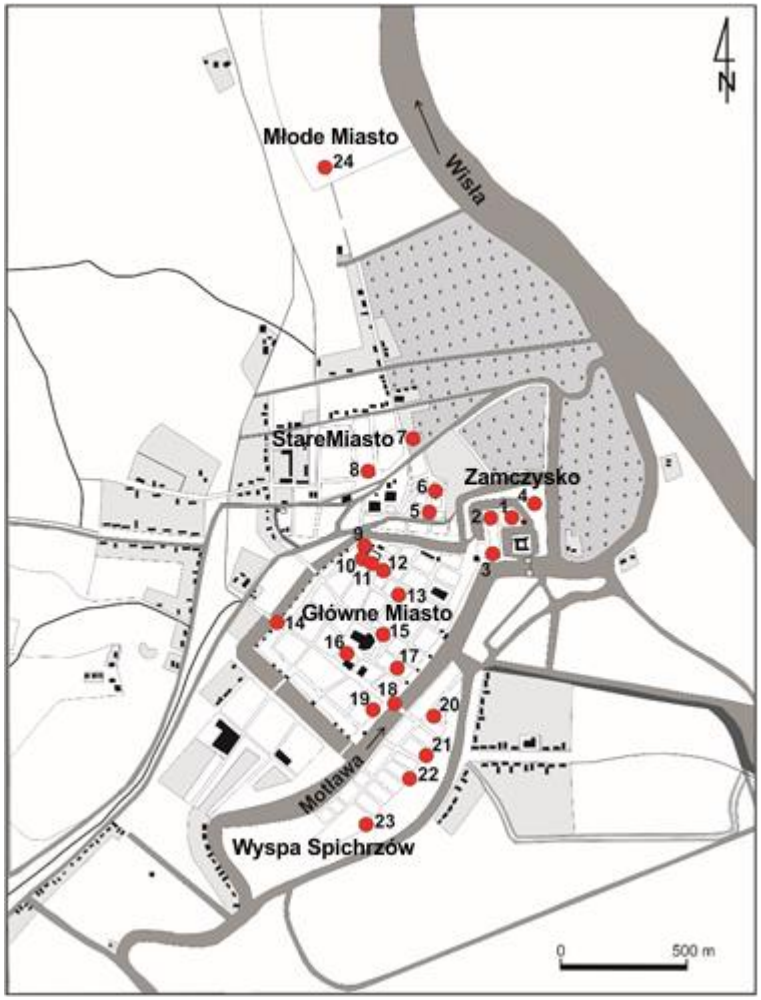
- reconstruction of the natural conditions of settlement development in the early Middle Ages
- description of the transformation of local ecosystems under the influence of urban development
- characterization of the ecological conditions in the town
- reconstruction of the composition of anthropogenic flora and vegetation in the consecutive stages of town development.

The materials for this study were collected from sites where cultural layers and underlying natural sediments were exposed during the archaeological works. At 13 out of 24 sites the material was collected directly from the trench walls, and the sediment sequences for the study were obtained in the form of profiles (Fig. 1). At 11 sites, samples were collected for pollen and non-pollen palynomorphs (NPPs) analysis, and at all sites samples for macrofossil analysis were collected, following the sequence of layers distinguished after the lithological description of sediments. To obtain longer sequences of natural sediments, at four sites (no. 7, 17, 21, 23) sediment profiles were additionally collected with an Instorf sampler, 5 cm in diameter, from beneath the trench bottoms. At the sites at Grodzka, Grząska and Powroźnicza streets, additionally to profiles from the trench walls, samples for macrofossil analysis were also taken from the selected cultural layers or archaeological objects. For 11 sites out of the 24 described in the review papers, included in the achievement (**no. 4, 5**), materials were obtained only from cultural layers of various functions (including yards, refuse heaps) and archaeological objects.

Pollen analysis enhanced by NPPs analysis was performed for 250 samples from 11 sites. The content of tree pollen, shrubs and herbaceous plants, as well as the remains of NPPs (e.g., cyanobacteria, green algae, fungi, eggs of internal parasites) was determined in the samples. Expanding the range of pollen analysis by the identification of NPPs at urban sites aimed to enrich the interpretation of materials in terms of description of the characteristics of local environment and changes occurring in the town under the influence of human activities. In limnic and peat sediments, at least 1000 AP plus all other pollen and microfossils were counted in each sample. 200–600 AP and 600-1400 NAP and microfossils were usually counted in samples from cultural layers. In general, the pollen material is rather rich, which allowed to determine 184 plant and 76 NPPs taxa (mainly green algae and coprophilous fungi) in the samples dated from 5^{th} to 15^{th} century.

Macrofossils were analysed from 469 samples from 24 sites, 161 of which were natural and semi-natural sediment samples (limnic sediment and peat). 308 samples represented useful layers of different functions and archaeological objects. Data on the composition of these samples were selected from the ARCHBOT-UGDA DATABASE, elaborated at the Gdańsk University Laboratory of Palaeoecology and Archaeobotany. Subsamples of 300 cm^3 constituted grounds for the analyses. In the case of samples taken by Instorf sampler, the whole volume of macrofossil samples was analysed due to their small size, then the number of remains was calculated in relation to 300 cm^3, so that the composition of samples could be compared to one another. The macroscopic material is characterized by taxonomic richness, which allowed to determine 512 plant taxa, including

391 species and sub-species. In addition, animal remains including Pisces, Bryozoa, Porifera, Ostracoda, Turbellaria and Hirudinea, were determined in the samples.



1-Teutonic Castle (M); profile
2-Dylinki St. (M)
3-Grodzka St. (M); profile
4-Wałowa St. (M, P, NPPs, G); profile
5-Tartaczna St. (M)
6-Sieroca St. (M)
7-Łagiewniki St. (M, P, NPPs); profile
8-Rajska St. (M)
9-Market Hall (M)
10-St. Nicholas church – yard (M, P, NPPs); profiles
11- St. Nicholas church – crypt (M, P, NPPs); profile
12-Dominican Centre (M)
13-Szeroka St. (M, P, NPPs, G); profile
14-Torture House (M)
15-Meat Market (M)
16-Piwna St. (M)
17-Grząska St. (M, P, NPPs); profile
18-Green Gate (M)
19-Powroźnicza St. (M, P, NPPs); profile
20-Chmielna St. (M)
21-Żytnia St. (M, P, NPPs); profile
22-Pszenna St. (M, P, NPPs, G); profile
23-Jaglana St. (M, P, NPPs, G); profile
24-Robotnicza St. (M, P, NPPs); profile

Fig. 1. Location of elaborated sites on a plan of Gdańsk from the mid-15th century (after Gedanopedia, modified); M - sites with macrofossil data, P - sites with palynological data, NPPs - sites with NPPs data, G - sites with geochemical data; red colour: sites where materials were collected only from cultural layers and archaeological objects

The age correlation of the materials from all the sites and the chronology of the stages of environmental transformations in Gdańsk is based on the archaeological dating of cultural layers and objects, as well as on AMS radiocarbon dating done on 54 samples in the Poznań Radiocarbon Laboratory. OxCal v. 4.4.2 (Bronk Ramsey 2017) and age calibration curve by Reimer et al. (2020) was used for dates calibration and calendar age calculation. The sediment profiles with the longest chronological range record events from the 5th to 15th century and are located in the area of the Old Town (Łagiewniki St.), the Main Town (Grząska St.), Granary Island (Pszenna St. and Żytnia St.) and the Young Town (Robotnicza St.).

Geochemical analyses of sediments were performed for samples from four sites. The content of mineral matter, organic matter, nitrogen, phosphorus, sulphur, carbon, major and trace metals, including lead, zinc, copper, iron and manganese, was determined at the Szczecin University Instrumental Laboratory of the Department of Geology and

Palaeogeography. These analyses were used to investigate the sediments from archaeological sites to provide additional arguments for the reconstruction of trophic changes, oxydo-reduction conditions and heavy metal pollution of the local environment.

The three papers included in the achievement (**no. 1, 2, 3**) contain detailed results of palaeoecological analyses of the selected sites located in the Old and Main Town (**no. 1**), in the area of Dominican holm (**no. 2**) and on Granary Island (**no. 1, 3**). **Two papers are more an overview and summary in their character**, and present research results from 24 sites from Gdańsk (**no. 4, 5**). The last paper was published in an archaeological monograph in Polish, so that the results of research into the natural aspects of settlement development in Gdańsk could be shared not only among archaeologists and historians, but also more widely among the enthusiasts of the town' s history.

Natural conditions of the medieval settlement development in Gdańsk

The palaeoecological studies conducted within the network of archaeological sites located in the oldest medieval districts of Gdańsk make it possible to describe the natural conditions that prevailed in their areas prior to the expansion of settlement. They indicate that between the 5th and 8th centuries, the area of the low-lying accumulation platform in the Wisła delta which would later be incorporated into the expanding town, was dominated by forest communities, which is evidenced by the high proportion of tree pollen in the analysed samples. *Alnus glutinosa* woods were widespread here on wetland habitats along watercourses and within oxbow lakes. This is confirmed by the predominance of alder pollen among the AP (Fig. 2A in this summary) and the accumulation of macroremains of black alder in the sediments. The results of palynological studies indicate that in addition to wetland forests, the area of the future town was also overgrown by patches of mixed deciduous forests with a higher proportion of *Quercus* and *Carpinus betulus*. This type of community would have grown only on small mineral elevations, e.g., on the mineral outcrop on the border of the future Old and Main Town, where a settlement point at the so-called Dominican holm was developed.

An essential element of the natural environment included shallow water bodies located in the vicinity of watercourses and forming part of the developed system of oxbow lakes of the Motława and Wisła rivers. Their presence in various parts of the study area is confirmed by the accumulation of limnic sediments dating to the 5th-8th centuries, which must have accumulated in meso/eutrophic freshwater bodies with stagnant or very slow flowing water. The basins provided ideal conditions for plant growth (*Nymphaea alba*, *Lemna trisulca*, *Nuphar lutea*, *Potamogeton natans*, *Myriophyllum verticillatum*, *Ceratophyllum demersum*), for green algae (i.e., *Pediastrum kawraiskyi*, *P. boryanum v. pseudoglabrum*), blue-green algae (*Gloeotrichia*), and also for aquatic fauna (Ostracoda, *Daphnia* and Porifera). The very diversified proportion of the remains of aquatic and wetland organisms in the sediments from this period allow us to assume that these water bodies were shallowing and overgrowing as a result of filling in with organic matter. The results show a significant change in hydrological conditions in the local ecosystems between the 9th and 10th centuries. The decrease in water level is confirmed by the reduction in the representation of the aquatic organism remains in the studied profiles (Fig. 2A, 2B), the change in the character of sediments and the presence

of sedimentation gaps at the boundary between the limnic sediments and the herbaceous peats lying above them. The hydrological disturbances resulted from the extinction of alder stands, the habitats of which were occupied by open wetland vegetation with among others *Thelypteris palustris, Scirpus sylvaticus, Carex pseudocyperus, C. disticha, Menyanthes trifoliata*. Fresh and wet meadow communities with a rich composition of species, such as *Ranunculus repens, Prunella vulgaris, Lychnis flos-cuculi, Filipendula ulmaria* and *Potentilla anserina* have also become an essential element of the local environment. Their highest proportion was recorded at this time in the south-eastern part of the study area.

As a result of research, specific natural conditions were documented, including an extensive hydrological network and the dominance of wetlands, which were considered by archaeologists and historians to be unfavourable for the development of settlements in Gdańsk (e.g., Zbierski 1978a; Maciakowska 2011). *The topics are presented in the work no. 3, 4, 5.*

Transformations of local ecosystems during the urban development in the Middle Ages

The results of palaeoecological research on sites recording the events from the 9th to the 11th century confirm the lack of settlement in the studied area until the 11th century and the limited human impact on the local environment until then. They provide evidence that hydrological changes associated with the lowering of water table, which resulted in a reduction of the area occupied by water basins and alder forests, constituted a factor that made settlement development in Gdańsk possible. Such a clear change of the environmental conditions may have determined the establishment of a new stronghold in the area of the Motława outlet to the Wisła in the middle of the 11th century. This was the moment when the process of gradual transformation of natural environment began. The results of palaeoecological analyses of the Gdańsk sites confirm that these changes occurred in accordance with the archaeologically confirmed time of settling the oldest districts of the city. The earliest changes were observed in the vicinity of the stronghold at Zamczysko, then in the Old Town, the Main Town, and the latest on Granary Island.

The landscape of medieval Gdańsk in the early period of its development was extremely differentiated. The results of analyses confirm the wet character of habitats, prevailing in many places despite the drop in groundwater levels. This refers especially to areas located in the immediate vicinity of watercourses and overgrown water bodies that were gradually regulated and included into the town hydrotechnical infrastructure. In these places, there were still excellent conditions for the development of plants typical of shallow water (*Myriophyllum verticillatum, Nymphaea alba, Lemna trisulca, Salvinia natans*), green algae (*Pediastrum kawraiskyi, P. boryanum* var. *boryanum, Botryococcus*) and aquatic fauna. The significant level of substrate humidity is confirmed by data from various parts of the study area from the 11th to 13th centuries (Fig. 2), illustrating the local presence of alder scrub, as well as wetland communities with *Caltha palustris, Menyanthes trofoliata, Iris pseudacorus, Typha angustifolia, Ranunculus sceleratus* and *Lycopus europaeus*, which occurred next to communities gradually spreading into the anthropogenic habitats. This mosaic character of vegetation with different habitat requirements was particularly characteristic of the Dominican holm area (sites 9-13, Fig. 2), where watercourses, wet meadows and wetlands were located next to more mineral substrates (Możejko et al. 2006). The diversity of habitats

in this area as late as in the 12th and 13th centuries was reflected in the composition of fossil material, where the remains of aquatic and wetland organisms were combined with diaspores of plants growing on dry and sandy grasslands (*Hypericum perforatum, Rumex acetosella, Calluna vulgaris, Arenaria serpyllifolia, Jasione montana*). The town ongoing expansion caused a reduction in substrate moisture as a result of land levelling and the regulation of water network. On some sites in the Main Town (Grząska St., Powroźnicza St., no. 17, 19) and Granary Island (Żytnia St., Pszenna St., no. 21, 22), a significant decrease in the proportion of aquatic and wetland remains was recorded only in the 14th and 15th centuries, which correlates with the historical and archaeological data on their late settlement.

Palynological data from the 12th-14th centuries illustrate the spread of meadows and pastures in the landscape of Gdańsk. Spectra from many sites dated to this period are characterized by a high proportion of pollen from Poaceae, *Plantago lanceolata* and *P. media,* correlated with accumulations of *Prunella vulgaris, Lychnis flos-cuculi, Lythrum salicaria, Ranunculus repens, Trifolium repens, T. pratense* and *Carex flacca* macrofossils. Palaeoecological materials provide data that verify the historical sources (Samól 2018), suggesting that grazing lands occupied significant areas on the periphery of the developing urban center, including the Young Town area (data from site 24). Fresh and wet meadows were also an important element of the landscape of Granary Island, which is confirmed by palaeobotanical materials from this part of the town. The accumulation of meadow plant remains in the sediments was also associated with the spores of coprophilous fungi (*Sordaria, Sporormiella, Podospora, Cercophora*), which document the presence of animal faeces and grazing areas in the southern part of the island as late as in the 15th century (Fig. 2A).

The gradual expansion of settlements in subsequent districts is confirmed by the change in the composition of pollen spectra, which is reflected in the predominance of herbaceous pollen over tree pollen, including the increasing proportion of plants (e.g., cereals) used by the inhabitants, field weeds (*Agrostemma githago*, *Centaurea cyanus*, *Convolvulus arvensis*) and ruderal plants (*Artemisia*, Chenopodiaceae, *Urtica*). Their richness is also characterized by the macrofossil materials, where regular and abundant *A. githago*, *Fallopia convolvulus*, *Mentha arvensis*, *Rumex acetosella*, *Stellaria media* or *Polygonum lapathifolium* can be found. The comparison of data from many sites demonstrates a very individual character of local environmental transformations resulting, among others, from differences in the time of their settlement. In the areas that were settled earliest, e.g., in the vicinity of Zamczysko or the Dominican Centre in the Main Town, the proportion of field weeds and weeds typical of ruderal habitats increased as early as in the 11th-12th century, whereas in the areas that were developed late, e.g., on Granary Island, it increased only in the 14th and 15th centuries (Fig. 2).

Therefore, an important result of palaeoecological research involves providing the data supporting the statements of archaeologists and historians as to the time of settlement of the oldest districts of the town (Paner 2015; Śliwiński, Możejko 2017) and the clear delay of medieval settlement development in Gdańsk in relation to the neighbouring areas (Łosiński 1982; Śliwiński 2009). *The topics are presented in the work no. 2, 3, 4 and 5.*

Development of anthropogenic flora and vegetation in the area of Gdańsk

The development of anthropogenic flora and vegetation in the Gdańsk area resulted from the changes that occurred in the local ecosystems under the influence of settlement and climate change. On the one hand, the area occupied by natural ecosystems gradually reduced; on the other, the progressive development and eutrophication of habitats favoured the expansion of plants that prefer nitrogen-rich and trampled grounds, and the increasing transport of crops to the port and town enriched the composition of anthropogenic vegetation. The botanical material from 24 sites from the 10/11th to the 15th century allowed to select the list of species characteristic of anthropogenic habitats, of which 31 belong to the cereal and flax weeds, and 99 to the group of weeds of root crops, gardens and ruderal habitats. In the material from Gdańsk, archaeophytes dominate among the segetal weeds, whereas apophytes slightly predominate in the second group. The diversity of segetal weeds in the materials increases only between the 12th and 14th century, which should be associated with the intensification of settlement and increasing demand for cereal products, which were brought to the city by transport and trade. Species diversity in the group of weeds of root crops, gardens and ruderal habitats gradually increases until the 12th and 13th centuries, reflecting the expansion of ruderal vegetation in the town, but also the higher significance of crops grown in local gardens. The comparison of the representation of weed remains of root crops, gardens and ruderal habitats in the materials from different districts of Gdańsk indicates that the dominant group among them referred to apophytes originating from fertile and wet riverside habitats, which occurred in many parts of the city in the early periods of its development. In intensively built-up areas, *Chenopodium album*, *Stellaria media* or *Polygonum lapathifolium* spread. On sites located in close vicinity of watercourses an important element of local vegetation included species forming nitrophilous tall herb vegetation, e.g., *Bidens cernua, Galium aparine* and *Polygonum persicaria*, whose high proportion was recorded in materials dated to the 14th and 15th centuries. The moist ground and the increase of nutrients in the town provided favourable conditions for the expansion of species growing originally only on floodplain grasslands, e.g., *Ranunculus repens*, *Potentilla anserina* and *Carex hirta*. An important element of ruderal communities and garden weeds throughout the period of town development included *Urtica dioica,* as well as *Solanum nigrum, Polygonum aviculare* and *Plantago major* growing on trampled places. The comparison of weed representation in the materials from the studied districts of Gdańsk shows that their proportion was clearly diminishing in the 14th and 15th centuries. It can be assumed that this was the result of changes in the spatial structure of the city and a higher density of buildings that limited the habitats for the development of anthropogenic vegetation.

A significant result of palaeoecological research involves the confirmation of the relationship between the dynamic expansion of anthropogenic flora and the development of settlement in the 11th and 13th centuries, as well as between the proportion of weeds and the time and pace of settlement development in particular districts. *The topics are presented in the work no. 4 and 5.*

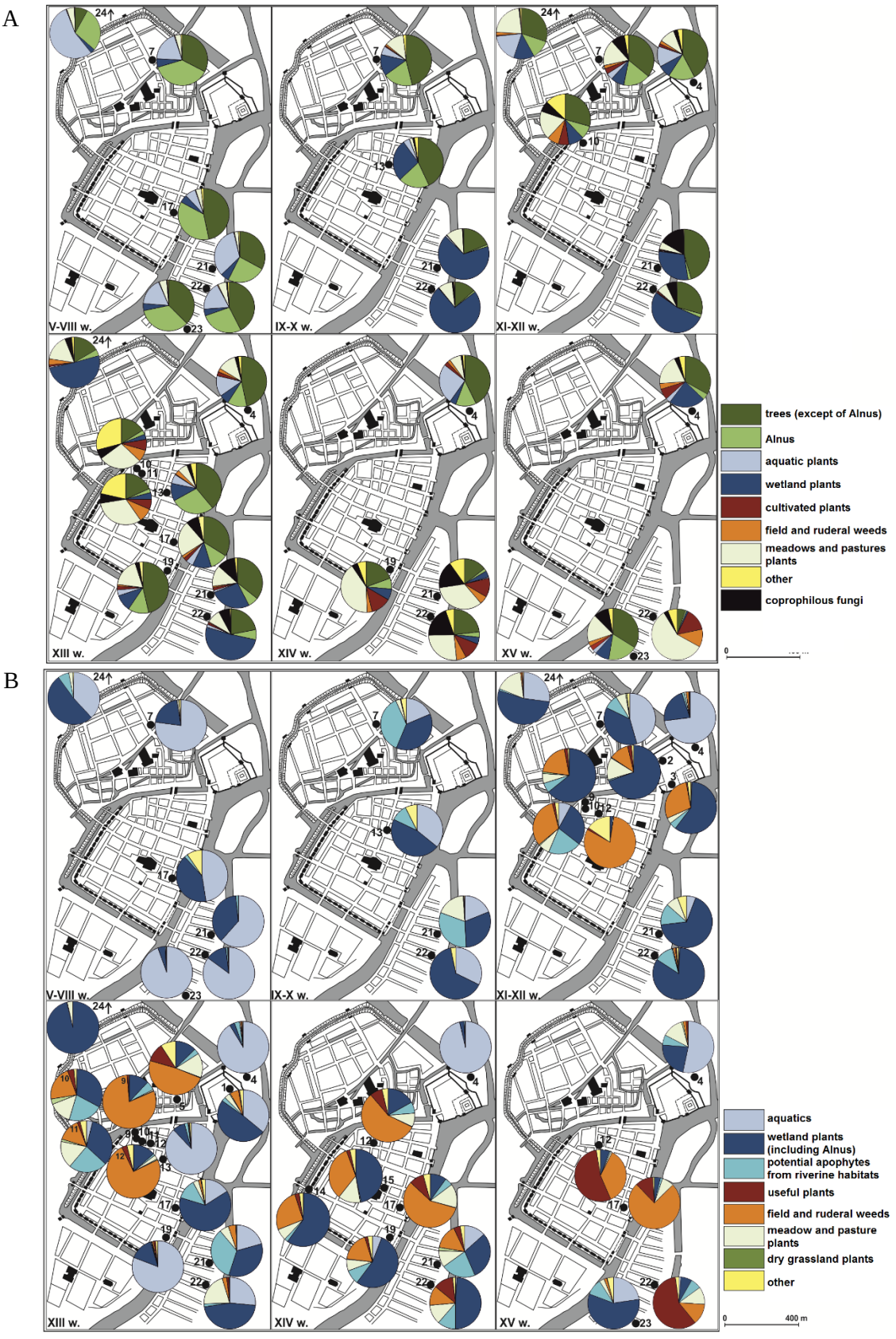


Fig. 2. Percentage proportions of pollen (A) and macrofossils (B) of taxa representing selected environments and useful plants on sites located in the oldest districts of Gdańsk in consecutive periods from the 5th to the 15th century (site numbers as in Fig. 1)

The characteristics of ecological conditions

The composition of fossil remains (pollen, seeds, fruits) in the material from Gdańsk allows the reconstruction of local ecosystem transformations and provides information on the diversity of habitat conditions in the studied area. The repeatable combination of plant and NPP remains found at many sites, gives the possibility to enhance the natural history of the town with an element connected with the reconstruction of ecological conditions, taking into account the spatial and temporal variability. Bioindicator values of organisms recorded in the fossil material are the key to palaeoenvironmental reconstructions, enabling the reconstruction of trophic, oxygenation and moisture conditions of habitats, as well as the changes in ecosystems under the influence of human activity (e.g., Jankovská, Komárek 2000; van Geel 2001; Sadori et al. 2010; Bosi et al. 2011). In the case of Gdańsk, complementary data in this scope are provided by the results of geochemical analyses of sediments.

During the 5^{th} to 8^{th} century, water bodies were present in many parts of the study area. The composition of the remains of organisms that occur in the limnic sediments indicates the meso/eutrophic character of the waters, which were colonized, among others by *Potamogeton perfoliatus, Salvinia natans, Stratiotes aloides, Nymphaea alba, Nuphar lutea, Alisma plantago-aquatica,* and favoured periodically the bloom of green algae, mainly of the *Pediastrum* genus and cyanobacteria of the *Gloeotrichia* genus. The geochemical data illustrate a gradual change in ecological conditions in the basins, associated with the increasing trophic status (higher Fe/Ca ratio) and temporary decreases in water oxygenation (high Fe/Mn ratio). They seem to have been related, among others, to the expansion of *Salvinia natans* in local ecosystems during the 7^{th}-8^{th} centuries, during the early period of the Medieval Climatic Anomaly. The influence of *Salvinia* on the changing ecological conditions is demonstrated, among others, by the correlation between an increase in the proportion of its microspores and megaspores in the sediments and a decrease in the abundance of aquatic fauna remains (*Daphnia* sp., Ostracoda, *Cristatella mucedo, Piscicola geometra*), which must have responded negatively to lower water oxygenation.

The decline in groundwater levels recorded in the study area during the 9^{th}-10^{th} centuries resulted in the spread of open wetland vegetation and the accumulation of herbaceous peats in the future town. Their occurrence at many sites, immediately on the limnic sediments, indicates the processes of the basins gradual shallowing. Geochemical data confirm that a decrease in trophic levels and improvement of oxygen conditions in local ecosystems (decrease in Fe/Mn ratio) occurred during this time. The huge spatial extent of wetland habitats was a major impediment to the early development of the city. The obtained results provide arguments supporting the need for the inhabitants of Gdańsk to create thicker levelling layers and insulation layers built up of reeds and chopped wood fragments in order to stabilize the ground and protect buildings from high groundwater levels (Maciakowska 2011). They also support archaeological investigations showing that most of the town houses were built upon large wooden piles, mostly of oak, driven into the ground, which stabilized and insulated the buildings (Paner 2001; Krzywdziński 2009). The comparison of palaeoecological data from various parts of the town indicated that changes in the moisture content of habitats in the Gdańsk area were not synchronous and had to be associated with gradual development and regulation of the existing water network. This is evidenced by the

presence of wetland habitats in the urban space even in the 12th-13th centuries and the very late settlement of some areas (e.g., Grząska St. in the Main Town, site no. 17, and Wałowa St. near Zamczysko, site no. 4) which, due to their close proximity to watercourses, were characterized by the most unfavourable conditions for development.

The ecological conditions in the medieval town were formed by various human activities. Food processing and storage, waste removal, animal husbandry and transport resulted in nitrogen and phosphorus enrichment of habitats, as confirmed by geochemical analyses of sediments. An increase in the supply of nutrients to the local water network resulted in an abundant development of eutrophic herbaceous vegetation with *Conium maculatum*, *Chenopodium hybridum*, *Bidens cernua*, *Urtica dioica*, *Galium aparine*. Their remains have been recorded in large numbers at many sites, including the Dominican holm, where a tannery operated in the 12th century (Gołembnik 2008), certainly supplying waste to the watercourse flowing through the area. Significant phosphorus and nitrogen pollution of habitats in Gdańsk since the 13th century may also have resulted from the lack or primitive system of sanitary facilities. High phosphorus content at archaeological sites has been linked to the accumulation of human and animal faeces (Mercuri et al. 2010; Cook et al. 2014). Moreover, in the case of Gdańsk it can be assumed that the accumulation of animal faeces, presence of which at the sites is confirmed by numerous remains of coprophilous fungi (*Sordaria*, *Sporormiella*, *Chaetomium*), was at least partly responsible for the phosphorus increase in the cultural layers. Poor sanitary conditions in the town, and at the same time, the health of people and some animals, are also illustrated by the regular presence of eggs of the intestinal parasites *Trichuris* and *Ascaris* in materials dated from the 11th century onwards.

The geochemical analyses of sediments from the Gdańsk sites also demonstrated a significant increase in heavy metal contamination of the local environment from the early 13th century onwards. The increasing content of copper, zinc, and lead in the cultural layers perfectly reflects the increase in local metalworking and processing, as well as the development of crafts in the city, which, according to archaeological data, intensified in the 14th century (Zbierski 1978b; Biskup 1978).

The result of complex analysis of sediments from urban sites in Gdańsk describes the changes in environmental conditions between the 5th and 15th centuries against the background of the increasing impact of human activity. *The topics are presented in the work no. 1, 2, 3 and 4.*

The bioindicator value of plants in reconstructing the climatic conditions in medieval Gdańsk

Analysis of plant macroremains, which allows to identify fossil material to the species level, provides direct data for the reconstruction of flora and vegetation composition. At the same time, it allows the use of ecological preferences of organisms in terms of trophy, humidity of the ground, pH, to reconstruct a specific combination of abiotic factors that determined the development of plant communities in the past. Taking into account the bioindicatory values of plants, among many taxa recorded in the material from the Gdańsk sites, noteworthy is the presence of species with higher thermal requirements. Among them there are the aquatic plants, *Salvinia natans* and *Stratiotes aloides*, which occurred in the

shallow, eutrophic waters of oxbow lakes or slow-flowing watercourses along with other macrophytes, especially in the period before the settlements' development. Megaspores and microspores of *Salvinia* have been recorded in various districts of Gdańsk in the sediments dating from the 5th to the 16th century, but their high proportion distinguishes materials from the 7th and 8th century, the period of a significant climate warming in the southern Baltic region (Seppä, Poska 2004). In some sites, they were associated with numerous leaf spines of *S. aloides*, and sometimes also with fruits, which are very rare in the fossil material due to the species' greater preference for vegetative reproduction. The presence of these species in palaeoecological materials correlates with the data indicating climate warming during the Medieval Climatic Anomaly (Helama et al. 2009; Büntgen et al. 2011). Therefore, they were used to reconstruct the conditions in the study area. The results suggest that their expansion in the early Middle Ages was stimulated by the climate warming of the time, which was manifested by an increase in temperatures and an extension of the growing season. The study area must have had mild winters with average temperatures around 0^0C, as frost limits the survival of *Salvinia* megaspores, and relatively warm springs with water temperatures around 12^0C, allowing them to germinate (Szmeja et al. 2016). The high-water temperatures necessary for male flower production (Snyder et al. 2016; Efremov et al. 2019) were also a factor in *Stratiotes* generative reproduction. The decrease in the population of both species, followed by their disappearance from the material from Gdańsk, may be associated not only with the regulation of water network during the town expansion, but also with their reaction to lower temperatures during the Little Ice Age (Mann 2002).

The group of climate bioindicators may include some of the weed species, mainly from ruderal habitats, which have spread in Gdańsk along with the development of settlements. Extremely favourable climatic conditions, including increased temperatures, milder winters, and less precipitation, favoured the expansion of thermophilous archaeophytes mainly of Mediterranean (*Conium maculatum, Nepeta cataria, Cichorium intybus*) and Irano-Turanian origin (*Descurainia sophia*, *Hyoscyamus niger*) (Zając 1979). Their highest occurrence in Gdańsk can be found in materials dated to the 12th and 13th century. Species from the group of relatively thermophilous apophytes, remains of which found in large numbers in the materials from the 11th century, can also be considered indicators of thermal conditions. Among them there are species that prefer dry habitats, e.g., *Hypericum perforatum*, *Potentilla argentea*, *Origanum vulgare*, *Arenaria serpyllifolia* and *Leucanthemum vulgare*. The bioindicator value of the discussed weed groups in reconstructing thermal conditions in medieval Gdańsk is also confirmed by their reaction to the climate cooling at the turn of the 14th century (Büntgen et al. 2011), which resulted in a reduction of the occurrence of thermophilous species in the town flora.

The species which allows the reconstruction of changes in climatic conditions in the study area also includes *Alnus glutinosa*. The decline of alder forests on the territory of the future town, recorded in the 10th century, may have resulted from the sensitivity of this species to prolonged droughts and hydrological changes in wetland habitats. This phenomenon, as shown by studies in recent years (Stivrins et al. 2017; Attachment 4, 4.13), was not local, but widespread in its geographic range across Europe.

The result of palaeoecological research includes the documentation of the considerable influence of climatic conditions during the Medieval Climatic Anomaly on local ecosystems and their role in shaping the anthropogenic vegetation of the town. *The topics are presented in the work no. 1, 3 and 5.*

Summary and conclusions

The most important achievement of this publication series is the description of the natural history of medieval Gdańsk, taking into account the natural conditions of settlement development and ecosystem changes in time and space. The palaeoecological studies conducted in the oldest districts of the town indicate that:

1. In the period preceding the settlement development, the western edge of the Wisła delta was covered mainly with alder forests. The landscape essential element included a network of watercourses and meso/eutrophic basins forming the system of oxbow. Other conditions prevailed on small mineral elevations, which were occupied by phytocenoses of mixed deciduous forests dominated by hornbeam and oak.
2. Gdańsk was established on wetlands, and the crucial factor for making the settlement possible was the lowering of water table around the 9th and 10th centuries, as a result of prolonged droughts during the Medieval Climatic Anomaly.
3. The transformations of the natural environment in Gdańsk took place gradually, in accordance with the archaeologically and historically documented, multi-stage process of forming the medieval agglomeration. Palaeobotanical sources confirm the limited human impact on the local environment until the 11th century, the successive spread of settlement in the 12th-13th centuries, and further expansion of urban space in the 14th-15th centuries.
4. In the initially periods of the city's development, the dispersed settlement and the different rate of land development favoured the occurrence of diverse vegetation composed of semi-natural and anthropogenic plant communities. Until the 13th century, patches of alder scrub were scattered in the study area, and patches of fresh and wet meadows were an important element of the landscape.
5. Reduction of wetland took place gradually and was associated with the construction of insulation and levelling layers that separate natural and cultural layers at many of the studied sites.
6. Human activity resulted in changes of ecological conditions. Habitat enrichment in nitrogen and phosphorus was the consequence of the increasing anthropogenic pressure and caused the development of rich nitrophilous vegetation. The ruderal weed communities with a significant dominance of moist species from nutrient-rich and wet riverine habitats spread in Gdańsk.
7. Climatic conditions, particularly high temperatures, were also a factor affecting the composition of vegetation in the medieval town, which favoured the expansion of relatively thermophilous weed species during the 11th-13th centuries.

The scientific achievement measurable effect involves confirming the historians' and archaeologists' conceptions about the time of settlement of the town oldest districts and providing arguments for the discussion on the influence of natural conditions on the time of settlement in Gdańsk. Moreover, the evidence of limnic sediments on many sites proves the existence of an extensive hydrological network in the studied area, the layout of which in the Middle Ages has not been recognized until now and this issue requires further research.

The presented achievement also justifies the need to undertake comprehensive analyses of sediments from archaeological sites, which may be helpful in planning other interdisciplinary, archaeological-environmental studies. The results from the network of sites presented here, that complement each other, demonstrate that this approach to research makes it possible not only to expand the range of organism groups identified in the fossil material, but also to provide a wide range of tools for more precise environmental reconstruction.

References

Alsleben A. 2007. Food consumption in the Hanseatic towns of Germany. W: S. Karg (red.) Medieval food traditions in Northern Europe. PNM Studiem in Archaeology & History. National Museum, Copenhagen, 13-37.

Bandini Mazzanti M., Bosi G., Mercuri A.M., Accorsi C.A., Guarnieri C. 2005. Plant use in a city in Northern Italy during the late Mediaeval and Renaissance periods: results of the archaeobotanical investigation of "The Mirror Pit" (14th–15th century a.d.) in Ferrara. Vegetation History and Archaeobotany 14: 442–452.

Beneš J., Kaštowský J., Kočárová R., Kočar P., Kubečková K., Pokorný P., Starec P. 2002. Archeobotany of the Old Prague Town defence system, Czech Republic: archaeology, macro-remains, pollen, and diatoms. Vegetation History and Archaeobotany 11: 107-119.

Bertacchi A., Lombardi T., Sani A., Tomei P.E. 2008. Plant macroremains from the Roman harbour of Pisa (Italy). Environmental Archaeology 13(2): 181-188.

Biskup M. 1978. Rozwój produkcji rzemieślniczej. W: E. Cieślak (red). Historia Gdańska 1 do roku 1454. Wydawnictwo Morskie, Gdańsk, 417-427.

Bosi G., Bandini Mazzanti M., Florenzano A. i in. 2011. Seeds/fruits, pollen and parasite remains as evidence of site function: Piazza Garibaldi – Parma (N Italy) in Roman and Mediaeval times. Journal of Archaeological Science 38: 1621-1633.

Bronk Ramsey C. 2017. Methods for Summarizing Radiocarbon Datasets. Radiocarbon 59(2): 1809-1833.

Büntgen U., Tegel W., Nicolussi K., McCormick M., Frank D., Trouet V., Kaplan J.O., Herzig F., Heussner K.-U., Wanner H., Luterbacher J., Esper J. 2011. 2500 years of European climate variability and human susceptibility. Science 331(6017): 578-582.

Cook S., Clarke A., Fulford M., Voss J. 2014. Characterising the use of urban space: a geochemical case study from Calleva Atrebatum (Silchester, Hampshire, UK) Insula IX during the late first/early second century AD. Journal of Archaeological Science 50: 108-116.

Crabtree P.J., Reilly E., Wouters B., Devos Y., Bellens T., Schryvers A. 2017. Environmental evidence from early urban Antwerp: New data from archaeology, micromorphology, macrofauna and insect remains. Quaternary International 460: 108-123.

Devos Y. 2018. Near total and inorganic phosphorus concentrations as a proxy for identifying ancient activities in urban contexts: The example of dark earth in Brussels, Belgium. Geoarchaeology 33(4): 470-485.

Efremov A.N., Sviridenko B.F., Toma C., Mesterhazy A., Murashko Y.A. 2019. Ecology of *Stratiotes aloides* L. (Hydrocharitaceae) in Eurasia. Flora 253: 116-126.

Gołembnik A. 2008. Miejsce i rola własności dominikanów w procesie rozwoju przestrzennego Gdańska - podstawowe problemy badawcze. W: A. Buko, W. Duczko (red.). Przez granice czasu, Księga Jubileuszowa poświęcona Profesorowi Jerzemu Gąssowskiemu, Pułtusk, 299-313.

Hall A.R., Huntley J.P. 2007. A review of the evidence for macrofossil plant remains from archaeological deposits from northern England. Environmental Studies Report. Research Department Report Series no. 87-2007, English Haritage.

Helama S., Merilainen J., Tuomenvirta H. 2009. Multicentennial megadrought in northern Europe coincided with a global El Nino-Southern oscillation drought pattern during the Medieval Climate Anomaly. Geology 37: 175–178.

Jażdżewski K. 1955. Charakterystyka wczesnośredniowiecznych warstw kulturowych w wykopie głównym na stanowisku 1 w Gdańsku. Studia Wczesnośredniowieczne 3: 164-211.
Jażdżewski K. 1958. Gdańsk 10-13 w. na tle Pomorza wczesnośredniowiecznego. W: G. Labuda (red.). Pomorze Średniowieczne, Warszawa, 73-120.
Jankovská V., Komárek J. 2000. Indicative value of Pediastrum and other coccal green algae in palaeoecology. Folia Geobotanica 35: 59-82.
Kościński B., Paner H. 2005. Nowe wyniki datowania grodu gdańskiego - stanowisko 1 (wyk. I-V). W: M. Fudziński, H. Paner (red.). XIV Sesja Pomorzoznawcza, Vol. 2, Od wczesnego średniowiecza do czasów nowożytnych, Gdańsk, 11-47.
Łosiński W. 1982. Osadnictwo plemienne Pomorza (VI-X wiek). Wrocław.
Koszałka J. 2005. Badania archeobotaniczne zespołu grodowego na Ostrowie Tumskim w Poznaniu – historia i najnowsze wyniki. Botanical Giudebooks 28: 173-194. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.
Kozáková R., Pokorný P. 2007. Dynamics of the biotopes at the edge of a medieval town: pollen analysis of Vltava river sediments in Prague, Czech Republic. Preslia 79: 259-281.
Kozáková R., Pokorný P., Havrda J., Jankovská V. 2009. The potential of pollen analyses from urban deposits: multivariate statistical analysis of a data set from the medieval city of Prague, Czech Republic. Vegetation History and Archaeobotany 18: 477-488.
Krzywdziński R. 2009. Stan badań nad budownictwem drewnianym Głównego Miasta Gdańska w XIV wieku. W: H. Paner, M. Fudziński, Z. Borcowski (red). Stan badań archeologicznych miast w Polsce. Muzeum Archeologiczne, Gdańsk, 215–243.
Latałowa M. 1999. Palaeoecological reconstruction of the environmental conditions and economy in early medieval Wolin – against a background of the Holocene history of the landscape. Acta Palaeobotanica 39(2): 183-271.
Latałowa M., Badura M., Jarosińska J. 2003. Archaeobotanical samples from non-specific urban contexts as a tool for reconstructing environmental conditions (examples from Elbląg and Kołobrzeg, northern Poland). Vegetation History and Archaeobotany 12: 93-104.
Lipiński J., Lorens P. 2016. Młode Miasto Gdańsk. Monoplan, Warszawa.
Maciakowska Z. 2011. Kształtowanie się przestrzeni miejskiej Głównego Miasta w Gdańsku do początku XV wieku, Gdańsk.
Mann M.E. 2002. Little Ice Age. W: M.C. MacCracken, J.S. Perry (red.). Encyclopedia of Global Environmental Change. John Wiley & Sons, Chichester, 504-509.
Mariotti Lippi M., Bellini C., Mori Secci M., Gonnelli T. 2009. Comparing seeds/fruits and pollen from a Middle Bronze Age pit in Florence (Italy). Journal of Archaeological Science 36: 1135–1141.
Märkle T. 2005. Nutrition, aspects of land use and environment in medieval times in southern Germany: plant macro-remain analysis from latrines (late 11th–13th century A.D.) at the town of Überlingen, Lake Constance. Vegetation History and Archaeobotany 14(4): 427-441.
Mercuri, A.M., Florenzano, A., Massamba N'siala, I., Olmi, L., Roubis, D., Sogliano, F. 2010. Pollen from archaeological layers and cultural landscape reconstruction: case studies from the Bradano Valley (Basilicata, southern Italy). Plant Biosystems 144 (4): 888-901.
Możejko B., Śliwiński B., Kaczor D. 2006. Zarys dziejów klasztoru dominikańskiego w Gdańsku od średniowiecza do czasów nowożytnych (1226/1227-1835). Archeologia Gdańska 1: 137-215.
Mueller-Bieniek A. 2012. Rośliny w życiu codziennym mieszkańców średniowiecznego Krakowa. Instytut Botaniki im. W. Szafera, Polska Akademia Nauk, Kraków.
Okuniewska-Nowaczyk I. 2005. Analiza pyłkowa osadów z Ostrowa Tumskiego w Poznaniu – doniesienie wstępne. Botanical Guidebooks 28: 165-172.
Paner H. 2001. 10th- to 17th-century domestic architecture in Gdańsk. W: D. Hausbau (red.). Lubecker Kolloquium zur Stadtarchaologie im Hanseraum 3. Glaser M. Schmidt-Romhild, Lubeck, 491-509.
Paner H. 2015. Rozwój przestrzenny wczesnośredniowiecznego Gdańska w świetle źródeł archeologicznych. Archaeologica Historica Polona 23: 139-161.
Pokorná A., Houfková P., Novák J., Bešta T., Kovačiková L., Nováková K., Zavřel J., Starec P. 2014. The oldest Czech fishpond discovered? An interdisciplinary approach to reconstruction of local vegetation in mediaeval Prague suburbs. Hydrobiologia 730: 191-213.
Reimer P., Austin W., Bard E. i in. 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0-55 cal kBP). Radiocarbon 62(4): 725-757.
Sadori L., Giardini M., Giraudi C., Mazzini I. 2010a. The plant landscape of the imperial harbour of Rome. Journal of Archaeological Science 37: 3294-3305.
Sadori L., Mercuri A.M., Mariotti M. 2010b. Reconstructing past cultural landscape and human impact using pollen and plant macroremains. Plant Biosystems 144 (4): 940-951.

Samól P. 2018. Młode Miasto Gdańsk (1380-1455) i jego patrymonium. Gdańsk.
Seppä H., Poska A. 2004. Holocene annual mean temperature changes in Estonia and their relationship to solar insolation and atmospheric circulation patterns. Quaternary Research 61: 22-31
Snyder E., Francis A., Darbyshire S. 2016. Biology of invasive alien plants in Canada. 13. *Stratiotes aloides* L. Canadian Journal of Plant Science 96: 225-242.
Sokołowski T., Wacnik A., Wardas M., Pawlikowski M., Pazdur A., Madeja J., Woronko B., Madej P. 2008. Changes of natural environment in Kraków downtown – its chronology and directions. Case geoarchaeological studies of Krupnicza Street site. Geochronometria 31: 7-19.
Stančikaitė M.' Kisielienė D., Mažeika J., Blaževičius P. 2008. Environmental conditions and human interference during the 6th and 13th–15th centuries A.D. at Vilnius Lower Castle, east Lithuania. Vegetation History and Archaeobotany 17: 239-250
Stivrins N, Buchan M.S., Disbrey H.R., Kuosmanen N., Latałowa M., Lempinen J., Muukkonen P., Słowiński M., Veski S. 2017. Widespread, episodic decline of alder (*Alnus*) during the medieval period in the boreal forest of Europe. Journal of Quaternary Science 32: 903–907.
Szmeja J., Gałka-Kozak A., Styszyńska A., Marsz A. 2016. Early spring warming as one of the factors responsible for expansion of aquatic fern *Salvinia natans* (L.) All. in the Vistula Delta (south Baltic Sea coast). Plant Biosystems 150(3): 532-539.
Śliwiński B. 2009. Początki Gdańska: dzieje ziem nad zachodnim brzegiem Zatoki Gdańskiej w I połowie X w. Gdańsk.
Śliwiński B., Możejko B. 2017. The political history of Gdańsk from the town beginnings to the sixteenth century. W: B. Możejko (red.). New studies in medieval and renaissance Poland and Prussia, London-New York, 17-46.
van Geel B. 2001 Non-pollen palynomorphs. W: J.P. Smol, H.J.B. Birks, W.M. Last (red.). Tracking environmental change using lake sediments terrestrial algal and siliceous indicators, vol 3. Kluwer, Dordrecht, 99-120.
Wasylikowa K. 1991. Roślinność Wzgórza Wawelskiego we wczesnym i późnym średniowieczu na podstawie badań paleobotanicznych. Studia do Dziejów Wawelu 5: 93-131.
Wasylikowa K., Wacnik A., Mueller-Bieniek A. 2009. Badania archeobotaniczne w nawarstwieniach historycznych z terenu Krakowa: metodyka-stan badań-perspektywy. Geologia 35(1): 89-101.
Wieserowa A. 1979. Plant remains from the early and late middle ages found in the settlement layers of the main market square in Cracow. Acta Palaeobotanica 20(2): 137-212.
Woolgar C.M., Serjeanston D., Waldron T. 2006. Food in medieval England. Diet and nutrition. Oxford University Press.
Vrydaghs L., Devos Y., Charruadas P., Scott Cummings L., Degraeve A. 2015. Agricultural Activities in the 10th–13th Century CE in Brussels (Belgium): An Interdisciplinary Approach. W: F. Retamero, I. Schjellerup, A. Davies (red.). Agricultural and pastoral landscapes in pre-industrial society: choices, stability and change. Oxbow Books, Earth Series 3: 221-236.
Zając A. 1979. Origin of archaeophytes occurring in Poland. Dissertation, Jagiellonian University, Kraków.
Zbierski A. 1978a. Rozwój przestrzenny Gdańska w IX–XIII wieku. W: E. Cieślak (red.). Historia Gdańska, t. 1: do roku 1454, Gdańsk, 71-125.
Zbierski A. 1978b. Wytwórczość rzemieślnicza. W: E. Cieślak (red.). Historia Gdańska, t. 1: do roku 1454, Gdańsk, 126-172.

5. Presentation of significant scientific activity carried out at more than one university, scientific institution, especially at foreign institutions

My scientific activity outside my home institution was connected with the cooperation in scientific projects and the need to improve my skills as a palynologist, to the extent that failed to be provided by the rich reference palynological collection of the Gdańsk University Laboratory of Palaeoecology and Archaeobotany (PRefSColl-UGDA).

In 2002, during the international conference Pollen Monitoring Programme 4th Meeting, where I presented some of the results of my PhD thesis, I met for the first time with a group of scientists conducting research on modern pollen deposition in Europe, also with Irena Pidek, PhD, DSc, ProfTit from Maria Curie-Skłodowska University in Lublin. The conference resulted in a decision to join the *Pollen Monitoring Programme* (a project within

the Commission on Palaeoecology and Human Evolution INQUA) and starting research on 8 sites in the Gdańsk Upland and the Kashubian Lake District (observations carried out since 2004 together with Marcelina Zimny, PhD). In 2007, I started cooperation with I. Pidek, PhD, DSc, ProfTit by joining as a contractor, the project of the Ministry of Science and Higher Education managed by I. Pidek, PhD, DSc, ProfTit between 2007 and 2010 (Attachment 4; 9.12); the project also involved A. Noryśkiewicz, PhD, DSc and A. Filbrandt-Czaja, PhD, DSc from the Nicolaus Copernicus University in Toruń, who were engaged in monitoring pollen deposition in other parts of Poland. During the project, I participated in an off-site workshop for contractors led by Anneli Poska, PhD from the University of Tartu (Estonia) for field training on vegetation mapping methods in the area of PMP sites. The cooperation with I. Pidek, PhD, DSc, ProfTit and other participants of the project resulted in the determination of relationships between the composition and structure of vegetation and the modern pollen deposition in selected communities in Roztocze, Brodnica and Kashubian Lake District, Bory Tucholskie and Gdańsk Upland. The results we obtained were published (Attachment 4; 4.7) with the data from other European sites thanks to the PMP collaboration. After the completion of the project of the Ministry of Science and Higher Education, I continued cooperation with I. Pidek, PhD, DSc, ProfTit, thanks to which in 2011 I took part in a personal exchange under the agreement on scientific cooperation between Poland and Estonian Academy of Sciences. My stay at the Institute of Ecology and Earth Sciences (University of Tartu) was connected with implementing the project *Pollen dispersal and deposition of the main European trees*. The stay aimed to work with the pollen database from Tauber traps (part of the results was collected in the Gdańsk University Laboratory of Palaeoecology and Archaeobotany), preliminary estimation of pollen productivity coefficients for several forest-forming species, and work on modelling pollen deposition-plant-landscape relationships.

At the end of my PhD studies (2004), I contacted Marie-José Gaillard-Lemdahl, PhD, Prof. from the Department of Biology and Environmental Sciences (University of Kalmar, Sweden). The impulse for the contact arose from the need to consult the results of some part of my PhD research with a specialist who deals with the reconstructions of climate and vegetation changes and their modelling based on the palynological data. The stay in Sweden enabled me to present analysis of aerial photographs and historical maps in terms of forest cover changes in the catchment areas of the lakes I studied. It was also an opportunity to discuss the results concerning the relationship between the qualitative and quantitative composition of surface spectra from lakes and the type of management of their catchments. During my stay I also attended a training on landscape modelling based on the palynological data with Anna Broström, PhD from the University of Lund. I used the acquired experience while writing my PhD dissertation and preparing a publication on the palynological surface spectra (Attachment 4; 4.18). Contacts with M.-J. Gaillard-Lemdahl, PhD, Prof. and A. Broström, PhD helped me to attend further trainings and workshops on quantitative vegetation reconstructions, including:

- POLLANDCAL training course in 2005 in Umeå University, Sweden (training on modelling landscape changes based on palynological data and vegetation composition, including the collection of materials for estimation of pollen productivity of taxa and relevant source area of pollen)

- NordForsk-Landclim workshop in 2010 in Department of Earth & Ecosystem Sciences, Lund University, Sweden (workshop on the methods for landscape reconstruction and climate change based on palynological data, LPJ-Guess software training)
- European Pollen Database meeting in 2016 in Science Faculty of the University of Aix-en-Provence, France (training in quantitative vegetation reconstructions using Landscape Reconstruction Algorithm)

The participation in trainings and workshops has improved my skills in interpreting the composition of fossil pollen spectra by learning about differences in pollen productivity and also in the selection of appropriate basins for palaeoecological studies, thanks to the knowledge of differences in the size of relevant source area of pollen. Regular meetings with a group of European palynologists during trainings and workshops resulted in a cooperation focused on creating a free database of modern pollen data (*The Eurasian Modern Pollen Database (EMPD) project*). The work coordinated by Basil Davis, PhD from the University of Lausanne resulted in publications that have appeared in reputable journals from the JCR list (Attachment 4; 4.10, 4.15).

Thanks to my visits to foreign institutions, I had an opportunity to participate in training courses that allowed me to improve my skills in fossil materials determination. During my PhD studies, I attended a course at Queen Mary University of London on the identification of fungal spores, including coprophilous fungi, conducted by James Innes, PhD and Jeffrey Blackford, PhD, which I used in the analysis of materials from archaeological sites in Gdańsk. Participating in a training course on the identification of non-pollen palynomorphs in 2012 at the Institute of Biodiversity and Ecosystem Dynamics (University of Amsterdam) not only enriched my palynologist's skill. This visit gave me the opportunity to verify some of the determinations in the materials from Gdańsk, thanks to the consultations which I had with the participants of the training course, including Bas van Geel, PhD, Prof., the initiator of palaeoecological studies with the use of non-pollen palynomorphs. The skills I have acquired allowed me to take into account the bioindicator value of algae, fungi, and other NPPs determined in materials from the Gdańsk sites for a more complete reconstruction of the conditions that prevailed in the medieval city and in the period preceding the development of settlement, which became part of all the articles included in the presented achievement (no. 1-5).

In 2007, I participated in a scientific course at the Nicolaus Copernicus University in Toruń (*Application of numerical methods in ecology*), where I learned about the methods of environmental data transformation and possibilities of using ordination techniques. The training allowed me not only to understand the theoretical basis, but also to perform the first analyses and interpretations of my own materials. I applied the knowledge obtained during the training in subsequent work by preparing canonical analyses to illustrate the co-occurrence of taxa in palynological materials (Attachment 4; 4.9), which provides a graphical presentation of pollen analysis results other than in the form of pollen diagrams. The statistical analyses I have done are also an important part of the two papers that are part of the presented achievement (no. 1 and no. 3). They supported the interpretation of the material in terms of identifying a group of taxa co-occurring in aquatic ecosystems in medieval Gdańsk. In

additional, correlations of palaeobotanical and geochemical data of sediments enabled me to determine relationships between the occurrence of organisms and environmental conditions.

In 2017, I started a collaboration with Kamil Niedziółka, PhD from the Faculty of Historical and Social Sciences at Cardinal Stefan Wyszyński University in Warsaw (currently an employee of the Gdańsk University Institute of Archaeology). His interest in the problem of dating the stronghold in Grąbczyn in Central Pomerania and the settlement micro-region of Lake Wierzchowo inspired us to undertake archaeological and environmental research. Collaborative preparation of research plan for the site, palaeoecological research idea, field reconnaissance, and project writing, made it possible, in 2018, to obtain funding that supported material collection, preliminary dating, and preliminary pollen analysis of lake sediments (Attachment 4; 9.15). Thanks to the cooperation it was possible to reconstruct the environmental changes in the research area and to confirm the strong development of settlement since the Lusatian Culture period. We have presented results of this study at three conferences (Attachment 4; 7.68, 7.93, 7.102), and work is in progress to prepare materials for publication because of the ongoing geochemical analyses of the sediments and the need to complete radiocarbon dating.

6. Presentation of teaching and organizational achievements as well as achievements in popularization of science

Teaching achievements

I have been teaching at the University of Gdańsk since 2000, initially as a PhD student, and since 2005 as assistant professor.

I have lectured to majors in: Biology, Protection of Natural Resources in the Faculty of Biology (*Diversity of cryptogamic plants*), Environmental Protection in the Faculty of Chemistry (*Palaeoecology*), Archaeology in the Faculty of History (*Paleoecology with elements of archaeobotany)* at the full-time Bachelor's course and a lecture for Biology majors at the Master's course (*Palaeoecology*). I co-led laboratory and field exercises conducted in the above-mentioned courses in eight subjects (*Diversity of cryptogamic plants, Identification of cryptogamic plants*, *Ecology of the biosphere*, *General ecology*, *Long-term changes in the natural environment*, *Practical palaeoecology classes*, *Palaeoecology*, *Project laboratory*). I have used my experience in plant remains identification, as well as my expert qualifications in forensic palynology during classes on postgraduate studies in Forensic Biology (lecture and exercises in *Forensic Botany*) and exercises on second-cycle study courses, stationary and extramural studies in Criminology (*Scientific methods of examining traces of crime using botanical methods*). Since 2009, I have also been responsible for developing the lecture program and organizing exercises for the courses *Diversity of cryptogamic plants, Identification of cryptogamic plants* for students at the Biology and Protection of Natural Resources students. As a supervisor of Bachelor's and Master's theses, I co-organized and conducted classes within the specialization and diploma laboratories, as well as seminars on Biology, Protection of Natural Resources and Criminology. I was a mentor of 7 Master's theses, supervisor of 7 Bachelor's theses and 15 Master's theses based on pollen analysis or analysis of macroremains of materials from natural and archaeological sites, as well as analysis of modern pollen spectra used in monitoring pollen deposition or as a

potential source of information about the place and time of forensic events. Many times, I have reviewed graduate and undergraduate theses from the Faculty of Biology and the Faculty of Chemistry (17). Currently, I am an associate supervisor in the PhD thesis of Ewa Janik, M.Sc. concerning the variability of wetland ecosystems responses to climate change during the late Glacial and Holocene periods in northern Poland. Between 2006 and 2008 I was a tutor in the Department of Plant Ecology. As a member of the Program Board of the Biology course and Program Board of the Protection of Natural Resources course, I participate in improving the study plan, which affects the quality of student education. As a member of the Faculty Quality Assurance Team (since 2016), I participate in questionnaire surveys of classes in the Faculty of Biology.

I improved my teaching competences by taking part in:

1. the 2nd Didactic Conference *Academic Didactics: tradition and modernity* (2014)
2. teaching workshop led by experts in modern academic teaching from Aarhus University, Denmark, *Workshop on Peer Feedback and Rubrics* (2020)
3. webinar *Promoter Responsibilities. Theory and practice*, Science Watch Poland Foundation (2021)
4. training *Working with students with mental health problems*, as part of the project "Available UG - a comprehensive program for the elimination of barriers to education for people with disabilities" (2022)

Achievements in popularization of science

My activities in the field of promoting science and knowledge include mainly topics related to the significance of palaeoecological research on the assessment of current dynamics and future changes of the environment, as well as the natural history of Gdańsk (including popularization of the NCN project results, which I led between 2011 and 2015).

In the framework of the task *Educational programs for high school students in Pomeranian Voivodship. 2. Learn about the work of a biologist*, I performed 12 workshops (*How the natural environment of Gdańsk has changed over the past 1500 years*; *Climate and man in the study of the past environment*) for students from Gdynia, Gdańsk, Wejherowo and Słupsk visiting the University.

Within the series *Invite a scientist to school* I presented 8 lectures promoting the results of research on natural past of Gdańsk and at the same time encouraging to study at the Gdańsk University Faculty of Biology (*Natural conditions of medieval settlement in Gdańsk and the impact of town spatial development on changes in the natural environment*; *Is the past the key to the future? The record of climate and vegetation changes in the natural environment*).

I have also given lectures at the University of the Third Age (Sopot branch), Oliwa Academy of Art, League for Nature Protection (in the series *Civilization and dangers*), as well as during the event *Weekend with Archaeology*, organized by the Archaeological Museum in Gdańsk. I have presented the topics of research conducted in the Laboratory of Palaeoecology and Archaeobotany during the Baltic Science Festival (III, V, VII, VIII BFN), during the Night of Biologists (2017, 2018), as well as lectures during the Open Day of the Faculty of Biology (2014, 2017, 2018).

I also took part in the conference *The Oldest Cultural Heritage of Moryń*, in order to popularize the results of palaeoecological research obtained during the NCN project about Neolithic roundel in Nowe Objezierze, among the local community.

Organizational achievements

Prior to the award of PhD degree, I participated in organizing *the 25th Bog Excursion* (*North-west Poland, Part I: Wolin Island and Drawa National Park*), being responsible for preparing materials for field presentations.

In 2011, I participated in organizing an international conference that took place in Gdańsk (*Environmental Archaeology of Urban Sites; 7th Symposium & 4th International Conference of the Polish Association for Environmental Archaeology*). My role was to work in the organizing committee and to co-edit the conference volume. I performed the same functions when I co-organized *the 10th Environmental Archaeology Symposium/Conference of the Polish Botanical Society* held in 2016 in Poznań.

In 2017, I co-organized and led the workshop *Fundamentals of archaeobotany and palaeoecology for archaeologists*, as a part of an intercollegiate archaeology workshop organized by the Institute of Archaeology and Ethnology at the University of Gdańsk.

I was also co-organizer of events popularizing science and the Faculty of Biology, including twice the exhibition *Fossils and other plant traces as a source of knowledge about the past natural environment* during the Night of Biologists (2017, 2018), demonstration stands at the 3rd, 5th, 7th, 8th Baltic Science Festival (*What did former Gdańsk inhabitants have in their kitchen and on their table? Archaeobotany in Gdańsk*; *Climate and man in the research on the past of the environment*; *What information about changes in the natural environment in Gdańsk is provided by plant remains from archaeological sites?*).

At the Gdańsk University Faculty of Biology, I have been participating in the Divisional Quality Assurance Team since 2016. I also participate in the Program Board of the Biology course and the Program Board of the Protection of Natural Resources course.

7. Other information about professional career (apart from information set out in 1-6 above)

Description of other scientific achievements

<u>the period prior to the award of the PhD degree</u>

From the beginning, my scientific career was connected with the Department of Plant Ecology at the University of Gdańsk. I gained my first experience in working on archaeological site materials during my studies writing my Master's thesis under the supervision of Małgorzata Latałowa, PhD, DSc, ProfTit. The subject of my study involved the analysis of botanical composition of 18 samples taken from parcels of the Main Town in Gdańsk which, since the mid-15th century, belonged to the Gdańsk middle-class with shares in the cereal trade. The huge abundance of remains that I identified in samples, mostly from the latrines, enabled me to determine a rich list of taxa (176, of which 128 are species), including 54 representing useful plants. The materials analysis indicated that the diet of the inhabitants of the study site was varied, rich in plant foods and contained imported spices and exotic fruits, which indicated their wealth. The results constituted grounds for my Master's thesis,

which I completed in 2000, the Master of Science degree in Biology (Attachment 4; III.5.1), an article in an archaeological journal (Attachment 4; 4.4) and several conference presentations (Attachment 4; 7.3, 7.10, 7.12). While completing my Master's degree studies, I also became certified to teach biology at school. I use the knowledge gained during the pedagogical course while teaching students and secondary school students.

Between 2000 and 2005, I was a student of Environmental Doctoral Studies in Biology and Oceanology at the University of Gdańsk. While undertaking my doctoral studies, I decided to expand my skills in fossil materials identification. Under the mentorship of my dissertation supervisor, M. Latałowa, PhD, DSc, ProfTit, I took a palynological course in order to learn how to distinguish pollen grains, based on slides collected in the reference collection of the Laboratory of Palaeoecology and Archaeobotany (PRefSColl-UGDA). At the same time, I was developing the concept of my doctoral dissertation on *Palaeoecological reconstruction of the Late Holocene history of selected lobelia lakes in the light of changes in their catchments*. Thanks to the cooperation with Józef Szmeja, PhD, DSc, ProfTit team, who focuses on the observations of contemporary transformations of lakes, we selected six small basins for the study, diversified in terms of catchment development, water chemical characteristics and degree of eutrophication. My work was based on pollen analysis of 319 sediment samples and the analysis of macroremains in 286 sediment samples. Based on the results I reconstructed the main stages of the development of lake ecosystems over the last 4 thousand years against the background of changes in the natural environment in their catchments, especially the development of settlement and agriculture. The research indicated that in the past, the population dynamics regarding species characteristic of lobelia lakes was determined by natural environmental features, especially geological conditions of the catchment and the type and level of anthropopressure. They proved that lakes located in morainic landscapes are characterized by more favourable conditions for isoetids growth and are more resistant to eutrophication, than the lakes located on outwash plains. The study confirmed that in the analysed lakes, the contemporary abundance of isoetids does not differ from the volume of their populations, characteristic of at least the last thousand years, or is significantly higher than in the past. I also observed a positive relationship between the input of mineral material to sediment and an increase in the abundance of isoetids, which suggests that complete afforestation of the catchment and inhibition of erosion may reduce the population of these plants. Thus, based on the data I gathered, I concluded that some of the lobelia lakes probably require forms of "active protection". I conducted my PhD research with funding from the KBN: first through a low-cost project performed by an early-stage researcher, of which I was the manager (Attachment 4; 9.1), and then through the supervisor's project (Attachment 4; 9.3), where I was the main contractor. The results were included in the dissertation manuscript, in part published (Attachment 4; 2.1, 2.15) and presented at conferences (Attachment 4; 7.11, 7.23, 7.58, 7.85, 7.87).

My research at that time also focused on the possibility of using modern and historical pollen spectra to assess changes in climate, hydrological conditions, and anthropogenic transformations of vegetation in the Gdańsk area. As part of the UG-funded project managed by M. Latałowa, PhD, DSc, ProfTit (Attachment 4; 9.5), we attempted to reconstruct the environmental transformations in the town area over the last 3500 years, with particular

interest in the newest part of this history. My role in the project was to complete a pollen analysis in a profile from Lake Jasień located within the town area, recording the events over the last approximately 1500 years. I was also responsible for the pollen analysis of surface samples from two lakes, which provided reference material to estimate the spatial representativeness of the palynological material. The pollen analysis of Lake Jasień sediments indicated that its surroundings have long been transformed to the degree that can be observed today and have been intensively used for agricultural purposes. This resulted in intensified erosion processes in the catchment and increased the trophy of waters. The above data, together with palynological data from Pusty Staw (compiled in the project by M. Latałowa, PhD, DSc, ProfTit), were the first results illustrating the environmental transformations in Gdańsk, the reconstruction of which I worked on more intensively after completing my PhD thesis. These data were shared in the form of a study (Attachment 4; III5.2) with Wojciech Tylmann, PhD, DSc, ProfTit and used by him in doctoral dissertation (*Record of anthropogenic changes in modern bottom sediments of the lakes of Gdańsk*).

The continuation of research on the composition and spatial representativeness of surface samples from lakes, to interpret pollen diagrams more completely, resulted in data that became an important part of my dissertation. The analysis of the relationship between the composition of surface palynological spectra from lakes collected in transects and the characteristics of forest communities and catchment management revealed a high proportion of tree pollen irrespective of landscape. *Pinus* and *Betula* pollen were most abundant in all spectra, and the proportion of pollen from deciduous trees and herbaceous plants differed, reflecting the type of vegetation in the vicinity of the lakes. In order to interpret pollen spectra in terms of the area size they represent and to estimate changes in the lake catchment forest cover, I compared the results of pollen analysis of surface samples and historical pollen spectra with cartographic data. I calculated the proportions between the percentages of forested and non-forested areas in circles of different radii (taking into account the relationship between the site morphometry and the size of relevant source area of pollen), based on aerial photographs and 19th century topographic maps. The comparison of results showed that contemporary and historical pollen spectra from all sites are significantly loaded with regional pine pollen deposition, limiting the evaluation of catchment forest cover for periods characterized by pine dominance in communities. I concluded that a much better relationship between the vegetation composition in the catchment and pollen spectrum composition is illustrated by those levels in the diagrams where deciduous tree pollen is the major component. I presented the results of this study during my stay at the Department of Biology and Environmental Sciences (University of Kalmar, Sweden) and consulted with M.-J. Gaillard-Lemdahl, PhD, Prof., which allowed me to improve the results before sending it for printing (Attachment 4; 4.18) and presenting at conferences (Attachment 4; 7.1, 7.2, 7.88).

At the same time, I took part in investigations on *Evolution of coastal areas of the southern Baltic in the late Glacial and Holocene.* Within the framework of cooperation started by M. Latałowa, PhD, DSc, ProfTit with Ryszard K. Borówka, PhD, DSc, ProfTit from the US and Karol Rotnicki, PhD, DSc, ProfTit from UAM, I participated in interdisciplinary projects connected with the reconstruction of ecological changes and

chronology of palaeohydrological events in the area of Szczecin Lagoon (Attachment 4; 9.2) and Łeba Bar (Attachment 4; 9.4).

My task was to conduct the analysis of macroscopic remains in two cores from the eastern part of the Szczecin Lagoon, which provided additional information on the composition of local ecosystems during the Late Glacial and Holocene. Based on the correlation of the elaborated data with the results of pollen analysis, it was possible to describe the successive stages of area development: functioning of shallow mesotrophic basins and wetland ecosystems in the Alleröd and at the beginning of the Holocene; gradual increase of water level, eutrophication, development of water and rush communities until the transgression of sea waters into the Lagoon around 6.2-6.3 ths ^{14}C years BP, which caused a radical change of ecological conditions; processes of salinity decrease of the Lagoon waters, eutrophication and evolution to the present form as a result of isolation of the Lagoon from the influence of the Baltic Sea about 3-2.8 ths ^{14}C years BP. The participation in this research developed my skills in identifying the macroscopic remains from natural sites, as well as correlating different types of palaeoecological data. This collaboration resulted in my contributions to publications (Attachment 4; 2.2-2.5, 2.8, 4.1, 4.2, 4.5) and conference presentations (Attachment 4; 7.4, 7.5, 7.6, 7.13, 7.15, 7.19, 7.22, 7.42, 7.59, 7.71, 7.72).

It was a huge challenge for me to collaborate on a project concerning *environmental changes in the western part of Gardno-Łeba Bar*, where I was responsible for conducting macrofossil analysis and pollen analysis of some samples from two profiles. This was the first time, I was exposed to corroded pollen material, as well as an abundance of non-pollen palynomorphs, which provided impulses to improve my skills in identifying this type of remains. The analyses provided information on the transformation of local ecosystems in the western part of the Łeba Bar from the mid-Atlantic period to about 2 ths ^{14}C years BP, and approximate dating of the stages of hydrological change. The results indicate that: between about 7 and 6 ths ^{14}C years BP meso/eutrophic rushes and nitrophilous tall herb communities were present in the study area, and the gradual water level rise was associated with a high environmental dynamics (sandy layers in sediments, seawater inflows); ca. 6 ths ^{14}C years BP the development of wetland communities was stopped as a result of temporal influxes of saline waters, which resulted in the expansion of organisms preferring higher water and salinity levels (e.g. *Ruppia maritima*, *Operculodinium centrocarpum*); in the period of 5-4 ths ^{14}C years BP salinity decreased, trophy increased and the fresh water ecosystems reappeared; about 3.5 ths ^{14}C years BP a total reduction of salinity took place and since 3 ths ^{14}C years BP gradual lowering of water level has been recorded; development of terrestrial communities in the study area was stopped and the reservoir has been covered by sandy layer ca. 2 ths ^{14}C years BP due to the intensification of eolian processes, caused by hydrological changes and human activity. The results obtained in the project have been published (Attachment 4; 2.10) and presented at conferences (Attachment 4; 7.6, 7.9, 7.59, 7.60, 7.71).

During my PhD studies, I continued to practise the skill of identifying the archaeobotanical materials. I analysed the composition of plant and animal remains from the contents of four coffin burials dating to the 17th and 18th centuries from the Holy Trinity Basilica at the Norbertine Convent in Strzelno. Together with M. Latałowa, PhD, DSc, ProfTit I prepared a report for the Institute of Archaeology of the Nicolaus Copernicus

University (Attachment 4; III5.3) providing data on funerary practices. We have shown that plants that were part of the coffin contents had practical functions (the presence of species with conservation, odour masking or insect repelling properties). Chestnut blossoms placed in one of the coffins may have played a decorative role. A symbolic role was played by millet placed along the body of a young man and peach seeds in a child's burial. The results also provided evidence for the approximate dates of the burials explored: the presence of chestnut blossoms indicated May, and the results of pollen analysis of a sample from another burial suggested April as the probable date of death or burial of the male buried there. The integration of archaeobotanical and archaeological data made it possible to prepare this material for print (Attachment 4; 4.20) and to use the results in a subsequent publication (Attachment 4; 4.17), which compares the composition of 54 coffin pillows from Catholic and Protestant burials dating to the 17th-18th/19th centuries, collected during the study of 15 church crypts in different regions of Poland.

At that time, I contributed to the compilation of archaeobotanical data from sites in Gdańsk, elaborated by the team of our Laboratory, using, among others, data obtained in my Master's thesis. The research on the role of particular plant species in the diet and other aspects of life of the Gdańsk inhabitants made it possible to compare these results with the data from other historical centres of northern Poland from the 13th century to modern times. This work resulted in presentations at conferences (Attachment 4; 7.7, 7.14, 7.16, 7.17) and preparation of publications for printing (Attachment 4; 2.6, 2.7) in which we compared the use of different plant groups. We have shown that gardening and orcharding developed as early as in the 13th century in the towns under study, and a significant shift in the trade of plant material took place in the 15th century. These studies have confirmed that despite the consumption of an increasing number of cultivated species in the Middle Ages and modern times, plants collected from the wild still played a huge role in the diet of city inhabitants. The expanding database on the presence of useful plant remains in materials from different sites, objects, and chronological periods has enabled our team to participate in the Hanza Network Project (Attachment 4; 15.1), coordinated by Sabine Karg, PhD from the National Museum in Copenhagen. The project aimed to collect the existing archaeobotanical data from the Baltic regions in order to investigate the impact of the trading activities of the Hanseatic League on the dietary habits of the population in different regions of its influence. Particular attention was paid to the spread of new useful species in cities belonging to and directly associated with the League. In this project I participated in the preparation of compilation and elaboration of archaeobotanical data from Gdańsk, Elbląg and Kołobrzeg, which became grounds for an article as a part of a monograph published after the completion of the project (Attachment 4; 2.9), publications in Polish (Attachment 4; 2.11) and conference presentations (Attachment 4; 7.20, 7.90, 7.94). Our work resulted in a list of 94 plant species used by the inhabitants of northern Polish towns at the time of their association with the Hanseatic League, of which 45 were locally grown species and 9 were exotic.

At the end of my PhD studies, together with M. Zimny, PhD, I started studies on the modern pollen deposition in the Gdańsk Upland and the Kashubian Lake District. The monitoring conducted on 8 sites varying in the degree of afforestation and local vegetation composition allowed us to join the international project European Pollen Monitoring

Programme (Attachment 4; 15.2) in 2004. We presented the first results of our observations in 2005 during a project group meeting at a conference in Bulgaria (Attachment 4; 7.8), where we also had the opportunity to meet researchers from other European institutions, which resulted in cooperation that I continued after the Conferment of Doctoral Degree.

I was employed as a technical staff member in the Department of Plant Ecology during the final year of my doctoral study, and after completing my PhD in 2005, I was employed as an assistant professor.

Scientific activity after the conferment of the PhD degree - scientific and research achievements that are not the basis for applying for the postdoctoral degree of doctor habilitated

After my PhD defence I continued my observations of modern pollen deposition with M. Zimny, PhD. The increasing amount of data on the differences in pollen deposition and pollen seasons of the taxa forming communities on the Gdańsk Upland and Kashubian Lake District, enabled us to make an effort to correlate the data with the results of observations from the aerobiological monitoring, conducted at the same time at the measurement station in Gdańsk. We presented the results illustrating the years of intensive pollination of the most important tree species in the communities of the Gdańsk Upland and the strong correlation of data from diverse types of measurements at the next PMP group meeting (Attachment 4; 7.24). At this meeting we also presented the results of our work on defining the relationship between pollen representation in moss samples and vegetation composition (Attachment 4; 7.38), which enabled us to join in the preparation of a co-authored publication (Attachment 4; 4.8). In this publication, we compared the composition of pollen spectra from Tauber traps and moss samples from a number of sites located in different forest types in Europe. We were able to show that pollen deposition in moss samples is comparable to the average pollen deposition in the pollen trap over a period of at least 2 years, and often over much longer periods. Furthermore, we found an overrepresentation of pine, spruce, and fir pollen in moss samples with marked regional differences. In 2007, research on the representativeness of palynological surface spectra in relation to the vegetation composition was funded under a project for Young Scientists, which I received from Gdańsk University own research funds (Attachment 4; 9.7); and in subsequent years through the collaboration in a project funded by the Ministry of Science and Higher Education, managed by I. Pidek, PhD, DSc, ProfTit from UMCS in Lublin (Attachment 4; 9.12). The results obtained in the projects were presented at conferences (Attachment 4; 7.27, 7.30, 7.36, 7.43, 7.44, 7.73) and, thanks to the cooperation with researchers from other European centres, published against the background of data from other monitoring sites (Attachment 4; 4.7). The comparison of annual beech pollen deposition along the N-S transect of Europe demonstrated higher variability between measurement years at the same site than between the traps from the same year, in the same region. Our study has shown that years with high beech pollen production occur less frequently, than years with low pollen production and often correspond to years with high and low seed production. In addition, comparison of data from a network of sites showed the synchronous nature of beech flowering in Europe, including subregions of the same country, indicating a significant role of climate in pollen production and release. Continuous monitoring in the Gdańsk Upland and

Kashubian Lake District since 2004 (now 18 years of observations) and submission of data to the PMP database, also enabled me to contribute to the preparation of a publication focused on the application of modern spatial pollen data for the interpretation of fossil pollen spectra (Attachment 4; 4.16). In this work, we used monitoring data from 351 traps from Europe to conduct observations between 1981 and 2017, as well as determine the pollen accumulation values from fossil spectra. The examined dataset confirmed that with annual pollen monitoring deposition in Europe, it is possible to track changes in tree pollen productivity as a result of climate change (e.g., an increase in pine pollen in northern Scandinavia as a result of rising temperatures). The comparison of mean annual values of pollen accumulation of the most important forest-forming taxa at the continental scale confirmed the possibility of using contemporary data from the PMP database to reconstruct the vegetation composition in the Holocene.

Many years of cooperation with a group of European palynologists within the Pollen Monitoring Programme, participation in foreign workshops and trainings concerning the methods of reconstructing landscape and vegetation changes based on palynological data, gave me the opportunity to join another international project *The Eurasian Modern Pollen Database (EMPD) project* (Attachment 4; 15.3). Since 2012, I have been involved in work coordinated by B. Davis, PhD of the University of Lausanne aimed to collect as much modern pollen data as possible (from Tauber traps, moss samples, surface samples from lakes, peat bogs) in a free, open-access database, operating as part of the European Pollen Database. This database is also part of the Neotoma database, the main repository of global palaeoecological data. This cooperation resulted in my contribution to two publications (Attachment 4; 4.10, 4.15), presenting the construction and development of the EMPD database, as well as possibilities of using the collected information for interpretation of fossil spectra, reconstruction of climatic conditions and quantitative changes in the landscape, e.g., under the influence of human activities.

Shortly after completing my PhD, I collaborated with J. Pempkowiak, PhD, DSc, ProfTit and K. Kuliński PhD, DSc from the Institute of Oceanology PAS in Sopot, which resulted in further studies of the sediment composition of lobelia lakes. These allowed us to determine the quantity and quality of lignin phenols in the sediments of three lakes I studied during my PhD, and thus to compare the proportion of these compounds with profile lithology and palynological data. In a co-authored paper (Attachment 4; 4.6), we showed that significant differences in lignin concentrations observed along profiles and between sites, correlate well with palynological data illustrating the dominant vegetation type and soil erosion rates in lake catchments. In all the lakes, gymnosperm wood was the main source of lignin products. The proportions of each lignin phenols group were positively correlated with the proportion of pine pollen in the sediments and with higher degradation of organic matter in the sediments with a higher proportion of non-woody tissues. This study indicated the usefulness and potential for a wider application of lignin oxidation products in palaeoecological reconstructions, mainly when investigating the local presence and the role of angiosperms and gymnosperms in local vegetation.

I was able to develop my expertise in palynology through my participation with M. Latałowa, PhD, DSc, ProfTit in the analysis of animal (sheep/goat) coprolites from the

Sudanese site of Wadi Umm Rahau in the area of the 4th cataract, which supported the analysis of macroremains from this site. The presence of single pollen grains of *Tribulus*, Asteraceae, and Poaceae reflected the importance of these plants in the diet of animal livestock at the site (Attachment 4; 7.40).

My scientific activity was still connected with the archaeobotanical research in the area of Gdańsk. Between 2006 and 2010, the team of the Laboratory of Palaeoecology and Archaeobotany simultaneously conducted 3 projects of the Ministry of Science and Higher Education (Attachment 4; 9.9-9.11), which enabled us to continue developing materials and collecting results in a common database (ARCHBOT-UGDA DATABASE). In these projects I was a contractor responsible for co-participation in the collection of material from archaeological sites, the co-elaboration of macrofossil samples, and first of all, pollen and NPPs analysis of 95 samples from 5 sites from the town, which became a new element of research on sites in Gdańsk. Thanks to the projects, we have undertaken efforts to reconstruct the conditions in Gdańsk in the Middle Ages and in modern times and the development of flora and anthropogenic vegetation on its area, and to describe the role of plants used by its inhabitants from the 10th to the 18th century. The projects provided notable results in the form of publications (Attachment 4; 2.12, 4.11) and numerous conference presentations (Attachment 4; 7.25, 7.39, 7.41, 7.45, 7.46, 7.70, 7.77, 7.84, 7.86, 7.89, 7.91, 7.95-7.97). My participation in projects and the experience I gained in collecting materials, selecting them to fulfil different research tasks gave me the opportunity to elaborate the conception and obtain another NCN-funded project (Attachment 4; 9.6), which I managed from 2011 to 2015. The collection of materials from the period preceding the development of the town and new sites from the oldest districts of Gdańsk, as well as focusing on high-resolution pollen analysis, NPPs and geochemical analyses of sediments, resulted in preparing publications that were part of the presented scientific achievement. In 2011, we presented the results of our research in Gdańsk at the international conference *Environmental Archaeology of Urban Sites*, organized by the Laboratory team.

My next project was related to *palaeoecological studies of the littoral zone of the Powidzkie Lake in the Gniezno Lake District*, in the area of a submerged Lusatian Culture site. The aim of research included preliminary identification of the age of Lake Powidzkie sediments and assessment of their usefulness for research in the context of environmental changes caused by the development of settlements. My participation involved a preliminary pollen and NPPs analysis in a profile collected during underwater archaeological work at the site where traces of a Lusatian settlement were found. I was also a mentor for parallel analyses of macroscopic plant and animal remains in the same core, conducted as part of Master's thesis (*Remains of plants in cultural layers associated with the Lusatian Culture settlement in Polanowo, Słupca district, Wielkopolska*). The achieved results and their correlation with reference profiles from the vicinity of Lednica and Gniezno indicate that the analysed profile contained a sedimentary gap covering the younger part of the Alleröd, the younger Dryas and a major part of the Holocene. In Alleröd, a dynamic development of a lake ecosystem with stonewort meadows and macrophytes typical of mesotrophic waters rich in calcium carbonate occurred at the site. Fluctuations in water levels during the Holocene, which caused shoreline changes and destruction of previously accumulated sediments due to

wave activity in the lake coastal zone, were certainly the cause of the hiatus that occur in the sediments. The upper part of profile may have accumulated during the period connected with the Lusatian Culture, but the composition of pollen spectra indicated rather a late stage of the settlement phase or a period immediately after the abandonment of the Lusatian settlement. Unfortunately, none of the five examined profiles from the coastal zone revealed material that could botanically be interpreted as a cultural layer. Therefore, further palaeoecological analyses of the bottom sediments were not justified due to their destruction in the littoral zone of the lake. The obtained results are a part of a monograph edited by Andrzej Pydyn, PhD, DSc (*Archaeology of Lake Powidzkie*, Attachment 4; 2.13).

I also performed carpological and macrofossil analyses in materials from four peat bogs located in Białowieża Forest within the project conducted in the Laboratory led by M. Latałowa, PhD, DSc, ProfTit (Attachment 4; 9.13). The project aimed to reconstruct the history of the Białowieża Forest communities and to describe their long-term dynamics, taking into account natural and anthropogenic factors. My role in the project also included mentoring two Master's degree students who performed macrofossil analyses of materials from two other peat bogs (including review of determinations, assistance in compilation and interpretation of results), selection of materials for radiocarbon dating, and compilation of data on the composition of macroremains in all profiles from the Białowieża Forest. The results of carpological analyses enabled the reconstruction of local vegetation succession and palaeohydrological changes during the development of individual peatlands based on a list of 71 plant and 9 animal taxa. The determination of macrocharcoal contents of varied sizes in the sediments of the studied sites provided grounds for the reconstruction of fire events. Their correlation with microcharcoal contents in palynological samples made it possible to indicate the local character of some of those fires and their role in the changes of trophy and humidity of habitats on the investigated sites. The results were used to prepare the final report of project N N305 167839 and were presented at conferences (Attachment 4; 7.49, 7.50, 7.99).

Between 2012 and 2018, I participated in the NCN project *The Migration Period between the Oder and the Vistula*, led by Aleksander Bursche, PhD, DSc, ProfTit from the Institute of Archaeology, University of Warsaw (Attachment 4; 9.14). The research conducted by the team of the Laboratory of Palaeoecology and Archaeobotany aimed to collect and elaborate palynological data in order to reconstruct the environmental background of cultural development in the 1st millennium AD and the dynamics of settlement during this period. My role was to co-collect and analyse materials from 52 palynological sites from northern and central Poland (4 elaborated by me), and to make a series of maps illustrating changes in pollen proportions of selected taxa in consecutive phases of the 1st millennium AD. The substantial number of sites gave us the opportunity to compare the scale of deforestation and the development of vegetation typical of different forms of land use, resulting in a comprehensive picture of settlement change over subsequent periods. The palynological data confirmed extensive Roman Period settlement in the study area, with regional differences in terms of chronology and the extent of deforestation and the scale of cereal growing. The crisis of the Migration Period was reflected in the whole study area, and according to our data the process began in the 3rd–4th century in Pomerania and Chełmno Lake District, but the whole depopulation was greatest in the 5th–6th century (except for Mazury Lake District). A

comparison of data from the sites for which precise chronostratigraphic models has been obtained shows that the periods of decline of settlement were not synchronous across the study area. Our palynological data also illustrate differences in the chronology of the beginnings of deforestation and development of agriculture due to the new wave of settlement in the Early Middle Ages, in the 7th and 8th centuries mainly in Pyrzyce Lowland, Wolin Island, Bytów and Chełmno Lake Districts, and in the 9th and 10th centuries, further economic development in Pomerania. The results elaborated within the project were published as part of the monograph *The Migration Period between the Odra and the Vistula* (Attachment 4; 2.14) and presented at conferences (Attachment 4; 7.48, 7.51, 7.52, 7.79, 7.80, 7.92, 7.98).

In the project NCN *The Migration Period between the Odra and the Vistula* I also took part in *analyses of materials from Wisieluch cave* (Kraków-Częstochowa Upland). Their aim was to determine the botanical composition of samples and to select materials for radiocarbon dating to confirm their accumulation during the Migration Period. It was a challenge for me to analyse the macroscopic remains in these materials, since due to the burning the plant remains were usually poorly preserved, which often made it impossible to identify them to the species level. In 24 samples I identified 48 plant taxa, 4 animal taxa and 1 fungal species. Radiocarbon dating of two samples confirmed that the layers under study were deposited as late as in the 14th century. Correlating the data with the results of a parallel pollen analysis, conducted by M. Zimny, PhD, made it possible to conclude that the layers genesis is anthropogenic. These showed the presence of useful plants (rye, oats, barley, millet, wheat) that had been processed on site in the cave. The high frequency of micro- and macrocharcoals and burnt cereal grains, especially the presence of burnt amorphous organic matter, suggested that these were traces of food preparation. Detailed results are included in the report prepared for the Institute of Archaeology, Warsaw University (Attachment 4; III5.8).

Collecting and analysing the palynological data from sites in northern Poland also constituted my contribution to the publication on the rapid decline of alder stands in Poland and Europe at the end of the first millennium AD (Attachment 4; 4.13). We described this phenomenon based on materials from almost 70 sites, indicating that it occurred over a large area of the temperate and boreal zone (in southern Finland, western Russia, the Baltic states, northern and central Poland). The data from Poland suggest that the decline was roughly synchronous and most likely occurred between the 9th and 10th centuries. Correlation of the proportion of alder pollen with anthropogenic indicators showed that human influence was not the major factor in the event. The influence of a series of abrupt climatic shifts that caused floods and droughts at the end of the first millennium AD seems to be more probable. We argue that, as today, this may have led to alder being more susceptible to pathogen outbreak such as *Phytophthora* fungi, responsible for alder decline in many regions of Europe. This study provides insight into long-term alder dynamics in the context of climate change and illustrates its great resilience, enabling the natural regeneration of alder stands after critical diebacks, if environmental conditions improve. On the other hand, it seems that the *Alnus* pollen decline could be used as an over-regional chronostratigraphic marker for 800–1000 AD in pollen diagrams from a large part of the European Lowland.

In 2017, I started collaboration with K. Niedziółka, PhD from the Faculty of Historical and Social Sciences at UKSW in Warsaw, which aimed to reconstruct *the environmental*

changes in the micro-region of Lake Wierzchowo and in the vicinity of the Grąbczyn stronghold in Central Pomerania. The archaeological data compiled indicated that the area had been an attractive place for people since the Paleolithic, with settlement development intensifying in the Late Bronze Age. My role was to elaborate the lake profile (pollen analysis, NPPs, microcharcoal analysis), which provided the data necessary to describe the environmental changes in the study area. The analyses conducted so far show that the bottom sediments of Lake Wierzchowo record the Holocene history of plant communities in its surroundings and the changes occurring as a result of settlement development. The first traces of the disturbance of forest communities, caused by human activity, can be associated with the presence of Mesolithic and Neolithic tribes. Moreover, the results of pollen analysis provide arguments in the discussion on the site importance in the settlement system of Middle Pomerania, as they illustrate a strong transformation of the local environment during the Lusatian and Pomeranian culture periods, and confirm the dynamic economic development based on animal husbandry and cereal cultivation during the Roman Period, as well as indicate a strong deforestation and an increase in anthropopressure in the Middle Ages. Works at this site shall continue.

Another project I participated in referred to the use of plants in late medieval Puck. The Master's thesis by K. Maciejewska completed under my supervision (*Useful plants in late medieval latrine materials from a site in Puck*), provided some data on plants used by inhabitants of a site located on the Main Market Square. My participation in the verification, and later in supplementing the determinations of archaeobotanical materials and their comparison with the data from Gdańsk dating to the same period, made it possible to compare the dietary preferences of the inhabitants of both towns. We have shown that in the late Middle Ages the diet of city inhabitants was similar, and the differences concerned the spices and vegetables used, with a higher variety recorded in the Gdańsk materials. The diet of Puck inhabitants was rather simple, characteristic of a middle-class society, based on locally grown and collected products. The obtained results became part of an article on *the transformation of local environment and plant use in late medieval Puck* (Attachment 4; 4.19), in which, thanks to the cooperation with other archaeobotanists involved in research within Puck, it was possible to summarize the botanical data from various parcels and cultural layers within the Old Town. The results of this work demonstrated that the expansion of Puck resulted in the development of habitats convenient for ruderal plants, among which a significant role was played by native species spreading from riverside habitats. Moreover, the analysis of the composition of plant remains provided evidence of land use outside the city, including meadow and pasture communities and forest communities. The results of this study were also presented at a conference (Attachment 4; 7.82).

Between 2016 and 2018, I was a member of a group of European palaeoecologists led by E. Dietze, PhD of the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam (Attachment 4; 15.4). Our collaboration aimed to reconstruct the impact of human-caused fires on landscape transformation in the Central European Lowlands. My role in the project was to provide data on microcharcoal content in sediments from six sites that I analysed in the previous projects, about the age of climatic events recorded in the profiles from northern Poland that were included in the study, as well as data on the history of

settlement development in this area. The collaboration resulted in a publication (Attachment 4; 4.12) and conference presentations (Attachment 4; 7.53, 7.54) in which we discussed the relationships between Holocene fire intensity and human impact in the area from western Germany to Estonia against the background of the reconstruction of changes in the landscape. The results confirmed that widespread natural fires only occurred during the early Holocene, and that natural conditions (climate and vegetation) limited the extent of wildfires from about 8.5 cal. BP. The variation in regional microcharcoal content in the sediments correlated with the periods of hunter-gatherer tribe activity in the Mesolithic, as well as the spread of sedentary cultures in the western and eastern parts of the Central European Lowlands. The intensification of human land use during the last millennium caused an increase in fire activity to early-Holocene levels. The research also refers to climate change scenarios in the future that predict drier and warmer summers, which may affect the frequency of natural fires in the study area.

The storage of microcharcoal data from Holocene sediments of selected sites in the PAGES Global Database enabled us to prepare the following publication (Attachment 4; 4.14), which was led by A. Feurdean, PhD from the Senckenberg Biodiversity and Climate Research Centre in Germany. This work aimed to determine the influence of changes in land cover (land use, dominant vegetation type) on wildfire occurrence over the last 12 ths years in temperate and boreal regions of Europe. The analysis of extensive data set of pollen and sedimentary charcoal records, in combination with climate simulations and statistical modelling, indicated that biomass burning was highest during the early Holocene and lowest during the mid-Holocene, and more spatially variable over the past 3-4 kyr. The simulations confirmed that a higher proportion of tree cover in the landscape has been a limiting factor in fire intensity (more difficult biomass burning with lower solar radiation reaching the forest floor and higher forest moisture). In temperate and boreal forests, biomass burning decreased to a minimum at 60-70% tree cover, and also increased when arable lands and grasslands reached ~15-20%. These studies also conclude that long-term fire hazards can be effectively reduced through land cover management.

Since 2016, I have also been involved in research on *reconstructing hydrological changes in the Wieprza valley*. My role included firstly to support the Master's thesis by Ewa Gołaszewska (Janik), including the revision of determinations of plants and animals macroremains and provide help in the results interpretation. After completing the master studies, E. Janik undertook PhD studies and continued research in Wieprza valley. In her PhD thesis, I am an assistant supervisor, while M. Latałowa, PhD, DSc, ProfTit, is the main supervisor. The dissertation is in the course of completing and thanks to the compilation of macrofossil material and its correlation with palynological, NPPs and Cladocera data it will be possible to reconstruct the succession of local plant communities and ecological conditions in the Wieprza valley in the period from 11.8 to 4 ths cal. BP. Preliminary results of this study were presented at the conference (Attachment 4; 7.100) and are in the course of preparing for publication.

Long-term observations of modern pollen deposition at sites located in forest communities on the Gdańsk Upland and Kashubian Lake District, allowed me to use these data and join the project *Impact of pollen on throughfall biochemistry in European temperate*

and boreal forests in 2018 (Attachment 4; 15.5). The project, coordinated by A. Verstraeten, PhD of the Institute for Nature and Forest in Belgium, aims to investigate the relationship between the abundance of tree flowering and chemical inputs into forest soils in Europe. The results so far show a positive correlation between pollen deposition and the supply of dissolved carbon and nitrogen to soils. The results also confirm the significant role of pollen deposition in forest nutrient cycling, especially potassium, various forms of nitrogen and phosphate, as presented at conferences (Attachment 4; 7.55, 7.56). The project is ongoing, and the work aimed to analyse materials and prepare publications is in progress.

Since 2018, I have also been involved in interdisciplinary research in the area of the Neolithic roundel in Nowe Objezierze, as part of a project coordinated by Lech Czerniak, PhD, DSc, ProfTit from the Department of History, University of Gdańsk (Attachment 4; 9.16). Together with Anna Pędziszewska, PhD, we performed pollen, NPPs, and microcharcoal analyses in a profile taken from a lake located in the vicinity of the roundel. We conducted analyses with higher resolution (every 1-2 cm; 149 samples in total) in a core section spanning the Boreal and Atlantic periods. The study aimed to reconstruct changes in vegetation composition in the period preceding the construction of one of the oldest and largest roundels in Europe (4.8-4.5 cal. BC), constructed by tribes of farmers who came to Poland in the Neolithic period. The obtained results confirm that the studied part of the core registers very precisely the events of the Mesolithic and Neolithic periods and strong environmental transformations due to settlement development. The presence of Neolithic tribes in the study area is documented by an increase in the proportion of pollen of anthropogenic indicators in the sediments, including cereals, taxa typical of ruderal habitats, meadow plants, and spores of coprophilous fungi, an indicator of the cattle grazing which was practiced at the lake shores. The results have been presented at conferences (Attachment 4; 7.57, 7.81, 7.83, 7.103, 7.104) and are in the course of preparing for publication as the project is close to completion.

My experience in the identification of modern, fossil pollen grains and plant macrofossils allowed me to apply for a forensic palynology expert certification. I have been performing this function at the Regional Court in Gdańsk since 2007, and thanks to that I was able to provide expert opinions and expertise for the Prosecutor's Office (Attachment 4; 5.5, 5.7).

In the immediate future, I plan to continue observations on modern pollen deposition in the Gdańsk Upland and the Kashubian Lakeland within the framework of the Pollen Monitoring Programme project, which will allow to enrich the database from European sites. Moreover, I plan to use the long-term observations at the same monitoring sites to show how recent intensified deforestation in the Tricity Landscape Park affected the pollen production and flowering rhythm of the most important woodland taxa of this area. My scientific interests also focus on the settlement development in Central and Western Pomerania. In the upcoming period I intend to focus on elaboration of macrofossil samples collected at the stronghold in Grąbczyn (continuation of research conducted together with K. Niedziółka, PhD), correlation of palynological and geochemical data from a profile taken in the vicinity of the stronghold (Lake Wierzchowo), which will allow us to describe the impact of settlement development on the local environment and to obtain information about the time of its origin. At the same time,

I am planning to participate in the next studies on the settlement development in the vicinity of Neolithic roundel in Nowe Objezierze (Western Pomerania). The continued cooperation with L. Czerniak, PhD, DSc, ProfTit from Gdańsk University and A. Matuszewska, PhD from the University of Szczecin is planned to reconstruct the environmental changes under the influence of settlement development in the Bronze Age. The archaeological survey has confirmed the presence of settlements and cemeteries dating back to the Early Bronze Age, and the profile collected from the lake and developed partly within the framework of the NCN project, provides an opportunity to undertake further palaeoecological analyses (pollen, NPPs, microcharcoal analysis). At this stage of the study, it was possible to select material from the lake sediments for radiocarbon dating and to carry out a preliminary pollen analysis. This will allow the selection of a suitable section of the 11 m profile, chronologically corresponding to the Bronze Age, for further palaeoecological studies, which will be elaborated at a higher resolution.

I also plan to continue my archaeobotanical research in Gdańsk. Thanks to the cooperation with archaeologists conducting salvage excavations at Tartaczna Street we managed to collect materials from houses and cultural layers dated back to the 12th and 13th century. Together with Monika Badura, PhD, DSc, Prof. at Gdańsk University, we are planning to verify the materials (including segetal and ruderal weeds) compiled as part of the Master's theses, perform an analysis of macroremains from additional samples, and present a complete study on the composition of fossil flora, which will be a part of a monograph published thanks to the project *'Studium życia Gdańska przedlokacyjnego*; Elaboration of research results on Tartaczna Street in Gdańsk between 2008 and 2010, co-financed by the Ministry of Culture and National Heritage within the framework of the Protection of Archaeological Monuments 2022 Project.

In the future I also want to participate in palaeoenvironmental research in the Young Town area of Gdańsk, a district which still lacks the palaeoecological data, because at this moment I was only able to perform a preliminary survey of the collected materials. The collaboration with Maciej Marczak Msc., an archaeologist who discovered the relics of the Young Town in 2018, allowed me to obtain two profiles that provided material for pollen analysis, NPPs, macroremains, and geochemical analyses. The main goal of this research will involve reconstructing the history of environmental transformations from the period prior to the development of the Young Town in the study area until its destruction in the 15th century. Preliminary analyses (pollen and radiocarbon dating) of the upper and bottom part of one of the profiles confirm that these sediments register events from the 7th to the 13th century, and therefore would be perfect for the description of conditions in this area just before the location of the town by the Teutonic Knights. As per the archaeological dating, the second of the collected profiles, apart from natural layers, also contains cultural layers from the period of the Young Town. The study of this material will provide additional information on the spatial development of medieval Gdańsk, as well as the natural conditions that prevailed prior to the development of the Young Town, which may have played a key role in the very late settlement of this district.

Summary of scientific achievements

My scientific accomplishments consist of 40 publications (including 5 listed as scientific achievements). These are 14 chapters in monographs, 25 original scientific articles, including 16 published in JCR journals and 1 chapter in the conference excursion guidebook.

I am the author and co-author of 104 conference presentations: 22 prior to the award of Doctoral Degree (4 in-person presentations), 82 after the award of Doctoral Degree (17 in-person presentations at international conferences and 15 in-person presentations at national conferences). I was a co-editor of conference volumes of one national and one international conference, and member of the organizing committee three times. Moreover, I performed 6 expert reports based on palaeoecological analyses in cooperation with other research centres, the Archaeological Museum in Gdańsk, archaeological companies and 2 expert reports for the prosecutor's office as an expert at the Regional Court in Gdańsk.

I was leading four research projects (two of them were financed from the funds of the Committee for Scientific Research and the National Science Centre, two from the funds for Young Researchers within the framework of own research of the University of Gdańsk). I was also a contractor in 12 projects conducted at my home institution and outside of it.

I was a mentor of 7 Master Thesis dissertations and after the award of Doctoral Degree I was a formal supervisor of 7 Bachelor Thesis dissertations and 15 Master Thesis dissertations. Currently I am an assistant supervisor of one PhD student.

SCIENTOMETRIC INFORMATION

1. **Information on the Impact Factor**
   Total Impact Factor of scientific publications according to Journal Citation Reports list:
   - evaluated for the specific year of publication: 51.105 (including scientific achievement: 8.32)
   - 5-years: 55.951 (including scientific achievement: 9.24)

2. **Information on the number of citations of the applicant's publications**

   318 (303 without self-citation; Web of Science), 398 (Scopus), 613 (Google Scholar), 651 (Research Gate) – as of May 29, 2022

3. **Information on *h*-index held**

   9 (Web of Science), 11 (Scopus), 13 (Google Scholar), 14 (Research Gate) – as of May 29, 2022

4. **Information on the number of the points awarded by the Ministry of Science and Higher Education**
   Sum of the points: 1432 (including 210 points of scientific achievement)
   417 points (The scoring based on the Communication of the Minister of Science and Higher Education dated January 26, 2017)
   1015 points (The scoring based on the Communication of the Minister of Education and Science dated February 9, 2021)

Detailed information is included in Attachment 4b.

Attachment 3b

AWARDS FOR SCIENTIFIC ACHIEVEMENTS

The first-degree team award, granted by the Chancellor of the University of Gdańsk in 2016, for contributions to interdisciplinary studies of the impact of climate change and human activities on the natural environment at local, regional and continental scales.

……..……..…….

(Applicant's signature)