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# Relics of cultivation in the vascular flora of medieval West Slavic settlements and castles

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**Abstract.** This monograph presents results of research on relics of cultivation and the present vascular flora of sites of medieval fortified settlements and castles in Central Europe. Special attention was paid to 109 West Slavic sites located in Poland, north-eastern Germany, and the Czech Republic. For comparison, floristic data were collected also at 21 sites of medieval settlements and castles of Baltic tribes, East Slavs, and Teutonic knights. Results of this study confirm the hypothesis that remnants of medieval fortified settlements and castles are valuable habitat islands in the agricultural landscape, and are refuges of the plants that have accompanied West Slavs since the Middle Ages. At the 109 West Slavic archaeological sites, 876 vascular plant species were recorded. The present flora of the study sites is highly specific, clearly distinct from the surrounding natural environment, as shown by results of analyses of taxonomic composition, geographical-historical and synecological groups, indices of anthropogenic changes of the flora, and degrees of hemeroby (i.e. human influence) at the studied habitats. The sites of fortified settlements and castles are centres of concentration and sources of dispersal of alien species. Aliens account for nearly 21% of the vascular flora of the study sites. Among them, a major role is played by archaeophytes (101 species). Some archaeological sites are characterized by a high contribution of so-called species of old deciduous forests (98 species). Despite many features in common, floras of archaeological sites vary significantly, depending on their geographical location, size, typology, and chronology of their origin. Historical sites occupied in the past by West Slavs differ in the current vascular flora from the sites occupied in the Middle Ages by East Slavs or Baltic tribes and from Teutonic castles. West Slavic archaeological sites are primarily refuges for 22 relics of cultivation. Considering the time of cultivation, 3 groups of relics were distinguished: (*i*) relics of medieval cultivation (plants cultivated till the late 15$^{th}$ century); (*ii*) relics of cultivation in the modern era (introduced into cultivation in the 16$^{th}$ century or later), and (*iii*) relics of medieval-modern cultivation. These species play a special role in research on the history of the flora of Central Europe and thus also of the world flora. Thus the best-preserved sites of medieval West Slavic settlements and castles should be protected as our both cultural and natural heritage. This work is a key contribution to geobotanical research on transformation of the vegetation associated with human activity. Considering the problem of relics of cultivation it corresponds also to basic ethnobotanical issues.

**Key words:** relics of cultivation, archaeophytes, species of old deciduous forests, Central Europe, West Slavs, archaeological sites, medieval fortified settlements, castles, Middle Ages, floristic indices, human impact, hemeroby

## Contents



CHOROLOGY

## 1. Introduction

The transformation of the natural environment caused by human activity is of interest to many academic disciplines. This process is analysed in various time perspectives and spatial systems as well as at various levels of organization of nature. At least since the mid-20th century, this field of research includes also studies of vegetation (e.g. Lambdon *et al.* 2008; Pyšek & Hulme 2011). Among them, two major directions of research can be distinguished. They differ in both research materials and methods, although their goal is similar. The first direction – archaeobotany (known also as palaeoethnobotany) – is based on fossil materials, i.e. pollen grains in peat deposits or plant macroremains in archaeological deposits (e.g. Tobolski 1991; Latałowa 1999a; Makohonienko 2000; Latałowa *et al.* 2007). The second direction of research is concentrated on analyses of the present vegetation and retrospective interpretation of changes in flora and vegetation (e.g. Faliński 1997, 2000; Zając & Zając 2000; Pyšek *et al.* 2005). Particularly frequently, such research was conducted in habitats strongly transformed by human activity, e.g. in arable fields (e.g. Korniak 1992; Warcholińska 1998; Latowski *et al.* 2010), towns and cities (e.g. Kunick 1974; Jackowiak 1998; Pyšek 1998; Sudnik-Wójcikowska 1998), industrial areas (e.g. Rostański 1998, 2006; Prach *et al.* 2001), and along railway routes (e.g. Brandes 1983, 1993; Latowski 1998, 2004, 2005, 2011; Latowski & Topuzović 1998; Wrzesień 2005). These studies enriched our knowledge with many important and interesting data about the functioning of plants under a strong human influence and about mechanisms of synanthropization of flora and vegetation. Results of the research revealed e.g. that under the influence of farming for many centuries, new plants associated with arable fields have developed, of various taxonomic ranks (e.g. Kornaś 1981; Zając 1988; Zając & Zając 2000). The above anthropogenic habitats were found to be floristically distinct from natural and semi-natural habitats, which is reflected in a relatively high contribution of alien species (e.g. Jackowiak 2000; Pyšek *et al.* 2003; Chmiel 2006). Factors like agriculture, urbanization, and industrialization cause a decline of many native plant species (e.g. Faliński 1966; Kornaś 1981; Chmiel 1995, 1998). Many authors emphasize also that arable fields, urban areas, and railway routes and roads play a great role in the spread of alien species (e.g. Tokarska-Guzik 2003, 2005; Wrzesień 2006; Májeková & Zaliberová 2009; Pyšek *et al.* 2009).

For some time, more and more researchers have been interested in the present flora of prehistoric and historic sites, such as burial mounds, fortified settlements, and castles or their ruins. They are very important traces of the history of human settlements, and significant elements of the cultural landscape of Central Europe (Behm 1997; Kobyliński 2000; Bogdanowski 2002). Particularly noteworthy are medieval constructions built between the 7th and 15th century, i.e. during the formation of many sovereign countries in this part of the Old Continent (Leciejewicz 1989; Serafini 2007).

Prehistoric and historic sites in Europe for a long time have been studied not only by archaeologists but also by archaeobotanists, who excavate from them fossilized plant materials. These form a basis for: (*i*) reconstruction of the history of transformations of the natural environment; (*ii*) identification of crop plant species and wild plants that were used by people for various purposes, e.g. in medicine, economy, and culture; and (*iii*) description of the course of important economic processes (Trzcińska-Tacik & Wasylikowa 1982; Lityńska-Zając & Wasylikowa 2005; Sádlo & Matoušek 2008).

However, studies of the present and fossil flora of archaeological sites and settlement complexes are rare. Only exceptionally archaeological, archaeobotanical, and floristic research is conducted simultaneously (see Zabłocki 1952, 1958; Wyrwa 2003). A major problem is the quantity and quality of comparative materials that can be found in archaeological deposits. The number of species found at archaeological sites is often small, and some taxa are identified only to genus or family level (see Celka 2000; Strzelczyk 2000). One of the best-studied medieval settlement complexes in Poland is the Lednica region. In this region the subfossil flora has been investigated for many years (e.g. Tobolski & Polcyn 1993; Polcyn 2003). The same applies to its present vascular flora (e.g. Jackowiak & Tobolski 1993; Celka *et al.* 2001, 2008).

Archaebotanical research is important in various parts of the world (e.g. XVII IBC 2005a, 2005b; Bieniek 2007; Makohonienko *et al.* 2007a; Bittmann & Mueller-Bieniek 2008). This is perfectly understandable because plants have been used by people since prehistoric times, initially by hunters-gatherers and later by farmers, more and more intensively. Plants were introduced into cultivation sometimes from places located at a distance of hundreds or thousands of kilometres. Changes in human economy caused changes in the species composition of crop plants (Kornaś & Medwecka-Kornaś 2002). Some of the species, when fields were abandoned, persisted close to them and were naturalized in various habitats for centuries. The process of naturalization of former crop plants concerns the whole period of human history and has been described in many parts of the world (e.g. Harris & Heenan 1992; Behm & Pivarci 1998; Laghetti *et al.* 2000; Reynolds 2002; Hodgson 2006; Parker *et al.* 2007; Powling 2009). In many regions, some of the plants are expansive or even invasive (Richardson *et al.* 2000; West 2002; Kowarik 2003; Pyšek *et al.* 2004; Lambdon *et al.* 2008; Galera & Sudnik-Wójcikowska 2010). The phenomena accompanying this process are increasingly frequently the subject of interdisciplinary research of archaeologists, ethnobotanists, and geobotanists. In geobotanical literature, the present flora of archaeological sites in Central Europe is also described more and more often (e.g. Trzcińska-Tacik & Wasylikowa 1982; Sádlo & Matoušek 2008; Celka 2008).

The last mentioned direction of research is also represented by the present study. It is a synthesis of large-scale field research aimed to assess the influence of medieval West Slavic settlements on the diversity of their present vascular flora. On the basis of the analysis of species composition and dynamics of the present flora of medieval earthworks and castles, I attempted to answer the following questions: (*i*) has the present flora of the areas inhabited for over 1000 years by Slavs preserved some traces of their earlier culture? (*ii*) how are the effects of the earlier human impact manifested in the present flora? (*iii*) what factors determine that floristic effects of medieval settlements vary in form and intensity?

The following hypotheses were verified: (*i*) the present vascular flora of archaeological sites is specific and clearly differs from the surrounding environment; (*ii*) an important feature distinguishing the flora of medieval fortified settlements is the presence of species that are relics of cultivation, which are thus indicator plants; (*iii*) floristic differences between archaeological sites result from their geographical location, typology, and chronology of their origin; (*iv*) archaeological sites of various tribes differ in flora.

These hypotheses are based on earlier, quite strong evidence, because already previously many authors attempted to answer similar questions but never so comprehensively. The flora of single archaeological sites was studied in Pomerania (Buliński 1993). More extensive, regional studies were conducted in Mecklenburg in northern Germany (Russow & Schulz 2002), the Chełmno region in northern Poland (Kamiński 2006a), and Wielkopolska in western Poland (Celka 1999). The research on fortified settlements in the Wielkopolska region showed that the present flora of fortified settlements differs from the surrounding agricultural landscape mostly because of the presence of relics of cultivation (Celka 1999).

This study is focused on the present spontaneous vascular flora of archaeological sites that are remnants of medieval West Slavic fortified settlements and castles in a large part of Central Europe. The study sites are mostly historic earthworks (i.e. mounds or rings of earth) located in Poland, eastern Germany, and the Czech Republic. For comparison, the analysis included also remnants of fortified settlements of Baltic tribes in north-eastern Poland, fortified settlements and castles in western Ukraine (i.e. East Slavic lands), as well as castles and castle ruins (including Teutonic castles) in the Chełmno region (northern Poland). The study sites differ in geographical location, type (concave and cone-shaped settlements, and castles), chronology (early or late medieval), size and structure, and the surrounding landscape (woodland versus farmland).

## 2. Outline history of West Slavs

Slavs appeared in the political arena of Europe in the 6th century AD. Knowledge about their origins is based on scanty written sources, linguistic evidence, and archaeological discoveries. According to the Polish autochthonous concept, the Slavic homeland was the area located in the catchment areas of the rivers Vistula and Oder (Odra). By contrast, according to an allochthonous concept, they derive from the catchment of the upper and middle Dniester (Derwich & Żurek 2002). For many years, also anthropologists have participated in this discussion. They have supplied many pieces of evidence supporting the autochthonous concept (see Piontek *et al.* 2008).

In the early 6th century, the territorial scope of Slavic peoples was markedly expanded thanks to colonization of new areas in the south and west. It was followed by expansion into areas abandoned e.g. by Germanic tribes during the Migration Period (i.e. Barbarian Invasions). Along the Baltic Sea and the rivers Elbe and Danube, Slavs found abandoned land. By contrast, in the Balkans, they had to fight with Greeks, Thracians, and Romans. In the 6th and 7th century, the territorial scope of Slavic peoples was greatly extended. Simultaneously, Slavic peoples differentiated into 3 groups: (*i*) South Slavs in the Balkans; (*ii*) West Slavs between the Danube, Elbe, Baltic, and Vistula; and (*iii*) East Slavs, occupying the a part of present-day Ukraine and colonizing new areas north and east of it (Fig. 1). The colonization of the Pannonian Basin by Hungarians in the late 9th century interrupted the intensive contacts between the Slavs living north of the Carpathians or Sudetes and the Slavs inhabiting the catchment of the Danube and the Balkans. This led to increasing differences between West and South Slavs. Differences between West and East Slavs date back to the 10th century, when the competing states of Kievan Russia and Poland were created, as they were christianized by the Eastern Orthodox and Roman Catholic Churches, respectively (Leciejewicz 1989; Derwich & Żurek 2002).

West Slavs inhabited the areas of present-day Poland (except the north-eastern part, occupied by the Baltic peoples), present-day eastern Germany (Fig. 2) reaching to the Elbe, and in the south, territories of the present-day Czech Republic and Slovakia. West Slavs were subdivided into many tribes. The most important among them were Vistulans, Western Polans, Masovians, Goplans, Silesians, Pomeranians, Polabian Slavs, Sorbs, Czechs, and Moravians.

The first West Slavic state was known as Samo's realm. It was created in the early 7th century and battled e.g. with the Franks. Another Slavic state was created in Moravia and Slovakia about 830 AD (Great Moravia). Its fall enabled unification of Czech tribes in the 9th and 10th centuries, and development of the Czech state. The tribes inhabiting present-day Poland were unified by Western Polans in the early 10th century, giving rise to the Polish state (Leciejewicz 1989; Derwich & Żurek 2002).

Slavic tribes living in the catchment area of the Elbe bordered on the German state. Their state organizations (e.g. Lutician Federation) were abolished by the Ger-


**Fig. 1.** Slavic peoples in the 8th-10th centuries (modified from Jan Rutkowski's map in Samsonowicz 2007)

man expansion in the 10th-12th centuries (Leciejewicz 1989; Derwich & Żurek 2002). As a result of long fights, the tribes living there were subdued by the German empire. The German expansion into Slavic lands was both demographic and cultural. The conquered territories were colonized by settlers from the west: craftsmen and merchants settled down in towns and cities, while knights and peasants in villages. Moreover, the local aristocracy was partly germanized (Labuda 1981). The Slavic population gradually declined there, not only as a result of extermination during wars, but also due to the flight or expulsion of Slavs from those territories (Sułowski 1981).

The most characteristic constructions built by West Slavs were various fortified settlements (also known as *gords*), with palisades and earthworks. Initially, concave settlements (ring-shaped) were built for defensive

**Fig. 2.** Reconstruction of a Slavic fortified settlement in Groß Raden near Sternberg (north-eastern Germany)

purposes. The inner open space was typically surrounded by ramparts (made of timber and earth) and a moat. The gords were usually the seats of the ruler or his highest officials. Most of the important functions of the state were coordinated there: ruling over the subjects, administration of the land, sentencing of criminals, settling of conflicts, and collecting of tributes (grain, etc.). The gord was defended by an armed team, so in case of emergency, the local people could shelter there. Gords were often accompanied by suburbia (singular *suburbium*) or settlements inhabited by merchants and craftsmen, who worked for the ruler and his courtiers. Major roads and merchant's routes crossed in gords.

Changes in the feudal system caused the creation of many small cone-shaped fortified settlements (mounds), which were the strongholds of knights and their families. However, successive changes in medieval economy resulted in gradual replacement of the wooden gords by towns and castles made of stones or bricks. Castles were built sometimes on remnants of the earlier fortified settlements, and towns or cities developed beside them. In this way, the so-called gord period, characteristic for West Slavs and lasting several hundred years, was finished as a result of the development of feudalism, and defensive constructions started to resemble the West European fortified castles (Leciejewicz 1989; Bogdanowski 2002).

## 3. History of research on the plant cover of archaeological sites

History of research on the present-day vegetation of medieval settlements in Central Europe dates back to the 18th century, when the botanist Georg Andreas Helwing (1666-1748), coming from Angerburg (now Węgorzewo), observed plants at sites of medieval fortified settlements in the Duchy of Prussia. He looked there for relics of cultivation (Helwing 1712, 1717, after Zabłocki 1958).

In the 19th century in Mecklenburg, German naturalists during field trips of scientific societies recorded plants found at sites of former Slavic settlements. This was reflected in their floristic notes (Willebrand 1852; Lisch 1861; Koch 1897; Krause 1897). In the early 20th century, on a wider scale, sites of Slavic settlements in Mecklenburg were studied by Bauch (1934a, 1934b, 1936, 1937a, 1937b, 1938). When investigating the flora of an island on Lake Teterow (Teterower See), he noted the occurrence of a group of species strongly associated with Slavic settlements, and named them *relics of cultivation* (German *Kulturreliktpflanzen*). After World War II, Bauch (1953) continued his research on the flora of medieval Slavic settlements. He studied in total about 150 medieval Slavic fortified settlements.

Hollnagel (1953a, 1953b) studied similar settlements located on lake islands in Neustrelitz-Land, and confirmed Bauch's hypotheses. The vegetation of a fortress at Cape Arkona on the island of Rügen was studied by Hundt (1968). Studies of the vegetation of archaeological sites and relics of cultivation in northern and north-eastern Germany were quite intensive in the late 20th century and at the beginning of the 21st century (Kintzel 1971; Voigtländer 1973; Hanelt & Hammer 1985; Prange 1996; Behm & Pivarci 1998; Russow 2000, 2002; Pivarci & Behm 2001; Russow & Schulz 2001, 2002).

In Poland, results of research on the flora of archaeological sites in Mecklenburg were first summarized by Garczyński (1959). However, the first data on single archaeological sites or a group of selected species of medieval settlements in the area of Poland can be found in some publications dating from the 19th century and early 20th century (e.g. Golenz 1861/1862; Bänitz 1865; Struve 1895; Miller 1899; Nanke 1899; Bock 1908; Decker 1912, 1924; Frase 1927; Wodziczko *et al.* 1938). On a wider scale, this problem was discussed by Buliński (1993, 1994) during his study of the flora of the Wierzyca Valley in Pomerania (north-western Poland). Complex investigations of the flora and vegetation of medieval settlements were later conducted in Wielkopolska (Celka 1999, 2004) and in the Chełmno region (Kamiński 2006a, 2006b; Bednarek *et al.* 2010). Published floristic data from single medieval settlements or specific areas originate from various parts of Poland, e.g. Pomerania (Sobisz & Młotkowska 1997; Głuchowska *et al.* 1998; Celka 2002), Masovia (Ciosek & Piórek 2001), Masuria (Zabłocki 1958), Wielkopolska (Celka 1997, 1998a, 2000a), Małopolska (Towpasz & Kotańska 2005; Suder & Towpasz 2010), Silesia (Hereźniak & Sieradzki 2008), the Carpathians (Bartoszek & Siatka 2008), Kuyavia (Korczyński 2010), and the Chełmno region (Ceynowa-Giełdoń 1996; Kamiński 2004, 2010; Wrońska-Pilarek *et al.* 2006). Besides, single species found at sites of medieval fortified settlements were studied in various parts of Poland. This applies e.g. to *Cypripedium calceolus* at the fortified settlement near Lake Kwiecko (Śpiewakowski *et al.* 1988, 1990; Korczyński & Śpiewakowski 1991) and *Adonis aestivalis* in northern Poland (Herbich 1989, 1996). Moreover, some publications are devoted to relics of cultivation in Poland and Central Europe (Miczyński 1950; Celka 1998b, 2000b, 2005, 2008; Ceynowa-Giełdon & Kamiński 2004; Celka & Drapikowska 2008).

Parallel investigations focussed on the vegetation of castles and their ruins. They were conducted in France (Chatin 1861; Kirschleger 1862; Krause 1896; Duvigneaud 1991), on the Åland Isles, and in southern Finland (Pettersson 1943, 1952). In Germany, similar studies involved single castles (e.g. Janssen 1990; Otto & Krebs 1991; Barthel *et al.* 1997) or specific areas (e.g. Lennar & Niessen 1910; Vollrath 1958-1960; Lohmeyer 1975a, 1975b, 1984; Brandes 1987a, 1996a; Schneider & Fleschutz 2001). Most extensive research was done by Hilgers (1995) on ruderal plants and relics of cultivation at 125 castles in the federal state of Rheinland-Pfalz, and by Dehnen-Schmutz (1998, 2000a, 2000b, 2001, 2004) on the vascular flora of 56 castles in southern and south-eastern Germany. In Lower Austria, the flora of ruins of 55 medieval castles was investigated by Hübl & Scharfetter (2008). In the Czech Republic, research on walls of castles and towns was conducted by Duchoslav (2002) and Simonová (2008). During botanical explorations of 25 castles along a transect from France through Germany and Slovakia, to Hungary, 693 species were recorded (Siegl 1998). In Poland, plants found around medieval castles and on their walls were studied in Silesia (Weretelnik 1982; Kwiatkowski & Struk 2003), the Kraków-Częstochowa Upland (Witkowska 2004; Sajkiewicz & Witkowska 2006, 2009), and in the town of Toruń (Ceynowa-Giełdon & Nienartowicz 1994). Moreover, the distribution of single species was investigated at castles, e.g. Mazaraki (1963) reported on the presence of *Epipactis microphylla* near the castle Lipowiec near Babice (in Chrzanów County, southern Poland).

The flora of various archaeological sites in France has been recently studied by Lemouland (2004) and Lemouland & Perrin (2007). Among the sites of medieval settlements, the least studied are non-fortified medieval settlements and settlements located outside medieval city walls. Most often they are poorly defined in the field, so their flora is analysed only during research on settlement complexes composed of various parts (Faliński 1972; Faliński *et al.* 2005; Celka 1998a; Towpasz & Kotańska 2005).

A separate direction of studies on plants associated with archaeological sites, concerns prehistoric and medieval burial sites. Botanical explorations of burial mounds (known as kurgans or tumuli) were initiated in Bulgaria by Paczoski (1933). In Poland, more detailed studies were conducted near the village of Haćki in the Podlasie region in eastern Poland (Faliński 1972; Faliński *et al.* 2005) and in the Małopolska Upland in southern Poland (Cwener & Towpasz 2003; Cwener 2004, 2005). The vegetation of a Yotvingian cemetery in the Suwałki region in north-eastern Poland was described by Urbisz (1989). In recent years, large-scale studies of the vegetation of burial mounds have been initiated in Ukraine (e.g. Moysiyenko & Sudnik-Wójcikowska 2006a, 2006b; Sudnik-Wójcikowska & Moysiyenko 2008a, 2008b, 2010).

## 4. Materials and methods

### 4.1. Selection, location, and description of study sites

In 1997-2007, vascular flora was studied at 130 archaeological sites (mostly medieval earthworks and castles). The main group (109 sites) are located in an area occupied in the early Middle Ages by West Slavic tribes (Appendices 1 and 2): in Poland (except its north-eastern part), the Czech Republic, and eastern Germany (Fig. 3). For comparison, the analysis included also 12 fortified settlements of Baltic tribes (Old Prussians, Yotvingians) in north-eastern Poland; 6 Teutonic castles in the Chełmno region (Poland); and 3 sites (a fortified settlement and 2 castles) in western Ukraine, inhabited by East Slavs (Figs. 4-8). When selecting the study sites, attention was paid to their geographical location, chronology, size, and other characteristics (on the basis of Hensel 1950, 1956, 1959; Hensel & Hilczer-Kurnatowska 1972, 1980, 1987; Hensel *et al.* 1995; Kowalenko 1938; Kamińska 1953; Kaletynowie & Lodowski 1968; Łosiński *et al.* 1971; Hermann & Donat 1973, 1979; Górska *et al.* 1976; Lachowicz *et al.* 1977; Lodowski 1980; Olczak & Siuchniński 1969, 1985, 1989; Schuldt 1985; Brzeziński & Iwanowska 1992; Marszałek 1993; Chudziakowa 1994; Kola 1994).

Information on the study sites, presented in Appendices 1 and 2, includes e.g. site name, administrative unit to which it currently belongs, geographical location, archaeological and environmental characteristics, site type, chronology, and size class.

Two major types of fortified settlements (earthworks) were distinguished: concave (some of them composed of several parts) and cone-shaped (also known as motte). Concave settlements are those whose interior is a depression (open space) surrounded by a rampart. The whole settlement is usually surrounded by a moat, sometimes also by an outer rampart (Figs. 9, 12a). Cone-shaped settlements are usually man-made mounds, often surrounded by a ditch (sometimes additionally also by an outer rampart) (Figs. 10-11, 12b). A third, minor type, is a promontory with a transverse rampart (only 2 sites: Stary Kraków and Remieńkień). Such settlements are situated on lake peninsulas or in the bends of river meanders. Fortifications consisted then of a ditch and a transverse rampart, which barred access to the promontory (Kowalenko 1938). Settlements with a transverse rampart, as well as sites that were initially concave fortified settlements, but later partly transformed into cone-shaped ones, were analysed jointly with typical concave settlements. Finally, 74 West Slavic sites were classified as concave settlements, while 14 as cone-shaped settlements.

All the sites with visible brick or stone walls or their ruins were classified as castles (although some of them were built on sites that were inhabited also earlier).

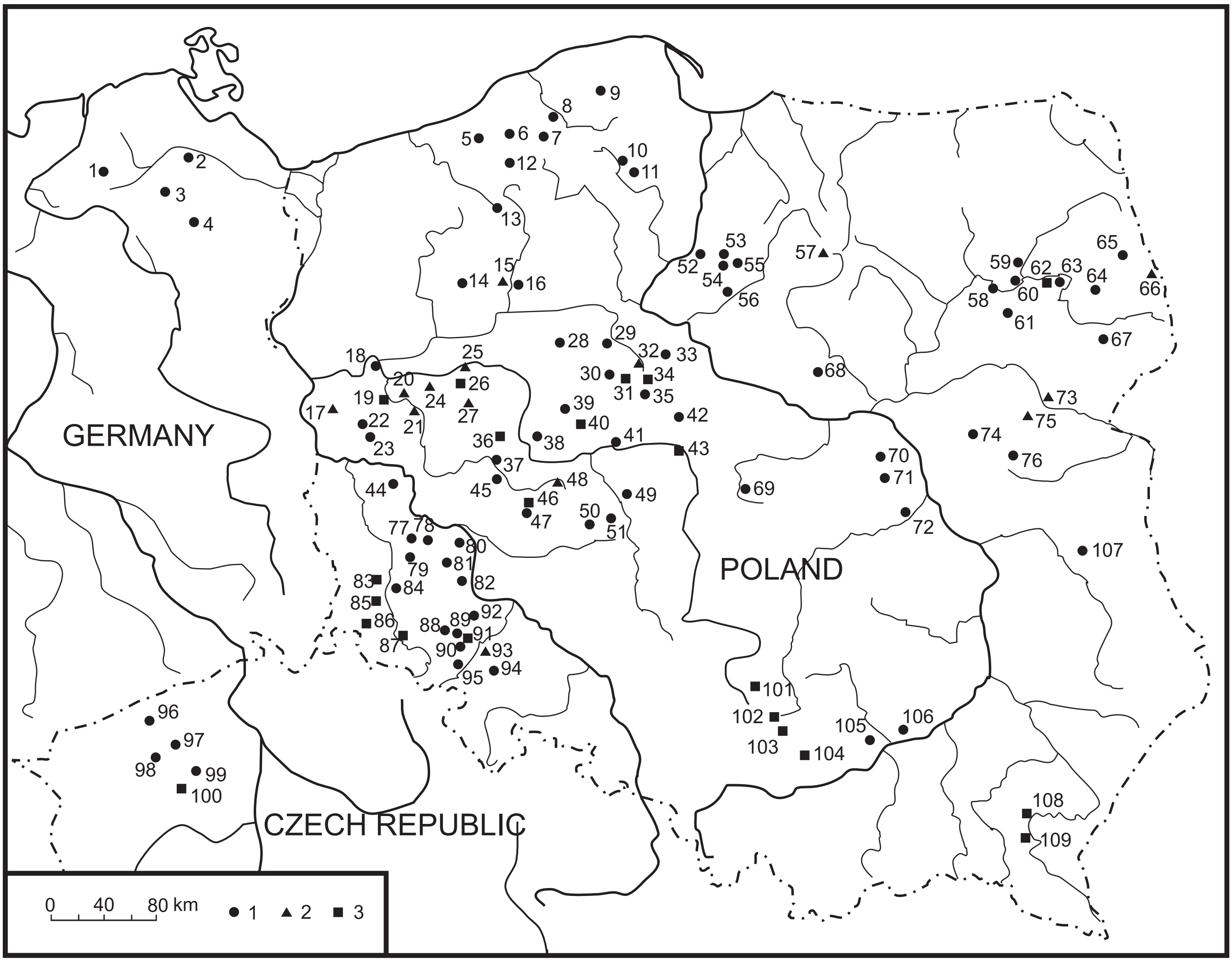



**Fig. 3.** Distribution of the studied West Slavic archaeological sites in Central Europe
Explanations: 1 – concave settlement, 2 – cone-shaped settlement, 3 – castle

Castles are generally large closed fortified structures combining the dominant defensive function with residential and economic functions (Bogdanowski 2002) (Figs. 12c, 13). In total, 21 West Slavic castles were included in this study.

On the basis of archaeological data, 5 chronological groups of sites were distinguished, depending on the period when they were inhabited: EM – early medieval (early 7$^{th}$ to mid 13$^{th}$ centuries); LM – late medieval (mid 13$^{th}$ to late 15$^{th}$ centuries); EM-LM – early to late medieval; EM-Mo – early medieval to modern era; and LM-Mo – late medieval to modern era. Group EM-Mo was small, so in further analyses, groups EM-LM and EM-Mo were analysed jointly. The analysis excluded 4 sites with a very complicated chronology (Haćki, Izdebno, Janowo, Vladař).

The study sites were divided into 3 size classes according to a modified scale of Olczak and Siuchniński (1976): I – small (up to 0.25 ha); II – medium-sized (0.26-1.00 ha); and III – large (exceeding 1.00 ha).

In a separate column of Appendices 1 and 2, environmental description of each study site is provided and the dominant habitats in the given study site are specified.

### 4.2. Methods of collection and analysis of floristic data

Basic research was conducted with the use of methods of floristic cartography. Each study site is an archaeological site: a fortified settlement (earthworks) or a castle. Depending on site type, it includes a cone-shaped mound (motte), ramparts, a depression (inner open space), walls, castle or its ruins, and/or moat(s). The study sites are usually delimited by a moat, rampart or wall. The vegetation and local environmental conditions within individual sites are generally highly variable. Within a small area, there is often a variety of habitats: clumps of trees or shrubs, xerothermic grassland, arable field, ruderal habitat, meadow, moat (filled with water all the time or only periodically wet), and/or walls (of a castle) with some plants growing on them.

**Fig. 4.** Concave settlement in Tum near Łęczyca (central Poland)

**Fig. 5.** Castle ruins in Odrzykoń near Krosno (south-eastern Poland)

**Fig. 6.** Yotvingian fortified settlement in Jegliniec near Szypliszki (north-eastern Poland)

**Fig. 7.** Ruins of a Teutonic castle in Kurzętnik near Olsztyn (northern Poland)

**Fig. 8.** Castle ruins in Korets near Rivne (western Ukraine)


**Fig. 9.** Concave settlement in Stradów near Kraków (south-eastern Poland): a – viewed from the west, b – rampart viewed from the south-east, c – moat and rampart viewed from the north-west, d – inner depression, viewed from the north-east, e – inner depression, viewed from the west

The analysis is based on original floristic relevés made in the field at all the study sites. In total, 600 floristic relevés were recorded. Depending on the local variety of habitats, up to 18 relevés were recorded at each study site. In each relevé, the following supplementary data were recorded: relevé number, site name and number, location of the site on the ATPOL grid (Zając 1978), date, habitat description, degree of hemeroby (see section 4.3.3), and available information on the site chronology. The floristic part of the relevé includes a list of species, with their abundance estimated on the following scale: 1 – not abundant, covering < 25% of plot area; 2 – moderately abundant, covering 25-50% of plot area; and 3 – very abundant, covering over 50% of plot area. Species documented with herbarium specimens are also noted in each relevé.

The collected herbarium materials have been deposited in the Herbarium of the Department of Plant Taxonomy, Adam Mickiewicz University, Poznań (POZ). Additionally, documentation of this study includes over 3000 photographs.

Apart from original data collected in the field, also scanty literature data were used. They originate mostly from several sources published in German in the 19th century (Golenz 1861/1862; Bock 1908). Nearly all species listed there have been found during this study. The only exceptions are records of *Botrychium multifidum, Diphasiastrum complanatum*, *Lycopodium*

**Fig. 10.** Cone-shaped settlement in Czaple Szlacheckie near Drohiczyn (eastern Poland)

**Fig. 11.** Wooded cone-shaped settlement in Wierzchowo near Szczecinek (north-western Poland)

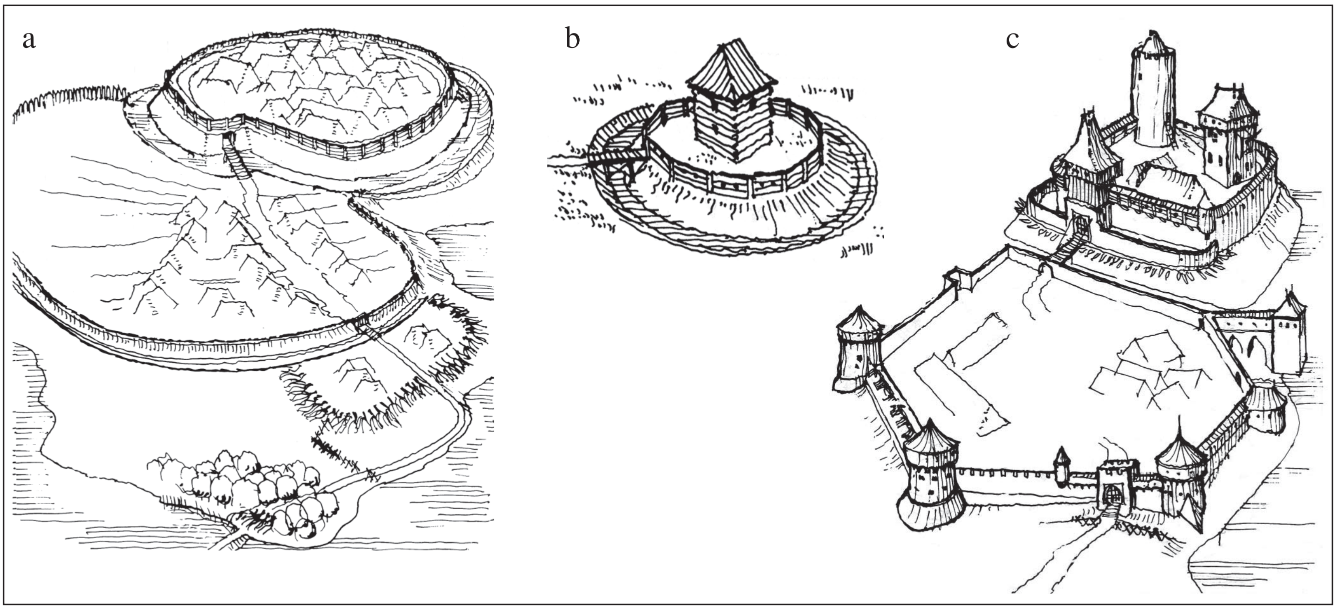



**Fig. 12.** Reconstructions of the 3 types of West Slavic archaeological sites (modified from Bogdanowski 2002): a – concave settlement, b – cone-shaped settlement, c – castle

**Fig. 13.** Castle ruins in Podzamcze near Ogrodzieniec (southern Poland)

*annotinum*, and *L. clavatum* at the fortified settlement in Niesulice (Golenz 1861/1862). In spite of repeated surveys, their presence has not been confirmed there. Consequently, those species were excluded from statistical analyses.

The data collected in the field were compiled in a database by means of FLORA-DAT1 software (Jackowiak & Kujawa 1989). Statistical analysis was made using Microsoft® Office Excel 2003 and STATISTICA 7.1 for Windows (StatSoft, Inc. 2008), while cartograms were prepared in CorelDRAW® X3.

For all the analysed parameters, mean, minimum, and maximum values were calculated, as well as standard deviation. Spearman rank correlation was calculated for all pairs of traits, and statistic significance was set at $p<0.05$. To assess the similarity between study sites, agglomerative clustering (Ward method) was used, based on Euclidean distances. It enabled separation of homogeneous groups of the study sites in respect of the analysed parameters. The results are presented in a dendrogram (Sneath & Sokal 1973) based on the Steinhaus index of floristic similarity (see below). The dendrogram was constructed using MEGA4 software (Tamura *et al.* 2007).

Beside the standard mapping of the flora, which involved all the study sites, 3 sites were selected for research extended to the immediate vicinity of the archaeological sites. The research was aimed to assess the influence of fortified settlements on the local floristic diversity. These 3 settlement complexes are located in Lednica near Gniezno and in Łekno near Wągrowiec (both in the Wielkopolska region, mid-western Poland) as well as in Wrześnica near Sławno (in Pomerania, north-western Poland).

## 4.3. Nomenclature and floristic classification methods

### 4.3.1. Geographical-historical classification

The geographical-historical classification of plant species in this study is based on concepts presented by Polish authors, particularly Krawiecowa (1951), Kornaś (1968, 1977, 1981), Krawiecowa and Rostański (1972), Trzcińska-Tacik (1979), Mirek (1981), Sudnik-Wójcikowska (1987), Jackowiak (1990, 1993), and Chmiel (1993, 2006).

All species were classified as either spontaneophytes (Sp, native species, which originate from the given area or have migrated into the area spontaneously, not due to human activity) or anthropophytes (An, alien species, intentionally or accidentally introduced into the given area due to human activity). Native species were further subdivided into non-synanthropic spontaneophytes (Sn found exclusively in natural and semi-natural habitats) and apophytes (Ap**,** synanthropic native species, permanent in strongly transformed habitats). Anthropophytes were subdivided into metaphytes (M, naturalized, permanent) and diaphytes (D, casual, not permanent at the study sites). Metaphytes were subdivided into archaeophytes (Ar, naturalized synanthropic aliens that appeared in the study area till the late 15th century) and kenophytes (Kn, naturalized synanthropic aliens that appeared after the discovery of America in 1492). Kenophytes are defined as by Kornaś (1968), so they roughly correspond to the term "neophytes" introduced by Meusel (1943). Among diaphytes, only one subgroup was distinguished: ergasiophytes (Ef, i.e. garden escapes). I assigned to this group also several species that are native to Central Europe but clearly escaped from cultivation at the studied archaeological sites.

Alien species were diagnosed on the basis of publications by Zając (1979, 1983, 1987a, 1987b, 1988), Dostál (1989), Lohmeyer & Sukopp (1992, 2001), Latowski (1994), Zając *et al.* (1998), Celka (1999, 2004), Pyšek *et al.* (2002), Rothmaler *et al.* (2005), and Tokarska-Guzik (2005).

### 4.3.2. Indices of anthropogenic changes in the flora

The scope of anthropogenic transformations of the flora of archaeological sites was assessed with the use of indices based on proportions between individual geographical-historical groups. In relation to the early concepts of classification of the process of synanthropization, proposed by Krawiecowa (1968) and Kornaś (1977), I used here mostly indices 1-8, defined by Jackowiak (1990, 1998), and indices 9-10, defined by Chmiel (1993, 2006). The symbols used in the formulae below are explained in the previous section.

1. Indices of flora synanthropization. Total synanthropization index ($WS_t$) is the percentage contribution of apophytes and anthropophytes to the total number of species, while permanent synanthropization index ($WS_p$) is the percentage contribution of apophytes and metaphytes to the number of permanent species.

$$WS_t = \frac{Ap + An}{Sp + An} \times 100\% \qquad WS_p = \frac{Ap + M}{Sp + M} \times 100\%$$

2. Indices of apophytization. Total apophytization index ($WAp_t$) is the percentage contribution of apophytes to the total number of species, while permanent apophytization index ($WAp_p$) is the percentage contribution of apophytes to the number of permanent species.

$$WAp_t = \frac{Ap}{Sp + An} \times 100\% \qquad WAp_p = \frac{Ap}{Sp + M} \times 100\%$$

3. Spontaneophyte apophytization index ($Wap$) is the percentage contribution of apophytes to the number of native species.

$$Wap = \frac{Ap}{Sp} \times 100\%$$

4. Indices of flora anthropophytization. Total anthropophytization index ($WAn_t$) is the percentage contribution of anthropophytes to the total number of species, while permanent anthropophytization index ($WAn_p$) is the percentage contribution of metaphytes to the number of permanent species.

$$WAn_t = \frac{An}{Sp + An} \times 100\% \qquad WAn_p = \frac{Ap}{Sp + M} \times 100\%$$

5. Indices of flora archaeophytization. Total archaeophytization index ($WAr_t$) is the percentage contribution of archaeophytes to the total number of species, while permanent archaeophytization index ($WAr_p$) is the percentage contribution of archaeophytes to the number of permanent species.

$$WAr_t = \frac{Ar}{Sp + An} \times 100\% \qquad WAr_p = \frac{Ar}{Sp + M} \times 100\%$$

6. Indices of flora kenophytization. Total kenophytization index ($WKn_t$) is the percentage contribution of kenophytes to the total number of species, while permanent kenophytization index ($WKn_p$) is the percentage contribution of kenophytes to the number of permanent species.

$$WKn_t = \frac{Kn}{Sp + An} \times 100\% \qquad WKn_p = \frac{Kn}{Sp + M} \times 100\%$$

7. Flora modernization index ($WM$) is is the percentage contribution of kenophytes to the group of naturalized anthropophytes (metaphytes).

$$WM = \frac{Kn}{M} \times 100\%$$

8. Index of floristic fluctuations ($WF$) is the percentage contribution of diaphytes to the total number of species.

$$WF = \frac{D}{Sp + An} \times 100\%$$

9. Flora naturalness index ($WN$) is the percentage contribution of non-synanthropic spontaneophytes to the total number of species.

$$WN = \frac{Sn}{Sp + An} \times 100\%$$

10. Indices of flora permanence. Anthropophyte permanence index ($WT_a$) is the percentage contribution of metaphytes to the total number of anthropophytes, while total permanence index ($WT_t$) is the percentage contribution of spontaneophytes and metaphytes to the total number of species.

$$WT_a = \frac{M}{An} \times 100\% \qquad WT_t = \frac{Sp + M}{Sp + An} \times 100\%$$

### 4.3.3. Degrees of human impact on the ecosystems: hemeroby scale

The scope of anthropogenic transformations of the studied habitats was classified using the 6 degrees of the hemeroby scale (Jalas 1953, 1955; Sukopp 1969, 1972; Kowarik 1988). They are described in detail by Sukopp (1969, 1972), whereas in Poland, the hemeroby scale was used e.g. by Jackowiak (1990, 1993, 1998), Chmiel (1993, 2006), and Celka (1999, 2004). Considering the specificity of archaeological sites, only 4 degrees of that scale were distinguished in this study:

- Oligohemeroby. Low level of human impact, which does not cause any changes in the soil, so vegetation is similar to the potential natural vegetation. At the study sites, this degree of hemeroby was represented by only several small patches of slightly transformed forests.
- Mesohemeroby. Human impact weak or periodical, associated with direct use of vegetation. Changes in the soil are reversible. At the study sites, this degree is represented by managed forests, various shrub communities, their edges, meadows, xerothermic and sandy grasslands, some microhabitats associated with moats, and crevices of walls made of local rock material.
- Euhemeroby. Human impact strong and permanent. Changes in the soil are substantial and irreversible, which enables formation of segetal (field weeds) and ruderal communities (in waste places) or strongly modified semi-natural communities. At the study sites, euhemeroby was subdivided into α-euhemeroby (including ruderal habitats, farmsteads, roadsides, rubbish dumps, archaeological excavations, wastelands, and strongly transformed shrub communities and wooded patches) and β-euhemeroby (segetal communities of arable fields).
- Polyhemeroby. Continuous, very strong and varied human impact, which permanently or periodically damages the vegetation. The soil is mixed with rubble, slag, organic waste, and other materials. At the study sites, this degree was represented by crevices of walls made of processed materials, and railway tracks crossing the remnants of the castle in Stęszew.

The lowest and highest degrees, i.e. ahemeroby (vegetation natural, no human impact) and metahemeroby (vegetation absent, extreme human impact) were not represented at the study sites.

### 4.3.4. Socio-ecological classification

Principles of the socio-ecological (or synecological) classification, presented by van der Maarel (1971) and Kunick (1974), consist in grouping of syntaxa that are formed in similar environmental conditions and are closely related due to plant succession. In Poland it was used by e.g. Jackowiak (1990, 1993, 1998), Chmiel (1993, 2006), and Żukowski *et al*. (1995). Here I used a modified and simplified classification proposed in my earlier works (Celka 1999, 2004). Individual syntaxa were identified on the basis of Matuszkiewicz (2001), Zarzycki *et al*. (2002), and Rothmaler *et al*. (2005). The following socio-ecological groups were distinguished (with the corresponding syntaxa listed in brackets):

G1. Aquatic and flush vegetation (*Lemnetea, Potamogetonetea, Utricularietea intermedio-minoris, Montio-Cardaminetea*),
G2. Raised bogs and bog meadows (*Scheuchzerio-Caricetea fuscae*),
G3. Communities of waterside therophytes (*Bidentetea tripartiti, Isoëto-Nanojuncetea*),
G4. Tall emergent vegetation: reedbeds and sedge communities (*Phragmitetea*),
G5. Meadows (*Molinio-Arrhenatheretea, Plantaginetea majoris: Agropyro-Rumicion crispi*),
G6. Xerothermic and sandy grasslands (*Sedo-Scleranthetea, Festuco-Brometea*),
G7. Thermophilous shrub communities and forest edge communities (*Trifolio-Geranietea sanguini, Rhamno-Prunetea*),
G8. Acid moors and forest clearings (*Nardo-Callunetea, Epilobietea angustifolii: Epilobion angustifolii* and *Fragarion vescae*),
G9. Coniferous forests and acidophilous broadleaved forests (*Vaccinio-Piceetea, Quercetea robori-petraeae*),
G10. Alluvial forests, willow thickets, and riparian tall-herb fringe communities with climbers (*Salicetea purpureae, Artemisietea: Convolvuletalia sepium*),
G11. Wet and bog forests, and alder thickets (*Alnetea glutinosae, Querco-Fagetea*: *Alno-Padion*),
G12. Thermophilous oak forests, mesophilous broadleaved forests, and nitrophilous shrub communities (*Querco-Fagetea*: *Quercion, Carpinion, Fagion; Artemisietea*: *Alliarion; Epilobietea angustifolii: Sambuco-Salicion*),
G13. Segetal communities (*Secalietea, Chenopodietea*: *Polygono-Chenopodietalia*),
G14. Ruderal communities (*Chenopodietea*: *Eragrostietalia, Sisymbrietalia; Artemisietea*: *Onopordion, Eu-Arction; Plantaginetea majoris*: *Polygonion avicularis*),
G15. Epilithic communities (*Asplenietea rupestris*),
G16. Species of indefinite phytosociological affiliation (mostly ergasiophytes and some kenophytes).

### 4.3.5. Frequency classes

Six frequency classes on a percentage scale were used in this study (Table 1).

**Table 1.** Frequency classes of species recorded on West Slavic archaeological sites

| Class description and abbreviation | No. of sites | % of sites |
|---|---|---|
| extremely rare (RRR) | 1-2 | ≤2.0 |
| very rare (RR) | 3-6 | 2.1-5.5 |
| rare (R) | 7-14 | 5.6-12.8 |
| frequent (F) | 15-30 | 12.9-27.5 |
| very frequent (FF) | 31-60 | 27.6-55.0 |
| common (C) | 61-109 | 55.1-100.0 |

### 4.3.6. Floristic similarity and dissimilarity indices, floristic value

When assessing the floristic similarity of the archaeological sites, 3 indices of floristic similarity were used:

- Jaccard index I (Trojan 1975)

$$Ja = \frac{c}{d} \times 100$$

where: c – number of species found at both sites, d – number of species found at only one site or the other

- Jaccard index II (Kornaś & Medwecka-Kornaś 2002)

$$K = \frac{c}{a+b-c}$$

- Steinhaus index (Perkal 1967)

$$w = \frac{2c}{a+b}$$

where: *a* – number of species at one site, *b* – number of species at another site, *c* – number of species common to both sites.

Floristic value ($W_f$) of a study site is a sum of rarity coefficients ($W_r$) of the species recorded there (Loster 1985):

$$W_f = \sum W_r \qquad W_r = \frac{N - n}{N}$$

where *N* – total number of study sites, *n* – number of study sites where the species was recorded.

Floristic dissimilarity index ($O_f$) of a study site is a mean value of rarity coefficients ($W_r$) of the species recorded there (Loster 1985):

$$O_f = \frac{W_f}{l_k}$$

where $l_k$ – number of species at the study site.

### 4.3.7. Other species characteristics and floristic classifications

Names of species and families follow those used by Mirek *et al*. (2002). The distinguished subspecies were counted in statistical analyses as separate species.

The Raunkiaer system is slightly modified here, as in Kornaś and Medwecka-Kornaś (2002). It includes the following groups: phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes. Species were assigned to individual groups on the basis of Zarzycki *et al*. (2002), Rutkowski (2004), or Rothmaler *et al*. (2005).

Classification of geographical elements of the native flora of the archaeological sites was based on the work of Zając & Zając (2009), who developed the system used by Pawłowska (1972). The origin of archaeophytes found in Poland was thoroughly investigated by Zając (1979, 1983, 1987a, 1987b, 1988), while the origin of kenophytes, by Kornaś (1968), Zając *et al*. (1998), and Tokarska-Guzik (2005). On the basis of those publications, with slight modifications, anthropophytes were divided into various distributional types.

Contributions of indicator species of old deciduous forests were analysed on the basis of their list compiled by Dzwonko & Loster (2001).

## 5. Results

### 5.1. Structure of the current vascular flora of medieval West Slavic settlements and castles

#### 5.1.1. Species composition

The flora of 109 West Slavic archaeological sites includes 876 species of 114 families and 432 genera (Appendix 3). They represent 6 classes, mostly dicotyledons (686 species) and monocotyledons (161 species). The 19 best-represented families (10 or more species each) account for 73% of the total number of species (Table 2). As many as 39 families are represented by single species. The ranking of families in respect of species richness deviates from their ranking in respect of the number of occupied sites (Table 2). The family Asteraceae (100 species) is represented at 106 West Slavic sites, whereas the families Poaceae (83 species) and Rosaceae (53 species) are recorded at all the 109 sites. The most frequently represented families include also the Lamiaceae (108 sites) and Rubiaceae (106). The genera represented by the largest numbers of species (5 or more) comprised in total 226 taxa (over 25% of the total number of species). The best-represented are the genera *Carex* (23 species), *Veronica* (16), *Salix, Trifolium*, and *Vicia* (12 each), and *Galium* (11). About 62% of genera (266) are represented by single species, while about 18% (77), by 2 species each.

#### 5.1.2. Frequency and abundance classes of species

Individual species were recorded at 1-98 sites. Over 31% of species are extremely rare at the study sites, i.e. recorded at only 1-2 sites (Table 3). The species classified in this study as very rare and rare, jointly account for nearly 42% of the total flora. There are also many

**Table 3.** Frequency of species recorded on West Slavic sites

| Frequency class | No. of sites | No. of species | % of species |
|---|---|---|---|
| RRR | 1-2 | 277 | 31.6 |
| RR | 3-6 | 195 | 22.3 |
| R | 7-14 | 172 | 19.6 |
| F | 15-30 | 145 | 16.6 |
| FF | 31-60 | 73 | 8.3 |
| C | 61-109 | 14 | 1.6 |
| Total | | 876 | 100.0 |

Explanations: see Table 1

**Table 2.** Major plant families recorded on West Slavic sites

| Family | No. of species | % of species | No. of sites | % of sites |
|---|---|---|---|---|
| Asteraceae | 100 | 11.4 | 106 | 97.2 |
| Poaceae | 83 | 9.5 | 109 | 100.0 |
| Fabaceae | 53 | 6.1 | 99 | 90.8 |
| Rosaceae | 53 | 6.1 | 109 | 100.0 |
| Brassicaceae | 45 | 5.1 | 83 | 76.1 |
| Lamiaceae | 44 | 5.0 | 108 | 99.1 |
| Scrophulariaceae | 36 | 4.1 | 101 | 92.7 |
| Apiaceae | 35 | 4.0 | 103 | 94.5 |
| Caryophyllaceae | 33 | 3.8 | 103 | 94.5 |
| Cyperaceae | 29 | 3.3 | 66 | 60.6 |
| Ranunculaceae | 25 | 2.9 | 87 | 79.8 |
| Boraginaceae | 19 | 2.2 | 77 | 70.6 |
| Polygonaceae | 18 | 2.1 | 93 | 85.3 |
| Salicaceae | 15 | 1.7 | 51 | 46.8 |
| Rubiaceae | 14 | 1.6 | 106 | 97.2 |
| Campanulaceae | 10 | 1.1 | 66 | 60.6 |
| Chenopodiaceae | 10 | 1.1 | 51 | 46.8 |
| Geraniaceae | 10 | 1.1 | 69 | 63.3 |
| Juncaceae | 10 | 1.1 | 45 | 41.3 |
| Total 19 families | 642 | 73.3 | 109 | 100.0 |
| Other 95 families | 234 | 26.7 | 109 | 100.0 |
| Total | 876 | 100.0 | 109 | 100.0 |

frequent species (nearly 14%) and, interestingly, very frequent ones (nearly 8% of the total number of species). Common species are the least numerous (only 2.2% of the total) and all of them are native (apophytes), e.g. *Urtica dioica* subsp. *dioica* (98 sites), *Dactylis glomerata* subsp. *glomerata* (83), *Sambucus nigra* (82), *Achillea millefolium* (76), *Hypericum perforatum* (74), and *Taraxacum officinale* (72). Among anthropophytes, the most frequent are the archaeophytes *Malva alcea* (47 sites) and *Ballota nigra* (44), and the kenophyte *Conyza canadensis* (43).

**Table 4.** Abundance classes of plant species on West Slavic sites

| Abundance class | Mean values of abundance | No. of species | % of species |
|---|---|---|---|
| Not abundant | 1.0 | 317 | 36.4 |
| Moderately abundant | 1.01-1.99 | 423 | 48.5 |
| Very abundant | 2.00-3.00 | 132 | 15.1 |
| Total | | 872 | 100.0 |

On the basis of mean abundance of individual species, 3 abundance classes were distinguished (Table 4). Moderately abundant species account for half of the flora of archaeological sites. The group of very abundant species comprises 22 very frequent and common native taxa. Most of them are hemicryptophytes and geophytes. They represent various socio-ecological groups, but most of them are meadow plants. This group has a decisive influence on vegetation structure of a majority of the study sites. It includes e.g. *Achillea millefolium, Agrostis capillaris, Bromus inermis, Calamagrostis epigejos, Carex hirta, Fragaria viridis, Poa nemoralis, P. pratensis*, and *Prunus spinosa*.

### 5.1.3. Geographical-historical classification and indices of anthropogenic changes of the flora

In the flora of West Slavic archaeological sites, native species prevail over anthropophytes (Fig. 14). Moreover, the ratio of non-synanthropic spontaneophytes to apophytes is 1.4. Among naturalized anthropophytes, archaeophytes (11.1%) prevail over kenophytes (6.2%). Diaphytes are represented only by ergasiophytes, which are 2.6-fold less numerous than archaeophytes (4.2%). No ephemerophytes (i.e. transient aliens) were recorded.

Numerous members of all geographical-historical groups can be found among extremely rare species (Table 5). The percentage contribution of non-synanthropic spontaneophytes declines in successive frequency classes. The contribution of apophytes is the highest among frequent and very frequent species. Only apophytes are common. Contributions of archaeophytes are nearly the same in the first 4 frequency classes: extremely rare, very rare, rare, and frequent. Only 4 archaeophytes are very frequent. Contributions of kenophytes decline in successive frequency classes, so that only one of them – *Conyza canadensis* – is frequent. Because of the accepted principles of geographical-historical classification, most of ergasiophytes are extremely rare or very rare (32 species). They are sporadically found at individual sites and are never abundant there. The remaining 5 ergasiophytes are rare (e.g. *Juglans regia* and *Malus domestica*). In the upper 3 frequency classes, ergasiophytes are absent.

More than half of the flora of archaeological sites are synanthropic species ($WS_t$=54.1%), mostly thanks to apophytes, rather than anthropophytes ($WAp_t$ is about 1.5-fold higher than $WAn_t$) (Table 6). Less than half of native species are apophytes (*Wap*=41.3%). Most of alien species are archaeophytes ($WAr_t$=11.5% and *WM*=34.4%). The contribution of diaphytes is relatively low (*WF*=4.2%)

The degree of transformation of the flora of archaeological sites is more similar to that of farmland (NE Wielkopolska, after Chmiel 2006) than to that of a large city (Poznań, after Jackowiak 1990). In comparison with them, the flora of West Slavic archaeological sites is

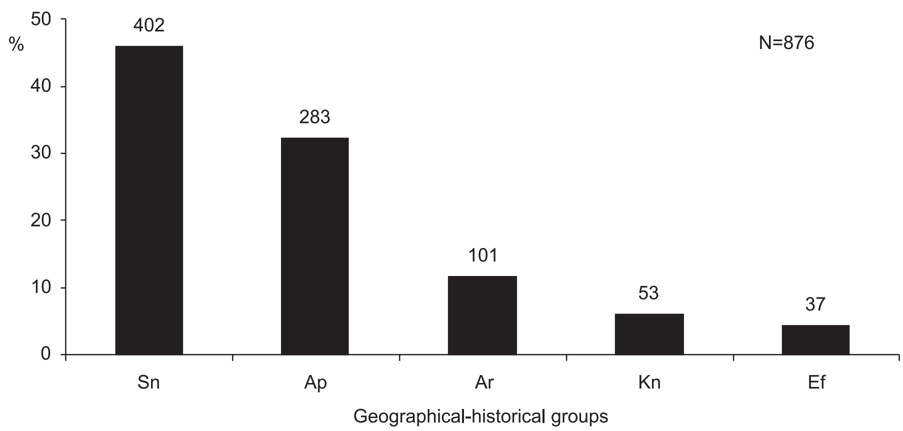



**Fig. 14.** Contributions of geographical-historical groups to the flora of West Slavic archaeological sites
Explanations: Sn – non-synanthropic spontaneophytes, Ap – apophytes, Ar – archaeophytes, Kn – kenophytes, Ef – ergasiophytes

**Table 5.** Contributions of geographical-historical groups within frequency classes of plants recorded on West Slavic sites

| Frequency class | Geographical-historical groups | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sn | | Ap | | Ar | | Kn | | Ef | | Total | |
| | N | % | N | % | N | % | N | % | N | % | N | % |
| RRR | 168 | 19.2 | 34 | 3.9 | 25 | 2.9 | 24 | 2.7 | 26 | 3.0 | 277 | 31.6 |
| RR | 103 | 11.8 | 48 | 5.5 | 25 | 2.9 | 13 | 1.5 | 6 | 0.7 | 195 | 22.3 |
| R | 78 | 8.9 | 51 | 5.8 | 24 | 2.7 | 14 | 1.6 | 5 | 0.6 | 172 | 19.6 |
| F | 47 | 5.4 | 77 | 8.8 | 19 | 2.2 | 2 | 0.2 | 0 | 0.0 | 145 | 16.6 |
| FF | 6 | 0.7 | 62 | 7.1 | 4 | 0.5 | 1 | 0.1 | 0 | 0.0 | 73 | 8.3 |
| C | 0 | 0.0 | 14 | 1.6 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 14 | 1.6 |
| Total | 402 | 45.9 | 286 | 32.6 | 97 | 11.1 | 54 | 6.2 | 37 | 4.2 | 876 | 100.0 |

Explanations: N – no. of species, other abbreviations – see Table 1 and Fig. 14

distinguished by lower indices of total synanthropization, total and permanent anthropophytization, total and permanent kenophytization, flora modernization, and of floristic fluctuations. By contrast, indices of total and permanent apophytization, total and permanent archaeophytization, flora naturalness, anthropophyte permanence, and total permanence are higher at archaeological sites (Table 6).

### 5.1.4. Geographic elements of the native flora and the origin of anthropophytes

The flora of West Slavic settlements and castles includes 685 spontaneophytes representing 3 geographic elements: Holarctic, connective, and cosmopolitan[1]. About half of them (343 species) are Holarctic (Fig. 15). As compared to the flora of Poland, the contribution of

**Table 6.** Indices of anthropogenic changes in the flora of West Slavic sites

| Index [%] | Index name | This study | City[1] | Farmland[2] |
|---|---|---|---|---|
| $WS_t$ | Total synanthropization | 54.1 | 62.7 | 56.1 |
| $WS_p$ | Permanent synanthropization | 52.1 | 54.6 | 49.7 |
| $WAp_t$ | Total apophytization | 32.3 | 26.9 | 26.7 |
| $WAp_p$ | Permanent apophytization | 33.7 | 32.8 | 30.6 |
| $Wap$ | Spontaneophyte apophytization | 41.3 | 42.0 | 37.8 |
| $WAn_t$ | Total anthropophytization | 21.8 | 35.8 | 29.3 |
| $WAn_p$ | Permanent anthropophytization | 18.4 | 21.8 | 19.2 |
| $WAr_t$ | Total archaeophytization | 11.5 | 9.5 | 9.4 |
| $WAr_p$ | Permanent archaeophytization | 12.0 | 11.6 | 10.8 |
| $WKn_t$ | Total kenophytization | 6.1 | 8.4 | 7.3 |
| $WKn_p$ | Permanent kenophytization | 6.3 | 10.4 | 8.4 |
| $WM$ | Flora modernization | 34.4 | 46.8 | 43.8 |
| $WF$ | Floristic fluctuations | 4.2 | 17.9 | 12.6 |
| $WN$ | Flora naturalness | 45.9 | 37.3 | 43.9 |
| $WT_a$ | Anthropophyte permanence | 80.6 | 50.1 | 57.0 |
| $WT_t$ | Total permanence | 95.8 | 82.1 | 87.4 |

Explanations: [1] – Poznań (Jackowiak 1990), [2] – NE Wielkopolska (Chmiel 2006, Sp/Ap included in Sp)

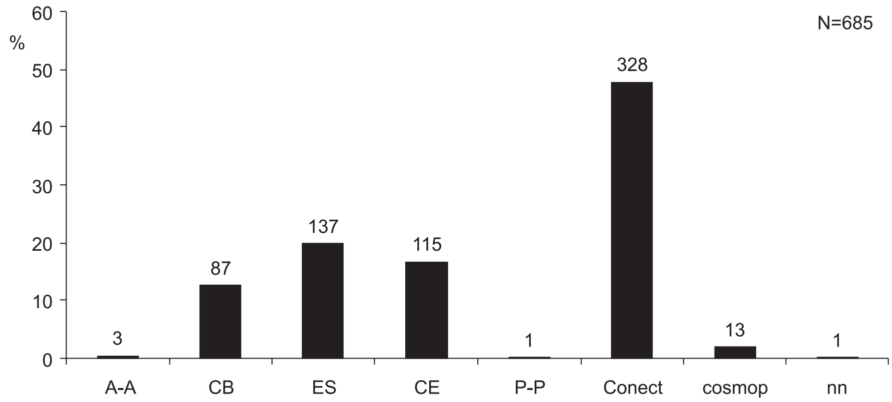



**Fig. 15.** Contributions of geographic elements and sub-elements to the native flora of West Slavic archaeological sites
Explanations: A-A – Arctic-Alpine sub-element, CB – Circum-Boreal sub-element, ES – Euro-Siberian sub-element, CE – European-temperate sub-element, PP – Pontic-Pannonian sub-element, Connect – connective element, cosmop – cosmopolitan element, n – not classified

[1] The analysis includes also several species found exclusively in Czech and German settlement and castles

Holarctic species is nearly 1.5-fold lower. Nevertheless, like in the Polish flora, the Holarctic element is dominated by Circum-Boreal, Euro-Siberian, and European-temperate sub-elements. However, the contribution of the last sub-element is very much lower than in the Polish flora. By contrast, the contribution of Euro-Siberian sub-elements is higher None of the recorded species belong to the Altaic-Alpic and Amphi-Atlantic sub-elements. The Arctic-Alpine sub-element is represented by 3 species (*Alnus incana, Angelica archangelica* subsp. *archangelica*, and *Saxifraga paniculata*), while the Pontic-Pannonian sub-element, by only one (*Melica picta*). At the archaeological sites, an important role is played by the connective element. It accounts for 48% of the flora and is nearly 1.5-fold higher than in the Polish flora. The connective element includes 328 species. Among them, 283 are partly Mediterranean and 166 are partly Irano-Turanian. The cosmopolitan element includes 13 species. Their wide distribution is either natural (pteridophytes: *Asplenium trichomanes, Pteridium aquilinum*; aquatic and marsh plants: *Lemna minor, Phragmites australis, Spirodela polyrhiza, Typha angustifolia, Utricularia australis*, etc.) or anthropogenic, i.e. resulting from their expansion due to human activity (e.g. *Plantago major, Polygonum aviculare, Stellaria media*).

The geographical structure of the flora of historical sites is shaped to a large extent by anthropophytes. Most of the archaeophytes distinguished by Zając (1979) are Mediterranean (28 species, e.g. *Ballota nigra*, *Carduus acanthoides* or *Malva sylvestris*), or Mediterranean-Irano-Turanian (17 species, e.g. *Adonis aestivalis*, *Conium maculatum* or *Papaver dubium*). In total, these groups comprise nearly 48% archaeophyte species. Besides, some archaeophytes are Irano-Turanian (8 species, e.g. *Hyoscyamus niger* and *Malva neglecta*), Mediterranean-Irano-Turanian (5 species, e.g. *Senecio vulgaris* and *Vicia hirsuta*), Central European (6 species, e.g. *Armoracia rusticana* and *Chenopodium bonus-henricus*), and Pontic-Pannonian (5 species, e.g. *Consolida regalis* and *Leonurus cardiaca*). Only 3 species come from southern and south-eastern Asia (*Anagallis arvensis, Echinochloa crus-galli,* and *Setaria pumilla*). The group of archaeophytes includes also 3 species that have survived exclusively at anthropogenic sites (termed *archeophyta resistentia*: *Chenopodium hybridum*, *Matriaria maritima* subsp. *inodora,* and *Veronica triphyllos*) and 4 man-made species (termed *archeophyta anthropogena*: *Bromus secalinus, Camelina sativa*, *Neslia paniculata*, and *Odontites verna*).

The group of kenophytes is dominated by North American plants (22 species, about 40%, e.g. *Acer negundo, Bromus carinatus* or *Solidago gigantea*). Only 3 species come from South and Central America (*Amaranthus chlorostachys, Galinsoga ciliata,* and *G. parviflora*), while 8 species originate from Asia (e.g. *Acorus calamus*, *Reynoutria japonica,* and *Veronica persica*). Eurasian kenophytes include 15 species (e.g. *Cardaria draba, Senecio vernalis,* and *Vicia grandiflora*). Seven kenophytes come from various parts of Europe, e.g. from South Europe (*Cymbalaria muralis* and *Geranium pyrenaicum*). One kenophyte is man-made: *Medicago varia*.

Also ergasiophytes come from various parts of the world: America (7 species, e.g. *Lycopersicon esculentum* and *Rudbeckia laciniata*), Asia (7 species, e.g. *Juglans regia* and *Thladiantha dubia*), and Europe or Eurasia (16 species, e.g. *Hemerocallis fulva, Iberis umbellata,* and *Syringa vulgaris*). Some of the taxa are native to Poland but at the archaeological sites they were evidently garden escapes (e.g. *Taxus baccata*, *Vinca minor*). Ergasiophytes include also some man-made species (e.g. *Mentha spicata* and *Prunus domestica*).

### 5.1.5. Spectrum of life-forms

The spectrum of Raunkiaer life-forms at archaeological sites does not deviate from the Central European standard (Fig. 16). The dominant life-forms are

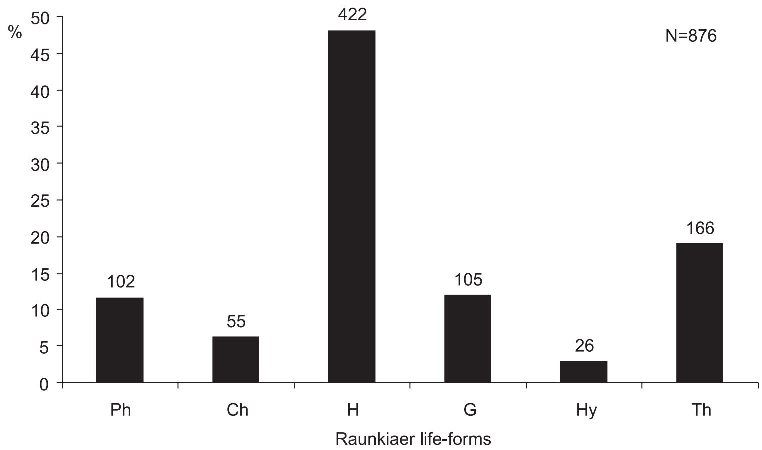



**Fig. 16.** Contributions of Raunkiaer life-forms to the flora of West Slavic sites
Explanations: Ph – phanerophytes, Ch – chamaephytes, H – hemicryptophytes, G – geophytes, Hy – hydrophytes, Th – therophytes

**Table 7.** Contributions of Raunkiaer life-forms within frequency classes of plants recorded on West Slavic sites

| Life-form | Frequency class | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RRR | | RR | | R | | F | | FF | | C | | Total | |
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| Ph | 24 | 2.7 | 22 | 2.5 | 22 | 2.5 | 21 | 2.4 | 11 | 1.3 | 2 | 0.2 | 102 | 11.6 |
| Ch | 23 | 2.6 | 9 | 1.0 | 9 | 1.0 | 10 | 1.1 | 3 | 0.3 | 1 | 0.1 | 55 | 6.3 |
| H | 125 | 14.3 | 84 | 9.6 | 82 | 9.4 | 79 | 9.0 | 42 | 4.8 | 10 | 1.1 | 422 | 48.2 |
| G | 39 | 4.5 | 18 | 2.1 | 22 | 2.5 | 16 | 1.8 | 9 | 1.0 | 1 | 0.1 | 105 | 12.0 |
| Hy | 11 | 1.3 | 10 | 1.1 | 3 | 0.3 | 2 | 0.2 | 0 | 0.0 | 0 | 0.0 | 26 | 3.0 |
| Th | 55 | 6.3 | 52 | 5.9 | 34 | 3.9 | 17 | 1.9 | 8 | 0.9 | 0 | 0.0 | 166 | 18.9 |

Explanations: N – no. of species, other abbreviations – see Table 1 and Fig. 16

hemicryptophytes, which jointly with therophytes account for over 67% of the flora. The ratio of hemicryptophytes to therophytes is 2.5. The contribution of cryptophytes is also high, and they are dominated by geophytes and phanerophytes (mostly shrubs).

Nearly all Raunkiaer life-forms are represented in all frequency classes. Exceptions are hydrophytes, which are absent in the classes of very frequent and common species (Table 7), and therophytes, which are absent in the class of common species. Contributions of the most species-rich groups (hemicryptophytes and therophytes) decrease with increasing frequency.

A geographical-historical analysis of life-forms shows e.g. that there are no archaeophytes among phanerophytes and hydrophytes, while no ergasiophytes among hydrophytes (Fig. 17). Except for therophytes, in all Raunkiaer groups most species are non-synanthropic spontaneophytes and apophytes. This is understandable, considering the dominance of native species in the flora of archaeological sites. A majority of hydrophytes and geophytes are non-synanthropic spontaneophytes. Archaeophytes and kenophytes dominate among therophytes, while ergasiophytes among phanerophytes.

### 5.1.6. Degrees of hemeroby of habitats and of the flora of archaeological sites

According to the 5-degree scale of hemeroby, oligohemerobic habitats (H1) are represented only by small patches of deciduous forests, at 3 fortified settlements located within extensive woodlands. The habitats found at archaeological sites are mostly mesohemerobic (H2), including water bodies, moats filled with water periodically or all the time, fragments of natural water bodies and watercourses, meadows and marshes, xerothermic and sandy grasslands, managed forests and shrub communities, and crevices in walls of castles located in the Kraków-Częstochowa Upland. Euhemerobic habitats are subdivided into α-euhemerobic (H3) and β-euhemerobic ones (H4). The former group includes ruderal habitats, farmsteads, roadsides, rubbish dumps, archaeological excavations, wastelands, and strongly transformed shrub communities and groups of trees. The latter group comprises segetal communities. Only few habitats are polyhemerobic (H5), e.g. crevices in walls of castles located outside the Kraków-Częstochowa Upland and railway tracks running across the castle in Stęszew.

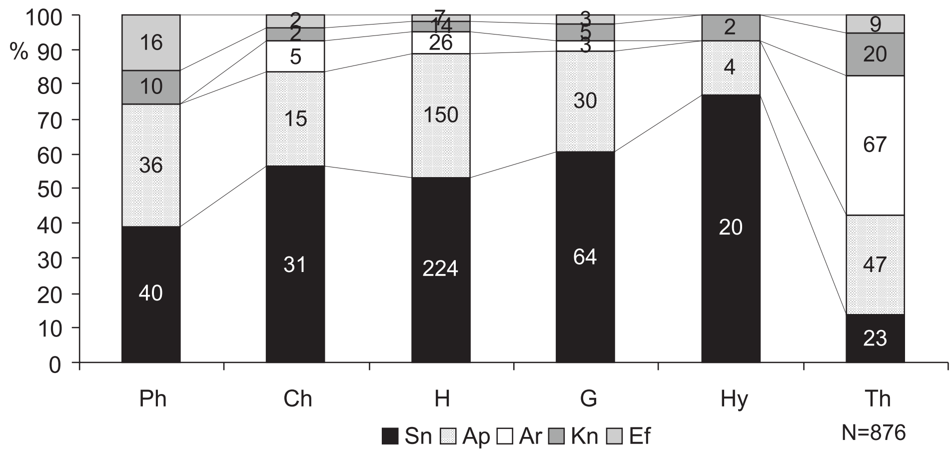



**Fig. 17.** Contributions of geographical-historical groups within Raunkiaer life-form groups at West Slavic sites
Explanations: see Figs. 14, 16

The mean degree of hemeroby of the habitats found within the study sites is 2.31. Over 71% of floristic relevés document mesohemerobic habitats, while 23% document α-euhemerobic ones. Relevés recorded at the other types of habitats account jointly for less than 6% of the total number of relevés (oligohemerobic 1.6%, β-euhemerobic 2.2%, and polyhemerobic 1.6%). These rare habitat types at the study sites are colonized by small numbers of species: 128, 104, and 70, respectively. The richest in species are mesohemerobic habitats (760 species) and α-euhemerobic ones (438). Nearly half of the 872 recorded species are stenohemerobic, i.e. found in habitats representing only one of the 5 degrees. As a rule, these species are classified in this study as extremely rare, very rare and rare (Table 8). About 35% (304 species) were present in habitats representing 2 degrees of hemeroby, while about 13% (110 species), in habitats representing 3 degrees. These taxa belong to all frequency classes, but most of them are rare very rare, rare, frequent, and very frequent. In habitats representing 4 degrees of hemeroby, 27 species were recorded (about 3%). These species are frequent, very frequent, or common. The contribution of euryhemerobic species, i.e. those found in habitats of all 5 degrees of hemeroby, is small (0.6%). This group consists of 5 widespread apophytes: *Galium aparine*, *Stellaria media, Taraxacum officinale, Urtica dioica*, and *Veronica hederifolia* (Table 8).

Most of stenohemerobic species (349) are found, as could be expected, in mesohemerobic habitats. Only in α-euhemerobic habitats, 64 species were recorded. Most of them are aliens, e.g. *Bromus carinatus, Reynourtia japonica* or *Sisymbrium loeselii*; but some species are native, e.g. *Carex spicata, Cerinthe minor* or *Cynosurus cristatus*. Only in β-euhemerobic habitats, 15 species were observed. They are predominantly archaeophytes, e.g. *Adonis aestivalis, Bromus secalinus* or *Stachys annua*. The lowest numbers of stenohemerobic species are found in oligohemerobic habitats (5 species: *Cardamine impatiens, Chrysosplenium alternifolium, Dentaria enneaphyllos, Sorbus torminalis*, and *Veronica montana*) and in polyhemerobic ones (6 species: *Asplenium ruta-muraria, A. trichomanes, Cystopteris fragilis, Diplotaxis tenuifolia, Cymbalaria muralis*, and *Papaver somniferum*). Their frequency is related to the hemeroby of the habitats. The extreme habitat types, i.e. oligohemerobic and polyhemerobic ones, are dominated by frequent and very frequent species, as these frequency classes comprise more than half of the total flora (Fig. 18a). Mesohemerobic habitats have the highest contributions of extremely rare and rare species, while in α- and β-euhemerobic habitats, chiefly rare and frequent were recorded.

Considering the geographical-historical classification (Fig. 18b), native species dominate in habitats representing all degrees of hemeroby except β-euhemerobic habitats. As the degree of hemeroby increases, the percentage contribution of non-synanthropic spontaneophytes declines. They dominate in oligohemerobic and mesohemerobic ones, where their species richness is 1.7-fold and 1.5-fold higher, respectively, than that of apophytes. By contrast, in α-euhemerobic habitats, the contribution of apophytes is 3.8-fold higher than that of non-synanthropic spontaneophytes. In β-euhemerobic and polyhemerobic habitats, non-synanthropic spontaneophytes are absent. In oligohemerobic habitats, apart from native species, one anthropophyte was observed (*Impatiens parviflora*). In polyhemerobic habitats, native species dominate again (apophytes exceed 74%). The contribution of anthropophytes is the highest in β-euhemerobic habitats (over 61%). Most of them are archaeophytes (about 54%) or apophytes (about 39%). Also in α-euhemerobic habitats, the dominant group are archaeophytes, besides them, kenophytes and ergasiophytes are also strongly represented.

As regards plant-forms, in all habitat types except β-euhemerobic ones, hemicryptophytes prevail, with high contributions of phanerophytes and geophytes (Fig. 18c). By contrast, β-euhemerobic habitats are dominated by therophytes. Their contribution is high also in α-euhemerobic and polyhemerobic habitats. Interestingly, the contribution of phanerophytes is high in oligohemerobic and polyhemerobic habitats. They are absent in β-euhemerobic habitats, while hydrophytes are

**Table 8.** Contributions of species recorded in habitats representing one or more degrees of hemeroby within individual frequency classes at West Slavic sites

| No. of degrees of hemeroby | Frequency class | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RRR | | RR | | R | | F | | FF | | C | | Total | |
| | N | % | N | % | N | % | N | % | N | % | N | % | N | % |
| 1 | 240 | 87.9 | 112 | 57.4 | 62 | 36.0 | 12 | 8.3 | 0 | 0.0 | 0 | 0.0 | 426 | 48.9 |
| 2 | 31 | 11.4 | 73 | 37.4 | 80 | 46.5 | 84 | 57.9 | 33 | 45.2 | 3 | 21.4 | 304 | 34.9 |
| 3 | 2 | 0.7 | 10 | 5.1 | 30 | 17.4 | 44 | 30.3 | 18 | 24.7 | 6 | 42.9 | 110 | 12.6 |
| 4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 4 | 2.8 | 20 | 27.4 | 3 | 21.4 | 27 | 3.1 |
| 5 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1 | 0.7 | 2 | 2.7 | 2 | 14.3 | 5 | 0.6 |
| Total | 273 | 100.0 | 119 | 100.0 | 192 | 100.0 | 183 | 100.0 | 86 | 100.0 | 19 | 100.0 | 872 | 100.0 |

Explanations: N – no. of species, other abbreviations – see Table 1

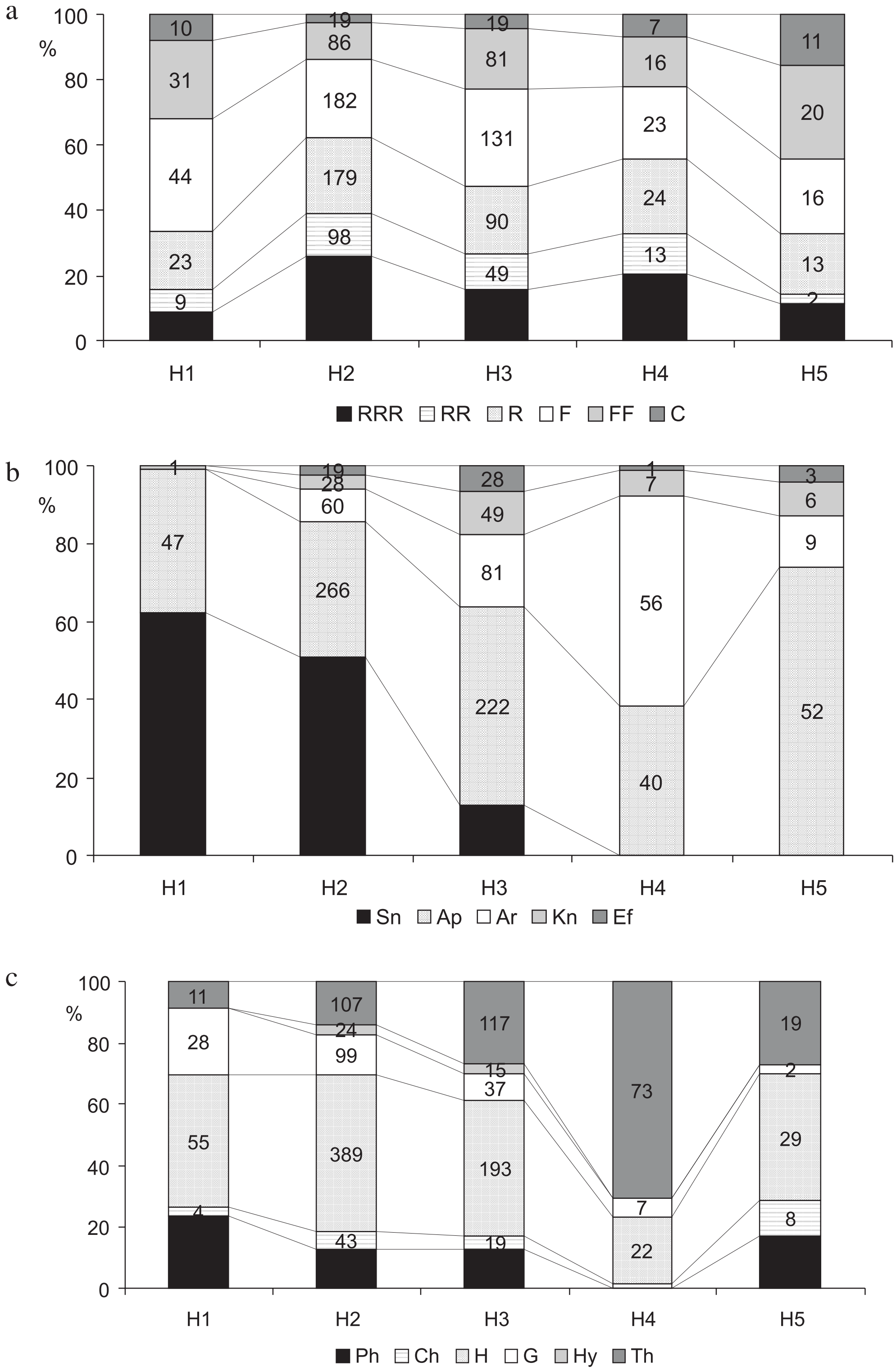



**Fig. 18.** Contributions of habitats with various degrees of hemeroby within frequency classes (a), geographical-historical groups (b), and Raunkiaer's life-forms (c)
Explanations: see Tables 1, 9 and Figs. 14, 16

absent in oligohemerobic, β-euhemerobic and polyhemerobic habitats. The contribution of chamaephytes is the highest in polyhemerobic habitats, while the contribution of geophytes declines with increasing human impact. It is highest in oligohemerobic habitats, where it is nearly equal to that of phanerophytes, and only about 2-fold lower than that of hemicryptophytes.

Contributions of socio-ecological groups (Table 9) indicate that oligohemerobic habitats are dominated by species of thermophilous oak forests, mesophilous deciduous forests, and nitrophilous shrub communities (G12), coniferous forests and acidophilous broadleaved forests (G11), or wet and bog forests and alder thickets (G9). These 3 groups jointly account for over 80% of

**Table 9.** Contributions of socio-ecological groups to the flora of habitat groups that differ in degrees of hemeroby at West Slavic sites

| Group | Degree of hemeroby | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H1 | | H2 | | H3 | | H4 | | H5 | |
| | N | % | N | % | N | % | N | % | N | % |
| G1 | 0 | 0.0 | 12 | 1.6 | 5 | 1.1 | 0 | 0.0 | 0 | 0.0 |
| G2 | 0 | 0.0 | 8 | 1.1 | 1 | 0.2 | 0 | 0.0 | 0 | 0.0 |
| G3 | 0 | 0.0 | 15 | 2.0 | 12 | 2.7 | 4 | 3.8 | 0 | 0.0 |
| G4 | 2 | 1.6 | 44 | 5.8 | 26 | 5.9 | 0 | 0.0 | 1 | 1.4 |
| G5 | 3 | 2.3 | 127 | 16.7 | 61 | 13.9 | 8 | 7.7 | 10 | 14.3 |
| G6 | 1 | 0.8 | 151 | 19.9 | 50 | 11.4 | 6 | 5.8 | 11 | 15.7 |
| G7 | 8 | 6.3 | 41 | 5.4 | 13 | 3.0 | 0 | 0.0 | 0 | 0.0 |
| G8 | 3 | 2.3 | 22 | 2.9 | 7 | 1.6 | 1 | 1.0 | 0 | 0.0 |
| G9 | 13 | 10.2 | 40 | 5.3 | 5 | 1.1 | 0 | 0.0 | 3 | 4.3 |
| G10 | 2 | 1.6 | 18 | 2.4 | 13 | 3.0 | 0 | 0.0 | 0 | 0.0 |
| G11 | 15 | 11.7 | 28 | 3.7 | 13 | 3.0 | 0 | 0.0 | 2 | 2.9 |
| G12 | 76 | 59.4 | 120 | 15.8 | 45 | 10.3 | 3 | 2.9 | 9 | 12.9 |
| G13 | 1 | 0.8 | 31 | 4.1 | 52 | 11.9 | 57 | 54.8 | 4 | 5.7 |
| G14 | 4 | 3.1 | 79 | 10.4 | 99 | 22.6 | 23 | 22.1 | 22 | 31.4 |
| G15 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 4 | 5.7 |
| G16 | 0 | 0.0 | 24 | 3.2 | 36 | 8.2 | 2 | 1.9 | 4 | 5.7 |

Explanations: H1 – oligohemeroby, H2 – mesohemeroby, H3 – α-euhemeroby, H4 – β-euhemeroby, H5 – polyhemeroby, N – no. of species, G1-G16 – see section 4.3.4

the flora. Their contributions clearly decline with increasing human impact, except for group G12, which is well represented even in polyhemerobic habitats. Outside oligohemerobic habitats, an important role is played by species of dry grasslands (G6) and meadows (G5). As the degree of hemeroby increases, contributions of ruderal and segetal species (G14 and G13) also increase. The last mentioned group, as could be expected, prevail in β-euhemerobic habitats. The broadest synecological spectrum is observed in mesohemerobic and α-euhemerobic habitats, where species of 15 groups are found. Epilithic communities (G15) were found only in polyhemerobic habitats.

After exclusion of extremely rare and very rare species, the remaining 480 species were analysed in respect of their scale of hemeroby. Three groups of species were distinguished: (*i*) associated with specific degrees of hemeroby; (*ii*) similarly frequent in habitats representing several degrees; and (*iii*) unevenly distributed in several degrees of hemeroby. Species of the last group are most numerous. Four species can be regarded as local hemeroby indicators in α-euhemerobic habitats, while 107 species in mesohemerobic habitats (*Chamomilla suaveolens*, *Malva sylvestris*, *Sisymbrium loeselii*, and *Sonchus asper*). It is noteworthy that no species from the higher frequency classes are associated exclusively with oligohemerobic and polyhemerobic habitats, while 46 species are associated exclusively with the least disturbed habitats, i.e. oligo- and mesohemerobic ones (Fig. 19).

### 5.1.7. Socio-ecological spectrum

Numbers of species in individual socio-ecological groups range from 4 (group G15, epilithic communities) to 153 (G6, sandy and xerothermic grasslands). Beside group G6, the most species-rich groups are: G5 (meadows), G12 (thermophilous oak forests, mesophilous broadleaved forests, and nitrophilous shrub communities), and G14 (ruderal communities) (Fig. 20). These 4 groups jointly account for nearly 60% of the flora.

In groups G1-G12 and G15, most species are native. Single expansive kenophytes are found in coniferous forests and acidophilous broadleaved forests (*Padus serotina, Quercus rubra*), alluvial forests (*Acer negundo, Echinocystis lobata*), mesophilous broadleaved forests (*Impatiens parviflora, Robinia pseudoacacia*), whereas single archaeophytes are observed on sandy and xerothermic grasslands (*Camelina microcarpa* subsp. *sylvestris, Lavatera thuringiaca, Valerianella locusta*), and in mesophilous broadleaved forests and nitrophilous shrub communities (*Allium scorodoprasum*, *Gagea arvensis*, *Viola odorata*).

Groups G5, G6, G7, G12, and G14 are represented at nearly all archaeological sites (Fig. 24). By contrast, the species-rich groups G1 (aquatic and flush vegetation), G2 (raised bogs and bog meadows), and G3 (communities of waterside therophytes) are found at a relatively low number of sites. This results from the small contribution of wet and aquatic habitats at the archaeological sites. They are usually represented only by fragments of moats, periodically or permanently waterlogged. Group 15 (epilithic communities) is composed of very few species: *Asplenium ruta muraria*, *Asplenium trichomanes*, *Cystopteris fragilis*, *Cymbalaria muralis*. Despite this, archaeological sites are characterized by a high constancy of these species, as they are relatively common on walls of castles.

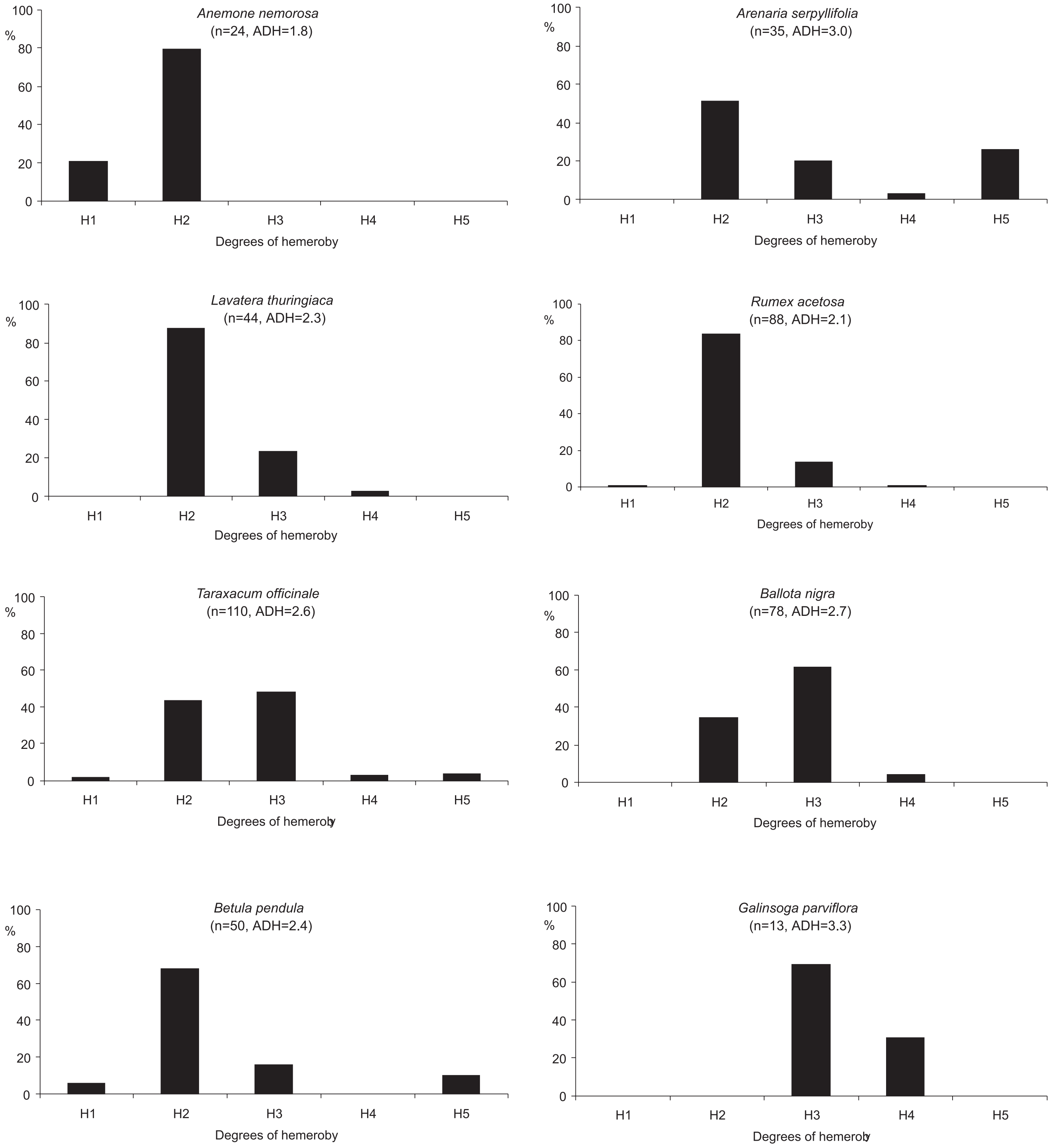



**Fig. 19.** Hemeroby scales of selected species at West Slavic sites
Explanations: H1-H5 – see Table 9, n – no. of sites, ADH – average degree of hemeroby

### 5.1.8. Species of old deciduous forests in the flora of archaeological sites

Contributions of indicator species of old deciduous forests were analysed in the flora of archaeological sites on the basis of 100 Slavic settlements located in Poland. Some archaeological sites are currently strongly affected by human interference: management of meadows and pastures, or urbanization (a number of them are located in city centres). However, as many as 82 sites were abandoned in the Middle Ages (500-800 years ago) and have not been inhabited since then. Some of them could be sporadically used by local people in case of danger, war, and hostile attacks. Most of these sites are covered by shrub communities or forest patches of various size. Many archaeological sites are situated

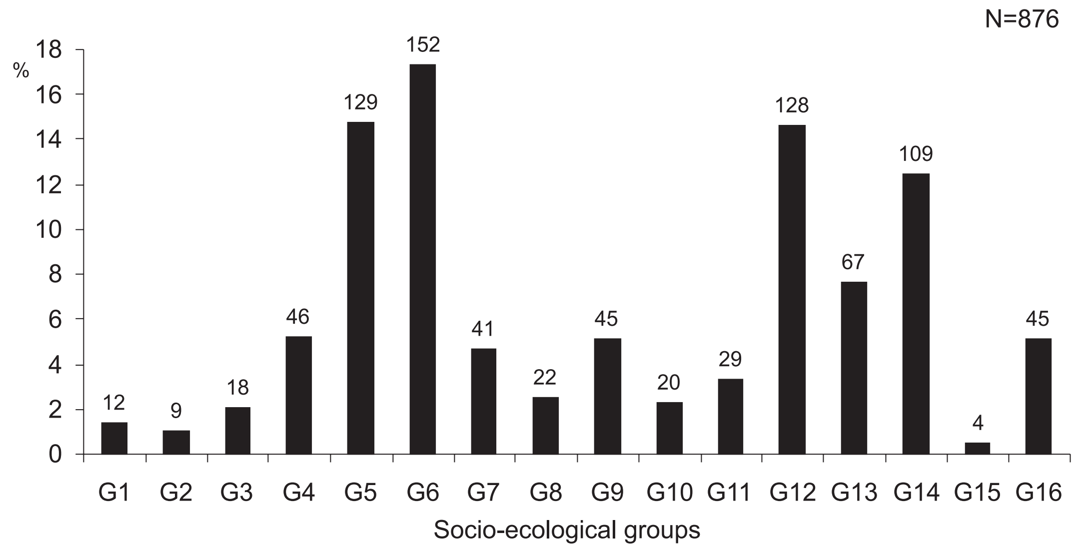



**Fig. 20.** Contributions of socio-ecological groups to the flora of West Slavic sites
Explanations: see section 4.3.4

far away from modern human settlements. Such sites could be subject to plant succession without human interference. In many cases, this has lead to regeneration of close-to-natural vegetation.

At the study sites, 98 species of old deciduous forests were recorded. This group accounts for 11.2% of the total flora (see Appendix 3). Most of the species are classified in this study as extremely rare, very rare, rare, and frequent. Only one species, *Geum urbanum*, is common at the study sites. In this group, the most numerously represented life-forms are hemicryptophytes (46%) and geophytes (35%), while the contribution of phanerophytes and therophytes is negligible. In the synecological spectrum, the dominant group are species of thermophilous oak forests, mesophilous deciduous forests, and nitrophilous shrub communities (G12, 71 species). The remaining species represented thermophilous shrub communities and forest edge communities (G7, 1 species), coniferous forests and acidophilous broadleaved forests (G9, 16 species) and wet and bog forests and alder thickets (G11, 10 species).

The contribution of species of old deciduous forests at the study sites ranges from 0 to 60%. They are absent in 13 fortified settlements and a castle that are de-

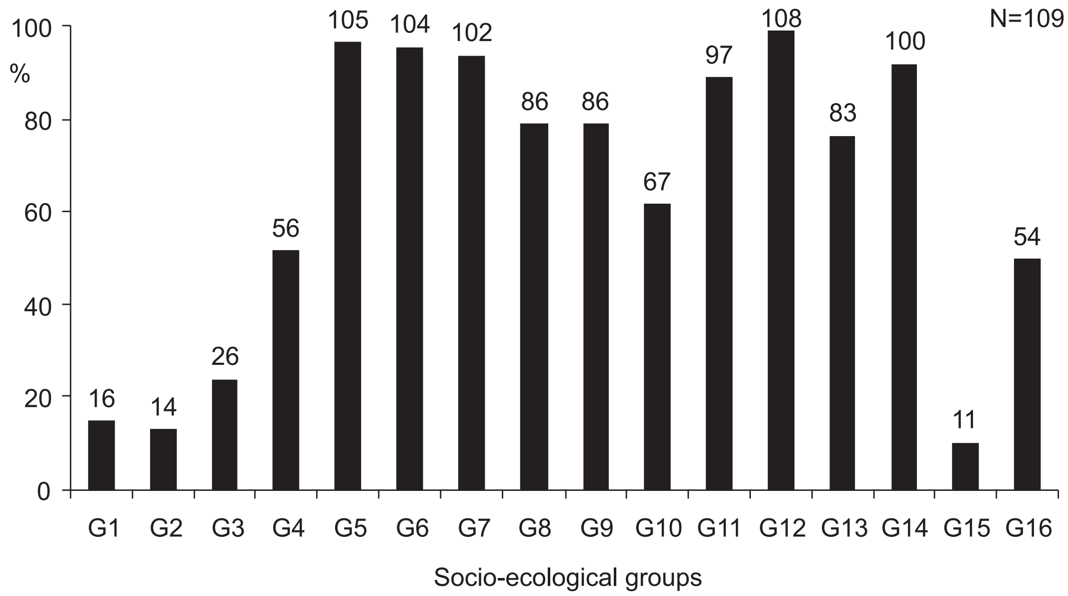



**Fig. 21.** Importance of socio-ecological groups in the studied vegetation, expressed as the number of West Slavic archaeological sites where they were recorded
Explanations: see section 4.3.4

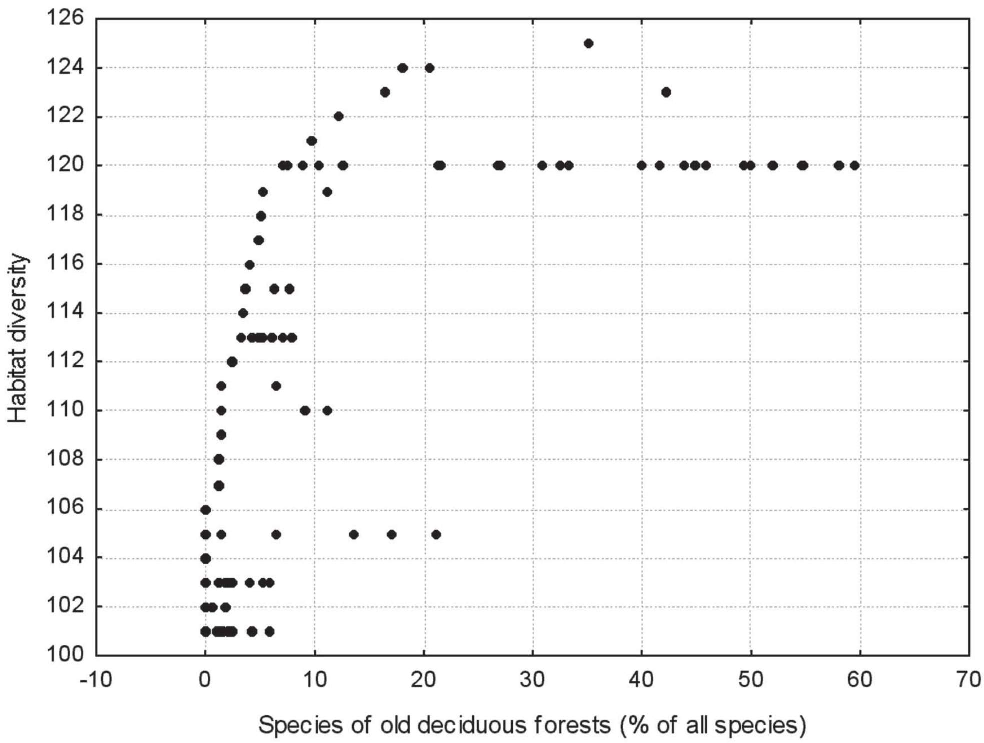



**Fig. 22.** Spearman rank correlation between the percentage contribution of species of old deciduous forests and habitat diversity (i.e. number of various habitats) at individual West Slavic sites ($R = 0.80$, $p < 0.05$)

void of forest and shrub communities. The contribution of species of old deciduous forests is strongly dependent on the types of plant communities developed there (Fig. 22). It was the highest (over 50%) at 8 sites that are completely wooded and located within extensive woodlands, e.g. 3 sites in Myślibórz and a fortified settlement in Ostrężnik.

### 5.2. Variation in the current vascular flora of West Slavic archaeological sites

#### 5.2.1. Number, frequency, and abundance classes of species

Numbers of species at individual West Slavic sites vary from 33 (fortified settlement in Ostrowiec) to 268

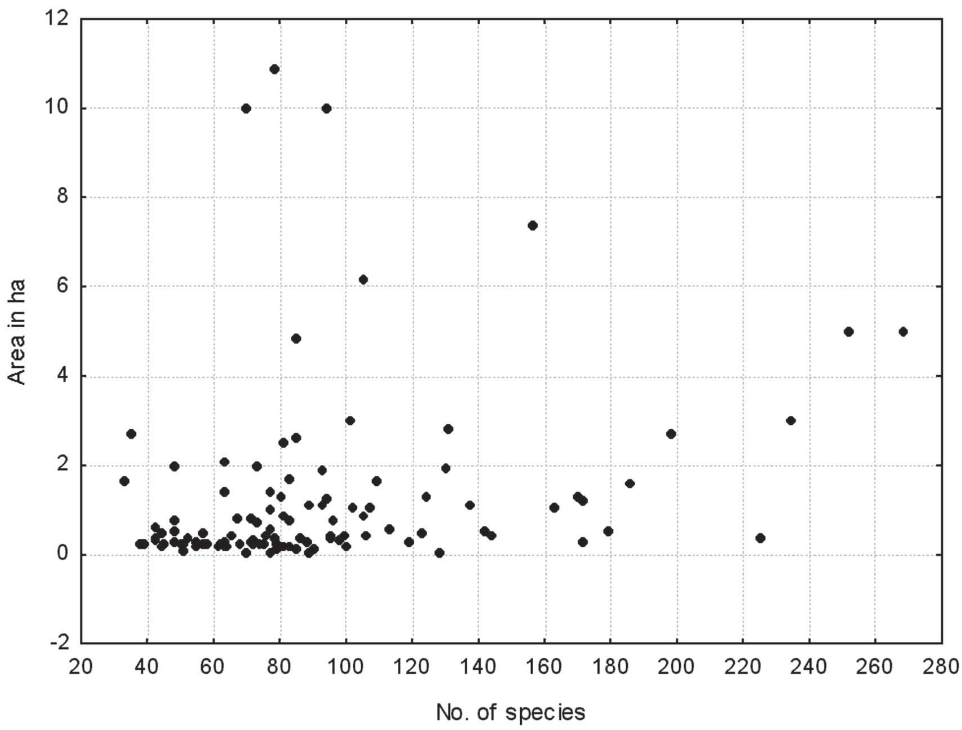



**Fig. 23.** Spearman rank correlation between species richness and size of West Slavic sites ($R = 0.37$, $p < 0.05$)

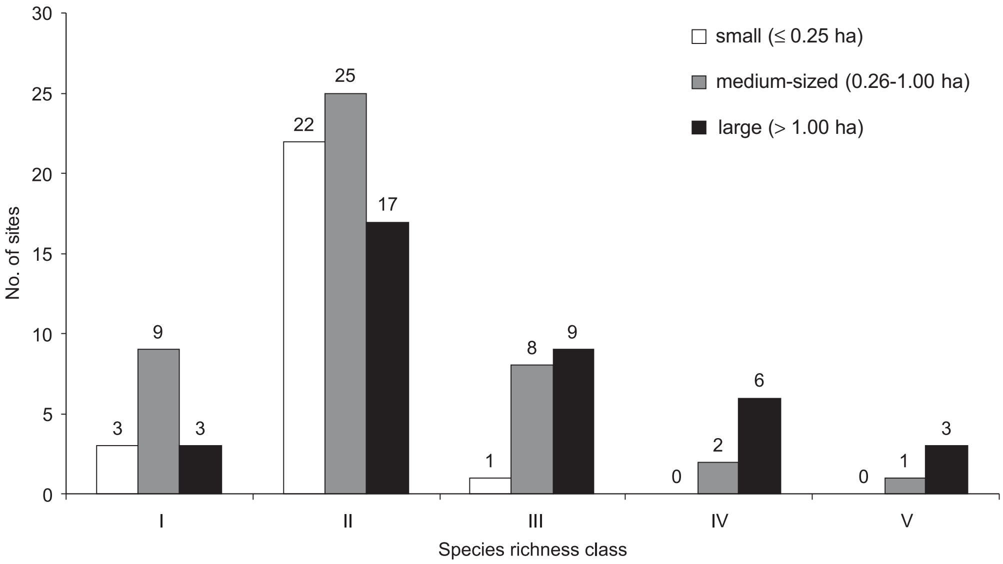



**Fig. 24.** Distribution of species richness at West Slavic archaeological sites
Explanations: I – ≤ 50 species at the given site, II – 51-100, III – 101-150, IV – 151-200, V – ≥ 201

(castle in Olsztyn near Częstochowa) (Appendix 4). The mean is 91.6 species per site, but a lower number was recorded at 69 sites, while a higher number at 40 sites. Their size ranges from 0.02 ha to over 10 ha. Site size is weakly positively correlated with species richness (Fig. 23).

Among the 5 classes of species richness, the largest number of study sites are assigned to class II, with 51-100 species (Fig. 24). The lowest number of species was recorded in fortified settlements located in extensive woodlands: in Pomerania and the submontane zone. They belong to all size classes: small (up to 0.25 ha), medium-sized (0.26-1.00 ha), and large (over 1 ha). The most species-rich are large, or rarely medium-sized, study sites with a high habitat diversity, located in various parts of the study area.

Among the 3 major site types (castles, concave fortified settlements, and cone-shaped settlements), the highest maximum and mean numbers of species were recorded at castles (Fig. 25), while the lowest values (except the minimum) were recorded in cone-shaped settlements. In particular, the maximum number of species in the latter site type is clearly the lowest, and the range of variation in species number was the lowest, too.

Among the 4 chronological groups of West Slavic sites, the highest mean and widest range of variation in species number were observed in study sites used from

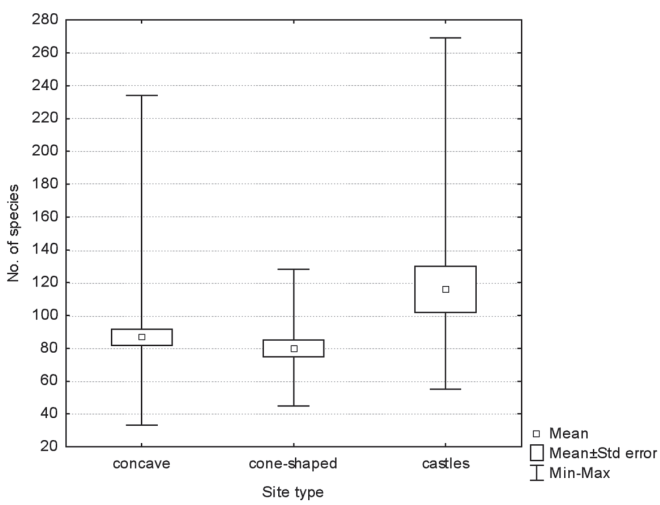



**Fig. 25.** Mean values and ranges of species number at the 3 types of West Slavic sites

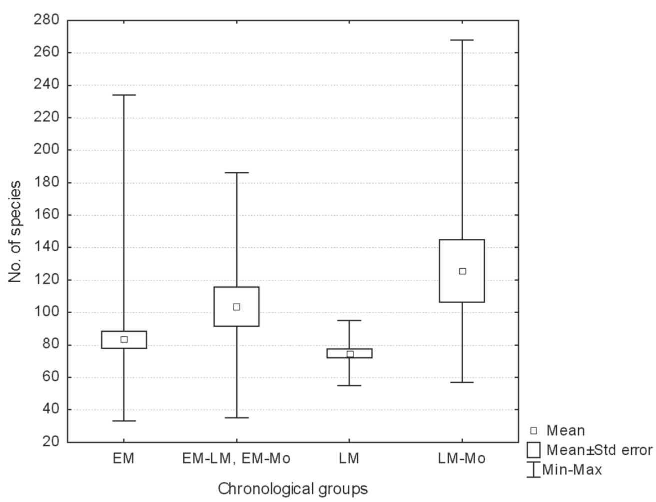



**Fig. 26.** Mean values and ranges of species number within chronological groups of West Slavic sites
Explanations: EM – early medieval, EM-LM, EM-Mo – early medieval to late medieval or to modern era, LM – late medieval, LM-Mo – late medieval to modern era

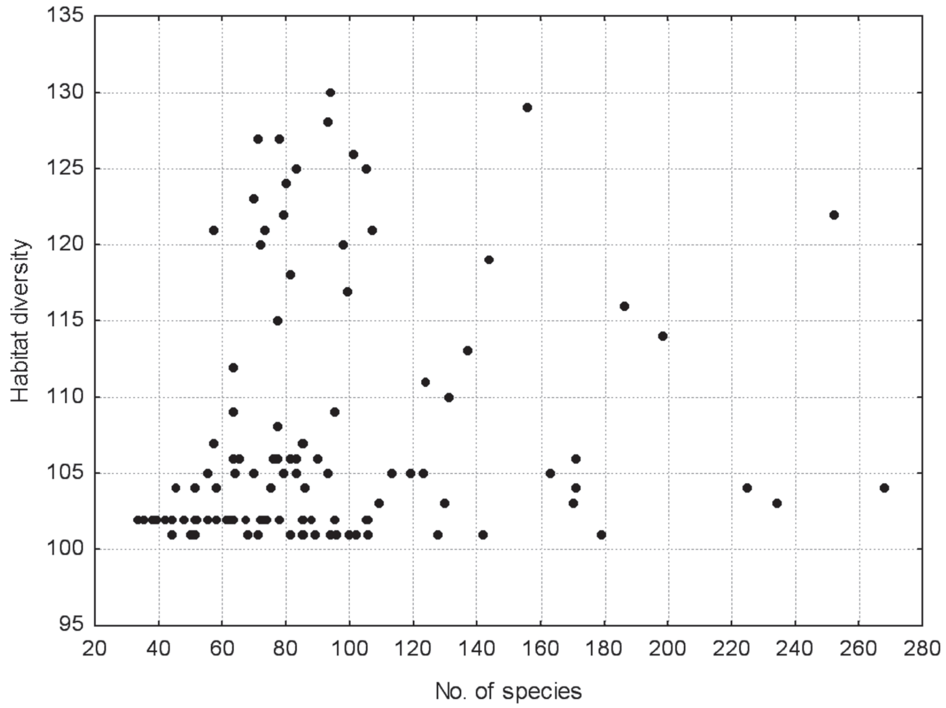



**Fig. 27.** Spearman rank correlation between species richness and habitat diversity ($R = 0.24$, $p < 0.05$) at West Slavic sites

late medieval to modern times (Fig. 26). Study sites used only in the late Middle Ages had the lowest corresponding values. A low mean but a wide range of variation were recorded in early medieval sites. Habitat diversity is only weakly but positively correlated with species richness (Fig. 27).

The dendrogram based on species diversity and abundance at the study sites (Fig. 28) shows that 2 large groups can be distinguished. The first group (A) includes wooded sites located within extensive woodlands, or rarely at their edges. The second group can be further divided into 2 subgroups, additionally subdivided into many smaller ones. Subgroup B(1-3) comprises archaeological sites with a high contribution of synanthropic communities. It consists of 3 smaller subunits. B1 includes study sites dominated by synanthropic species: most of the studied castles and fortified settlements used as arable fields or located within villages or towns. B2 is characterized by a high contribution of species typical of shrub communities, while B3 by a high contribution of meadow species. Subgroup C consists of the archaeological sites where xerothermic species prevail. Subgroup D is very heterogeneous. It includes study sites with a high contribution of meadow and marsh vegetation, located e.g. in river valleys and near lakes, as well as with a high contribution of thermophilous species, on ramparts and cone-shaped mounds. Subgroup D comprises also several castles. Three of them, located in the Kraków-Częstochowa Upland, form a small, separate subgroup (sites 101, 103, and 104) (Fig. 28).

Mean values and ranges of species number in the 6 frequency classes (Fig. 29) indicate that frequent and very frequent species prevail in a majority of study sites. On average, these 2 frequency classes jointly account for 63% of the total flora. Very frequent species have the widest range of variation and the highest mean value. Extremely rare and very rare species, jointly account for less than 10.0%. In Sycewice both frequency classes were not represented at all. Extremely rare species were absent at 28 sites, while very rare at 4 sites.

Most of the plant species recorded at West Slavic sites are moderately abundant or not abundant. Such species account jointly for 74-100% of the total flora (Figs. 30-32). At 9 sites, no species is very abundant. The group of species that are not abundant at the study sites are characterized by the highest mean and the widest range of variation. Site size is correlated with contributions of abundance classes of plant species. The correlation is positive for species that are moderately and very abundant, but negative for species whose populations are small (Figs. 33-35).

### 5.2.2. Anthropogenic changes of the flora

Among the 109 study sites, 90 have a highly synanthropic flora ($WS_t$>50%) (Appendix 5). In the flora of most archaeological sites, apophytes prevail over anthropophytes, as at 108 sites the total apophytization index $WAp_t$ is higher than the total anthropophytization index $WAn_t$ (Appendix 5). Only native species were recorded at all the 109 sites and for them, as expected, the mean and range of variation were the largest

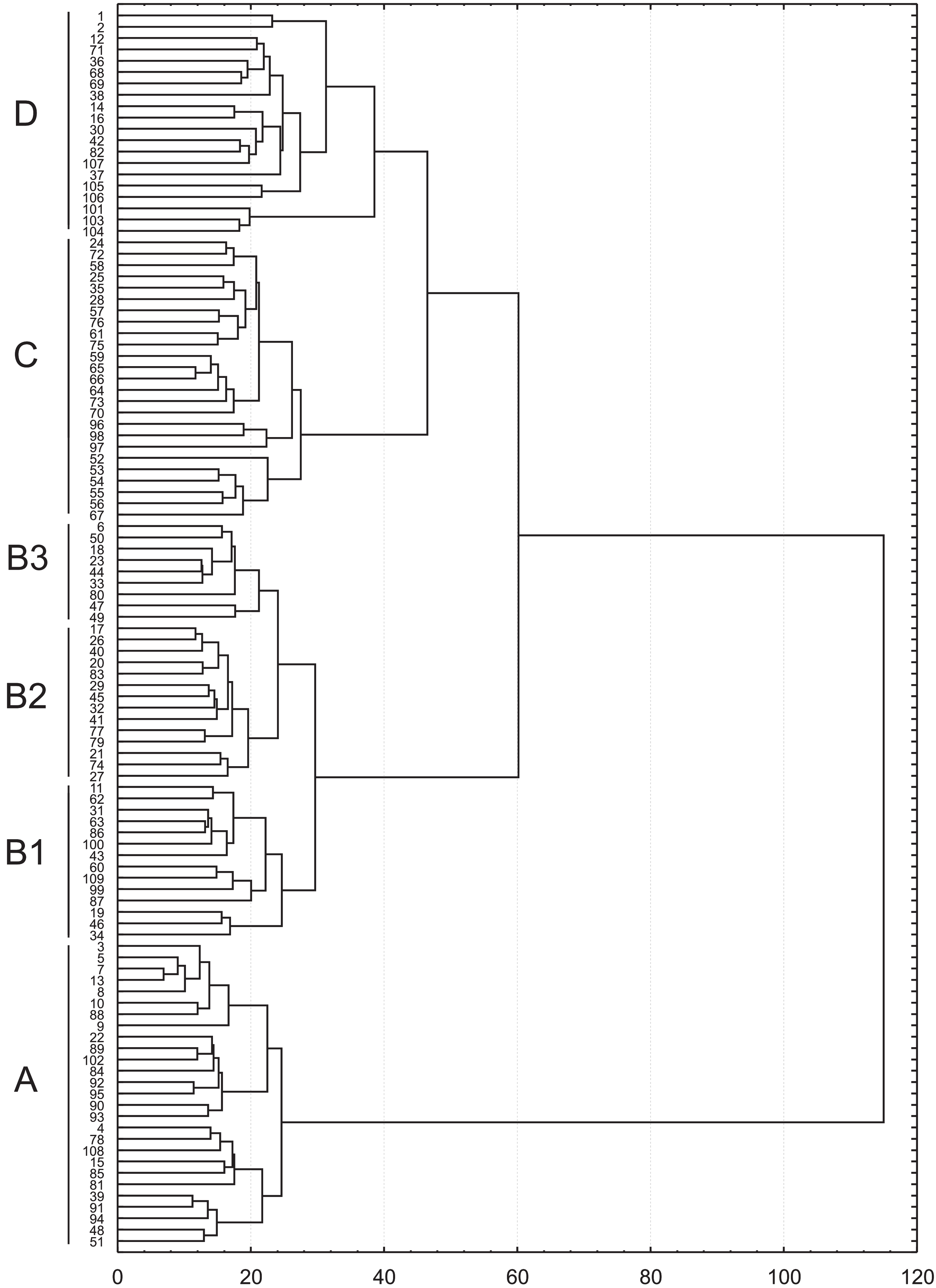



**Fig. 28.** Dendrogram of species richness and abundance at individual West Slavic sites, constructed on the basis of Euclidean distances (Ward's method)

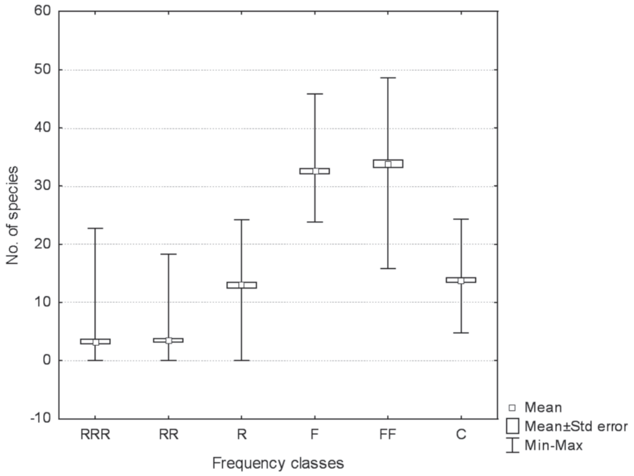
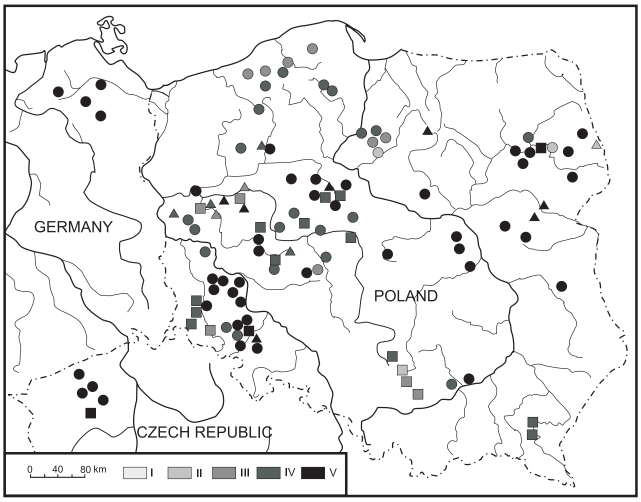
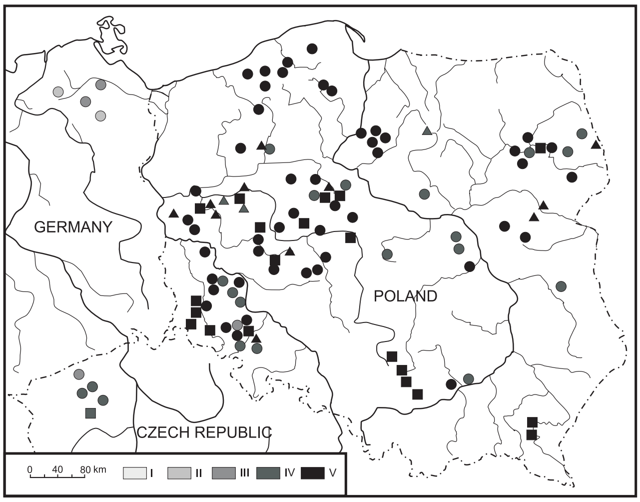



**Fig. 29.** Mean values and ranges of species number within frequency classes at West Slavic sites
Explanations: see Table 1



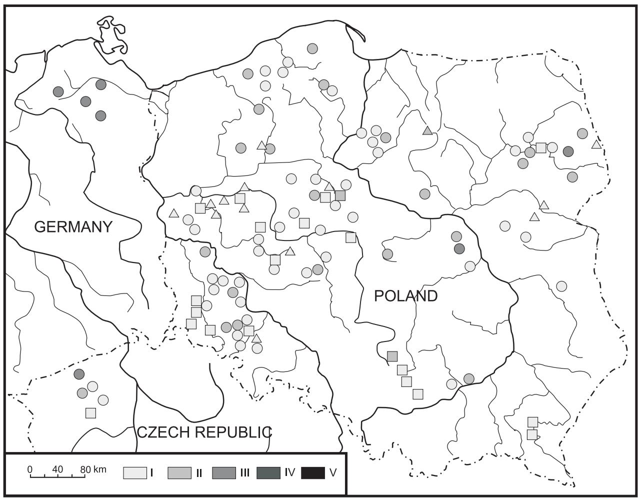

N=423, max=64.3, min=15.8, $\bar{x}$=42.1, σ=11.1

**Fig. 31.** Contributions of species that are moderately abundant at West Slavic sites
Explanations: see Fig. 3




N=317, max=82.1, min=16.7, $\bar{x}$=16.7, σ=14.1

**Fig. 30.** Contributions of species that are not abundant at West Slavic sites
Explanations: I – 0.0-10.0, II – 10.1-20.0, III – 20.1-30.0, IV – 30.1-40.0, V – over 40.0% of recorded species (at the given site); other abbreviations – see Fig. 3




N=132, max=26.0, min=0.0, $\bar{x}$=7.8, σ=6.4

**Fig. 32.** Contributions of species that are very abundant at West Slavic sites
Explanations: see Fig. 3

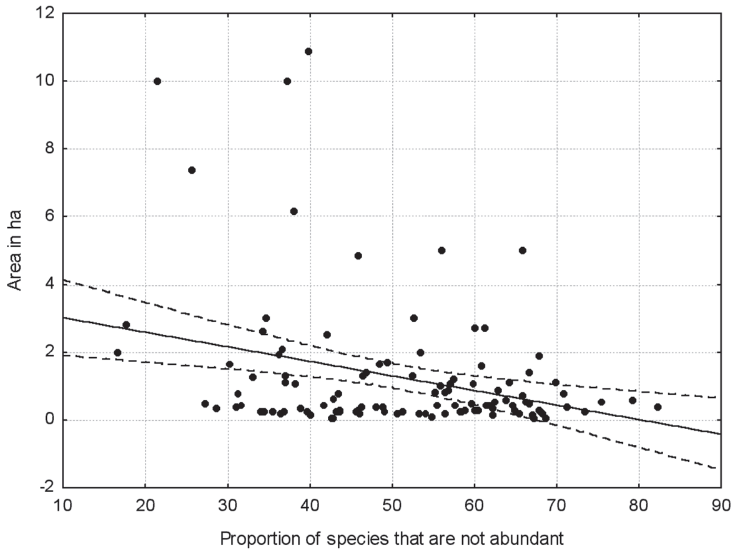



**Fig. 33.** Linear Pearson correlation between the contribution of species that are not abundant and size of West Slavic sites ($r$ = -0.30, $p$ < 0.01)

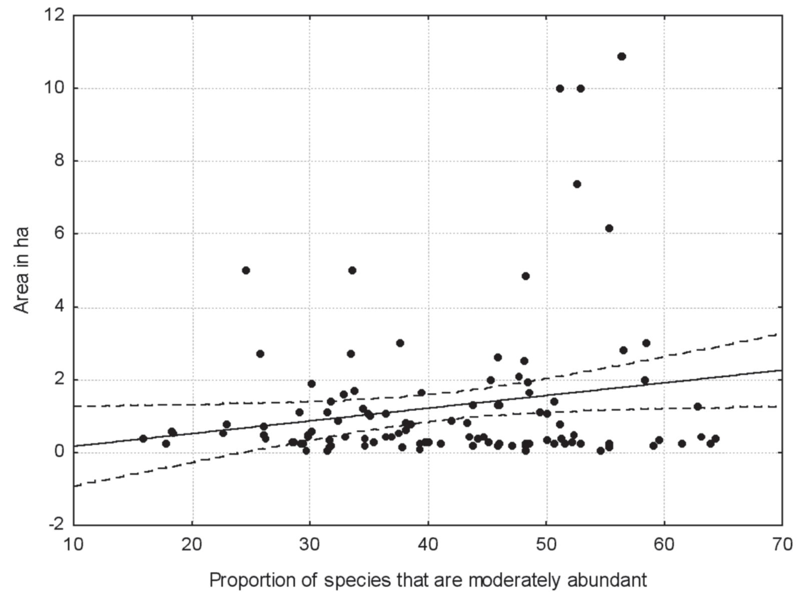



**Fig. 34.** Linear Pearson correlation between the contribution of species that are moderately abundant and size of West Slavic sites ($r = 0.20$, $p < 0.05$)

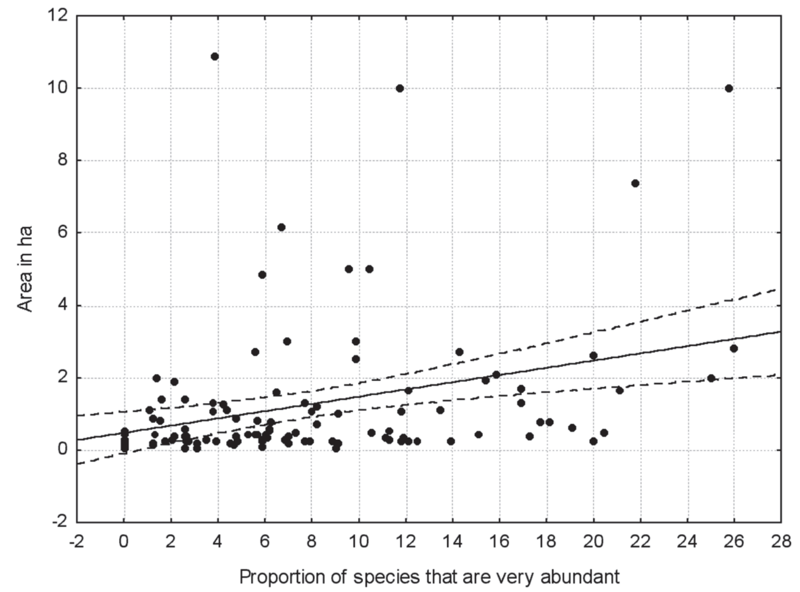



**Fig. 35.** Linear Pearson correlation between the contribution of species that are very abundant and size of West Slavic sites ($r = 0.32$, $p < 0.001$)

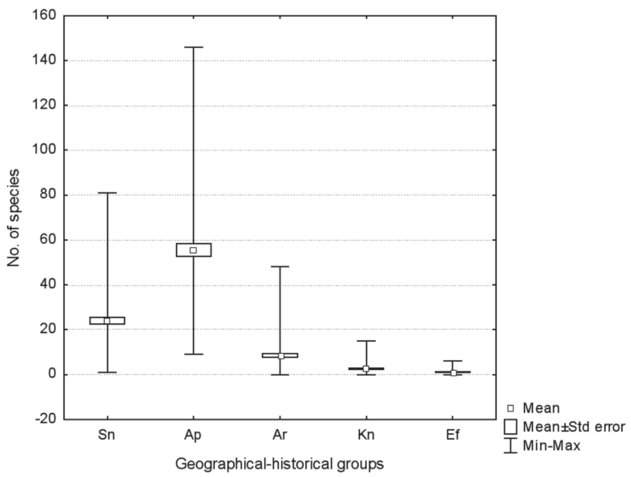
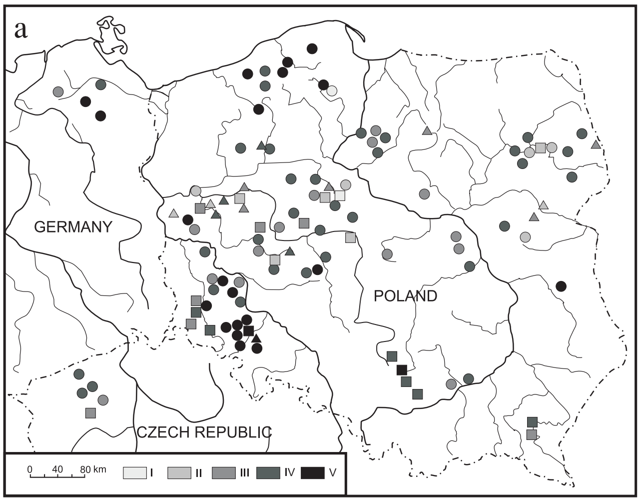


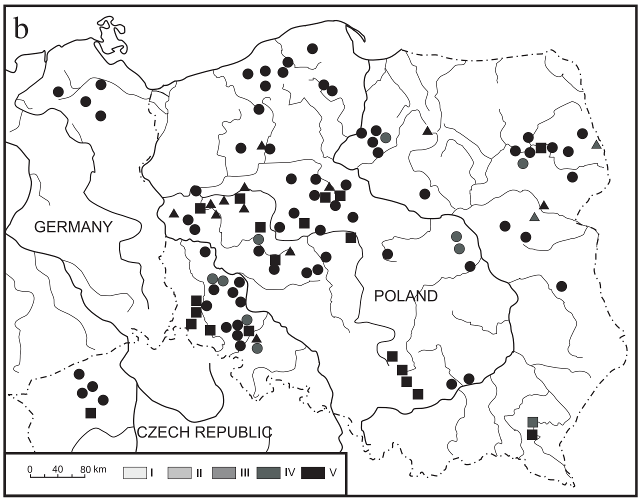

**Fig. 36.** Mean values and ranges of species number within geographical-historical groups at West Slavic sites
Explanations: see Fig. 14

(Fig. 36). Their joint contribution varies from 41.3% to 100%. All species were native at 5 fortified settlements and a castle (Gołczewo, Kłonice, Myślibórz I, Myślibórz III, Ostrowiec, and Sycewice). These sites are wooded and generally located within extensive woodlands, in the north and south parts of the study area. At the abovementioned sites and 13 others, located in similar places, the percentage contribution of non-synanthropic spontaneophytes is the highest (Fig. 37a, Appendix 5). At 91 sites, apophytes prevail over non-synanthropic spontaneophytes (*Wap*>50%) (Fig. 37b, Appendix 5). Most of these sites are fortified settlements and castles with a high habitat diversity and a small contribution of shrub communities and forest patches transformed by human activity.

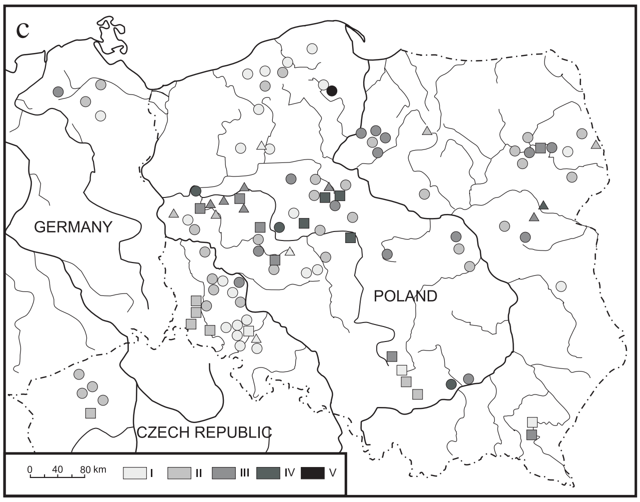
Anthropophytes are found at 103 fortified settlements and castles. For 23 sites, their contribution exceeds 20%.



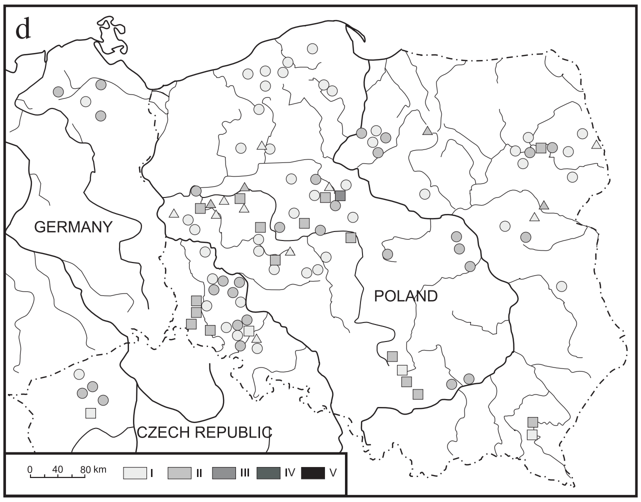

N=402, max=76.2, min=1.2, $\bar{x}$=28.4, σ=18.9



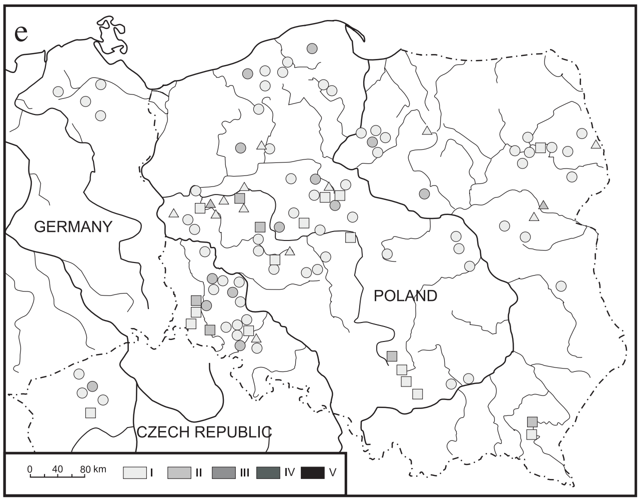

N=283, max=84.1, min=23.7, $\bar{x}$=60.0, σ=13.8




N=101, max=57.1, min=0.0, $\bar{x}$=8.2, σ=8.2




N=53, max=13.3, min=0.0, $\bar{x}$=2.4, σ=2.4




N=37, max=4.9, min=0.0, $\bar{x}$=0.9, σ=1.2

**Fig. 37.** Contributions of non-synanthropic spontaneophytes (a), apophytes (b), archaeophytes (c), kenophytes (d), ergasiophytes (e) to the flora of West Slavic sites

Explanations: I – 0.0-2.0, II – 2.1-10.0, III – 10.1-20.0, IV – 20.1-40.0, V – over 40.0% of recorded species; other abbreviations – see Fig. 3

The maximum is nearly 60%, recorded at a fortified settlement that has been turned into farmland, in Jamno. Only at that site the contribution of anthropophytes is higher than that of spontaneophytes. Among anthropophytes, as expected, archaeophytes play a major role. For 37 sites, their contribution exceeds 10%, but its maximum reaches over 57% (Fig. 37c). Most of these sites are covered by a mosaic of synanthropic vegetation and dry grasslands. They are usually concave fortified settlements and castles, rarely cone-shaped settlements. They were inhabited in various periods but chiefly from late medieval to modern times. The most frequent archaeophytes at the study sites were: *Ballota nigra*, *Capsella bursa-pastoris*, *Carduus acanthoides*, *Lactuca serriola*, and *Malva alcea*. The contribution of kenophytes is lower than that of earlier arrivals at 81 sites, while at 12 sites it is higher. Only for the castle in Kruszwica it exceeds 10% (Fig. 37d, Appendix 5). At 26 sites, kenophytes are absent, while at another 30 sites, they are represented by only one species. The contribution of kenophytes is the highest in castles and concave settlements inhabited mostly in the late medieval and modern times. The most frequent kenophytes at the study sites are *Aesculus hippocastanum*, *Chamomilla suaveolens*, *Conyza canadensis*, *Impatiens parviflora*, *Robinia pseudoacacia*, and *Symphoricarpos albus*. Diaphytes are represented exclusively by ergasiophytes. They were observed only at 49 sites, and the index of floristic fluctuations (*WF*) never exceeds 5% (Fig. 37e, Appendix 5). Ergasiophytes are found at study sites located in the vicinity of modern human settlements. They are very rare within extensive woodlands. At 35 study sites, only 1-2 species were recorded. The largest number of ergasiophytes (4-6 species) were observed at castles inhabited from late medieval to modern times, and in an early medieval settlement in Kórnik, but that settlement is located very close to a currently used cemetery.

### 5.2.3. Percentage contributions of life-forms

The dominant group at the study sites are hemicryptophytes. They were recorded at all the 109 sites and for them the mean and range of variation are the largest (Fig. 38). Their contribution is below 40% for only 3 fortified settlements: 2 wooded sites in Bolkowice and Jeżewo, and a fortified settlement that is now under cultivation in Jamno. At 70 study sites, the contribution of hemicryptophytes exceeds 50% and the maximum is nearly 80% (Fig. 39c). Phanerophytes rank second (Fig. 39a). They are found at all the study sites, whereas at 80 study sites their contribution exceeds 10%. They are often single trees and shrubs, but they have a strong influence on the general appearance of the study sites. At the fortified settlements and castles, geophytes also play an important role. They were observed at all the 109 study sites, and their contribution exceeds 10% at 67 sites (Fig. 39d). The remaining life-forms were absent from some study sites. Therophytes were recorded at 108 sites, chamaephytes at 105, while hydrophytes only at 34 sites. Annuals at 53 study sites account for over 10% of the total flora (Fig. 39f). The maximum is over 70%, in Jamno. Their participation is associated with the presence of segetal and ruderal communities, or rarely ruderal-like grasslands at the archaeological sites. The contribution of chamaephytes is lower than that of the above-mentioned groups, and only in 5 fortified settlements it exceeds 10% (Fig. 39b). The most frequently recorded species of this group include e.g. *Artemisia campestris*, *Ballota nigra*, and *Veronica chamaedrys*. Hydrophytes are the least represented life-form at the study sites (Fig. 39e). Their maximum contribution never exceeds 10%. At 17 sites, this group comprises only 1-2 species. The most frequent are *Polygonum amphibium*, *Lemna minor*, and *Alisma plantago-aquatica*. The low contribution of hydrophytes is due to the lack of moist and aquatic habitats at many study sites. At the other sites, this group of habitats includes moats or their remnants, covered with marsh vegetation, patches of moist or wet meadows, or rarely aquatic habitats with open water.

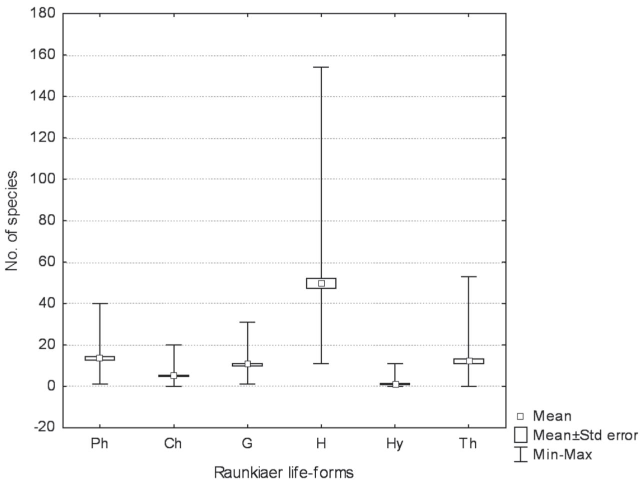
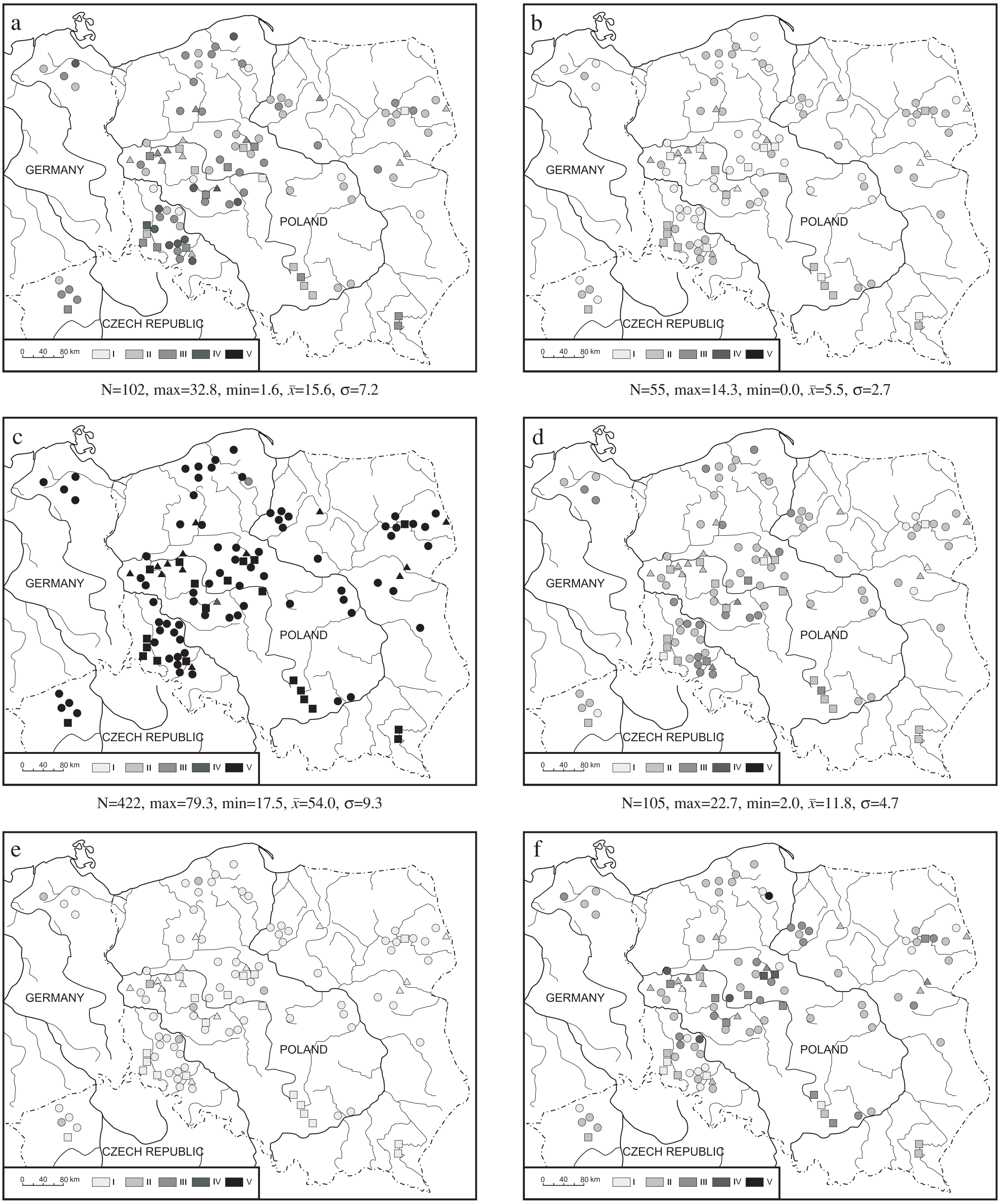



**Fig. 38.** Mean values and ranges of species number within Raunkiaer life-form groups at West Slavic sites
Explanations: see Fig. 16

### 5.2.4. Contributions of socio-ecological groups

None of the study sites included plants of all socio-ecological groups. The largest number, i.e. 15 groups, were represented at the castle in Międzyrzecz (Fig. 40). Ten synecological groups were represented at an average archaeological site. The widest range of variation in species number was observed for species of xerothermic and sandy grasslands (Fig. 41), while G12 is the most widely distributed. Species of this group are found at 108 sites, and they account for 24% of the total number of species on average (Fig. 42). They dominate or co-dominate in 39 fortified settlements and castles. Also members of group G5 are widespread (106 sites, dominant or co-dominant at 35), G6 (104 sites, dominant or co-dominant at 16), and G14 (100 sites, dominant at 19) (Figs. 21, 42). Also species of groups G7 and G11 are widespread (101 and 97 taxa, respectively), but they did not dominate in any of them. Field weeds (G13) found at 83 sites were major components of the flora of one site, which is nearly completely under cultivation (Jamno). Similarly, members of G9 are found at 87 study sites, but dominate only at one fortified




N=102, max=32.8, min=1.6, $\bar{x}$=15.6, σ=7.2

N=55, max=14.3, min=0.0, $\bar{x}$=5.5, σ=2.7

N=422, max=79.3, min=17.5, $\bar{x}$=54.0, σ=9.3

N=105, max=22.7, min=2.0, $\bar{x}$=11.8, σ=4.7

N=26, max=9.7, min=0.0, $\bar{x}$=1.2, σ=1.8

N=166, max=71.4, min=0.0, $\bar{x}$=2.1, σ=8.9

**Fig. 39.** Contributions of phanerophytes (a), chamaephytes (b), hemicryptophytes (c), geophytes (d), hydrophytes (e), therophytes (f) to the flora of West Slavic sites
Explanations: I – 0.0-5.0, II – 5.1-15.0, III – 15.1-25.0, IV – 25.1-35.0, V – over 35.0% of recorded species; other abbreviations – see Fig. 3

settlement located within a woodland (Gołczewo). At fortified settlements and castles, groups G1-G3 and G15 are the least frequent and least numerous (Figs. 21, 42). Ruderal species dominate in nearly 30% of cone-shaped settlements (4 sites) and nearly 50% castles (10 sites), but only 5% of concave settlements. In the last type of sites, species of groups G5, G6, and G12 are most numerous (Fig. 42). Considering site chronology, species

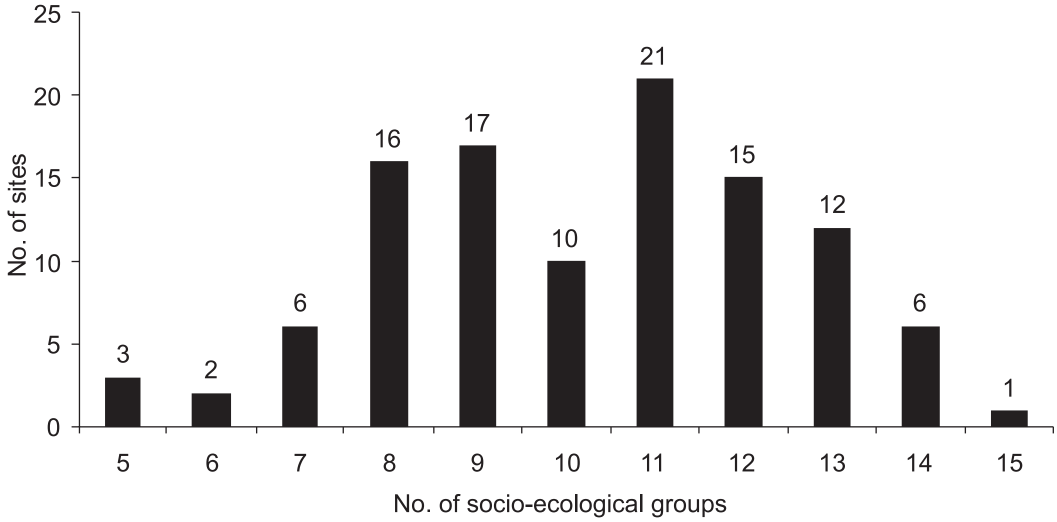



**Fig. 40.** Distribution of numbers of socio-ecological groups represented at West Slavic sites

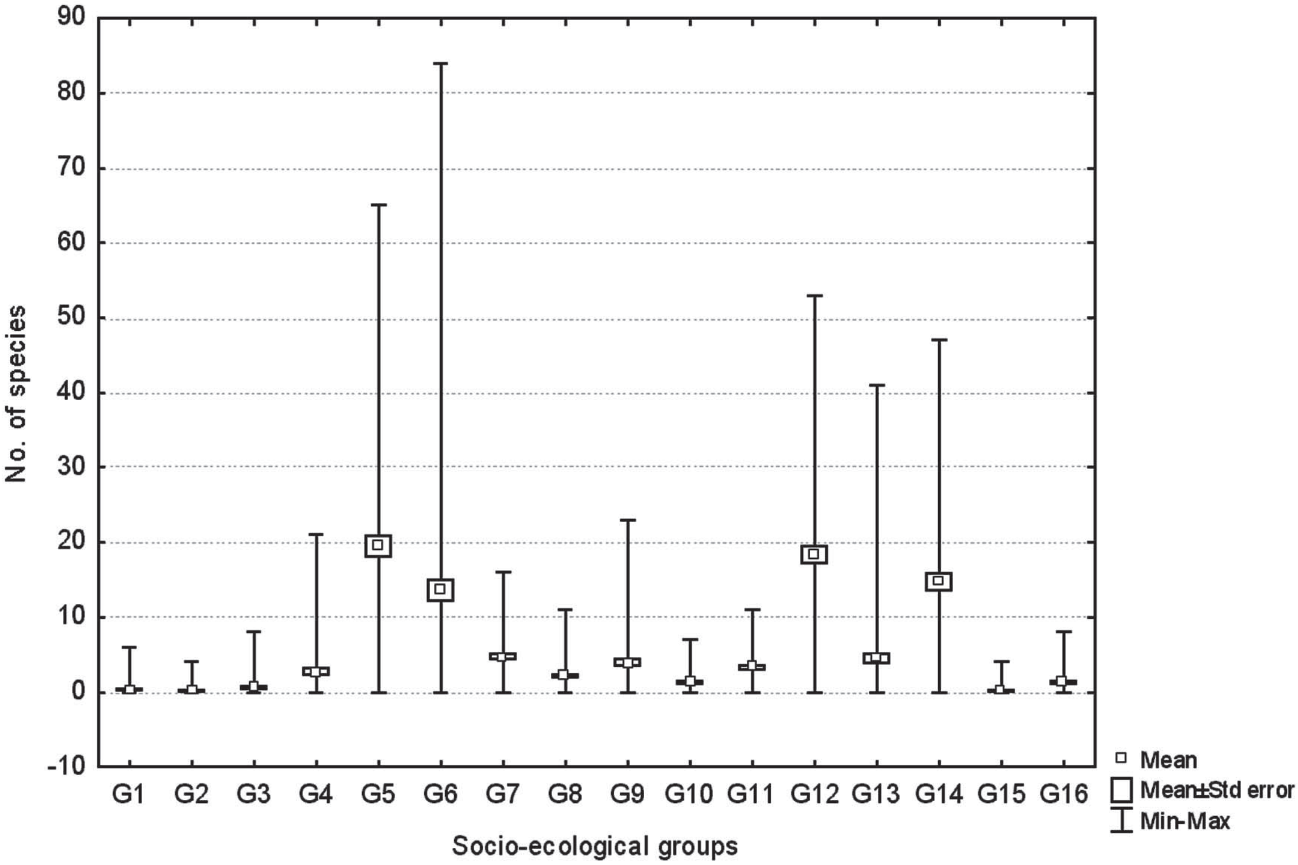



**Fig. 41.** Mean values and ranges of species number within socio-ecological groups at West Slavic sites
Explanations: see section 4.3.4

of group G14 prevail at late medieval sites as well as early medieval and late medieval ones inhabited till modern times (14 fortified settlements and castles, i.e. 33%). Early medieval sites have the highest contribution of species of group G5 (27 fortified settlements i.e. 43%). Contributions of groups G6 and G12 are comparable at early and late medieval sites (Fig. 42).

Species of group G15 are found only at castles that were inhabited in the late Middle Ages, in some cases also in the modern era, or – rarely – in the early Middle Ages. Also members of G16 are associated with coneshaped settlements and castles inhabited in the late Middle Ages, and sometimes also in the modern era.

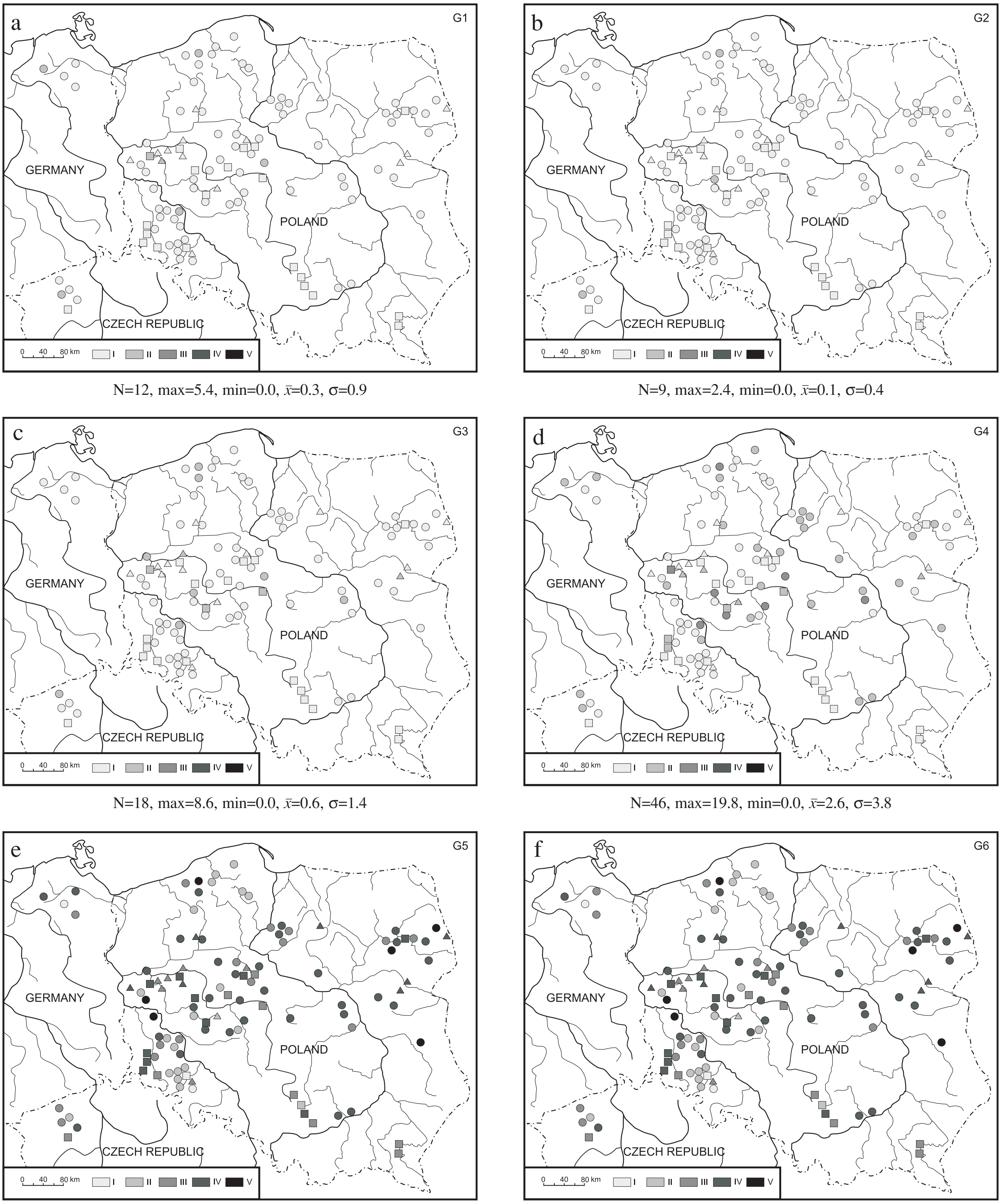
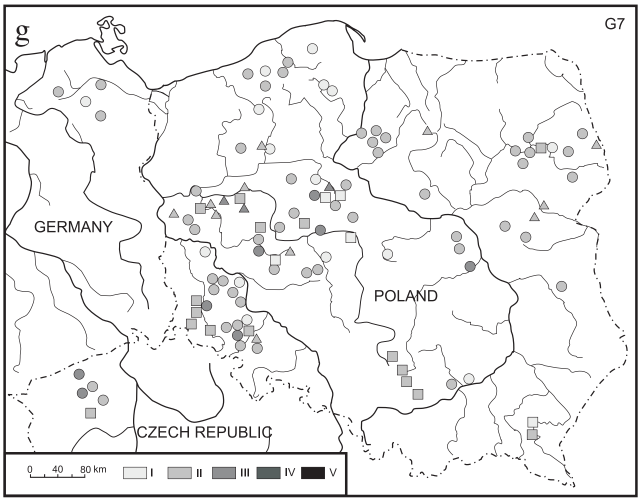
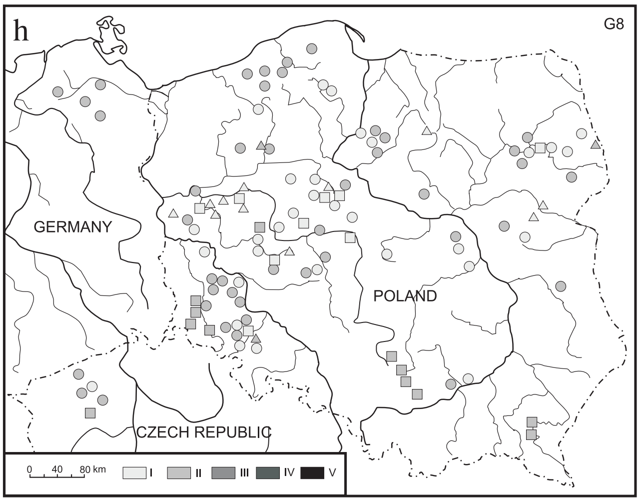



**Fig. 42.** Contributions of species: of aquatic and flush communities – G1 (a), raised bogs and bog meadows – G2 (b), of communities of waterside therophytes – G3 (c), reedbeds and sedge communities – G4 (d), meadow species – G5 (e), of sandy and xerothermic grasslands – G6 (f), of thermophilous shrub communities and forest edge communities – G7 (g), of acid moors and forest clearings – G8 (h), coniferous forests and acidophilous broadleaved forests – G9 (i), alluvial forests, willow thickets, and riparian tall herb fringe communities with climbers – G10 (j), of wet and bog forests, and alder thickets – G11 (k), of thermophilous oak forests, mesophilous deciduous forests, and nitrophilous shrub communities – G12 (l), segetal species – G13 (m), ruderal species – G14 (n), of epilithic communities – G15 (o), of indefinite phytosociological affiliation – G16 (p)

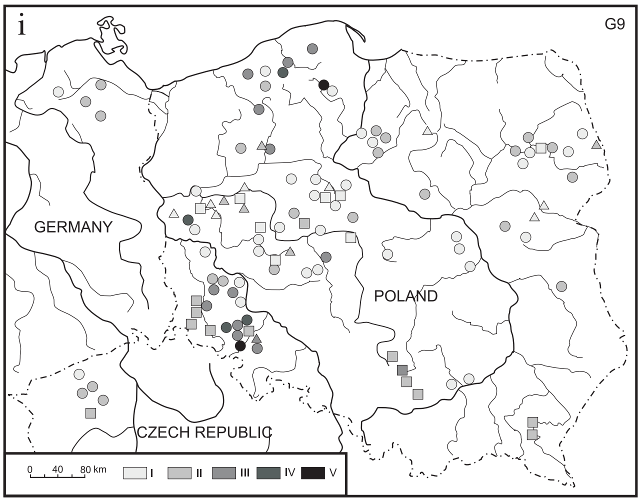
Explanations: I – 0.0-2.0, II – 2.1-10.0, III – 10.1-20.0, IV – 20.1-40.0, V – over 40.0% of recorded species; other abbreviations – see Fig. 3



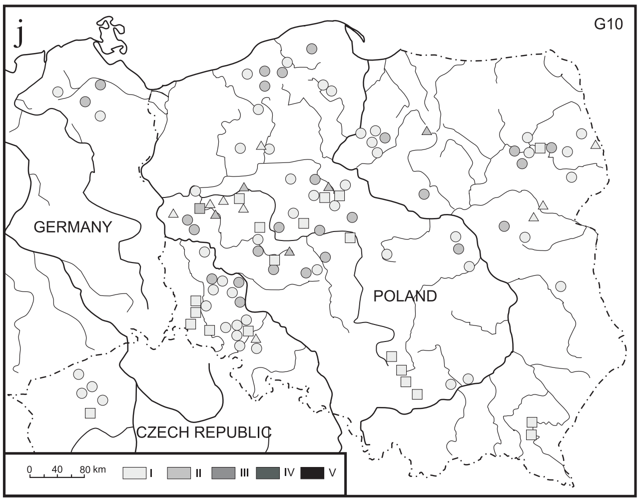

N=41, max=15.7, min=0.0, $\bar{x}$=5.1, σ=3.5



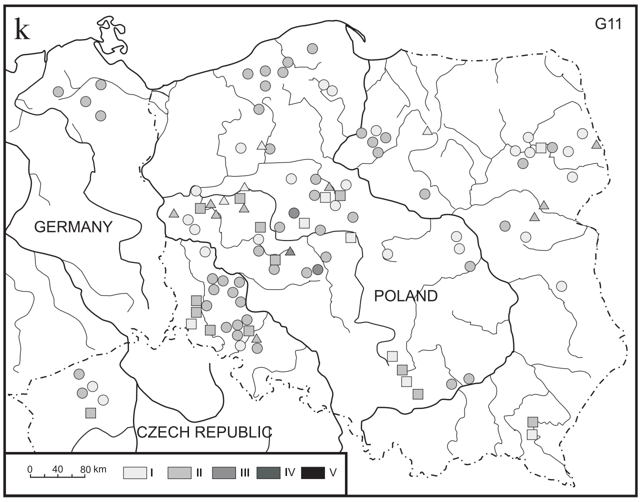

N=22, max=6.3, min=0.0, $\bar{x}$=2.3, σ=1.8



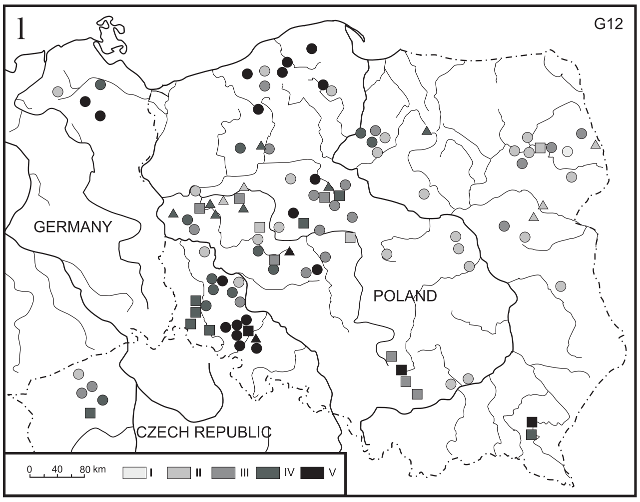

N=45, max=44.2, min=0.0, $\bar{x}$=5.5, σ=8.0




N=20, max=7.5, min=0.0, $\bar{x}$=1.4, σ=1.6



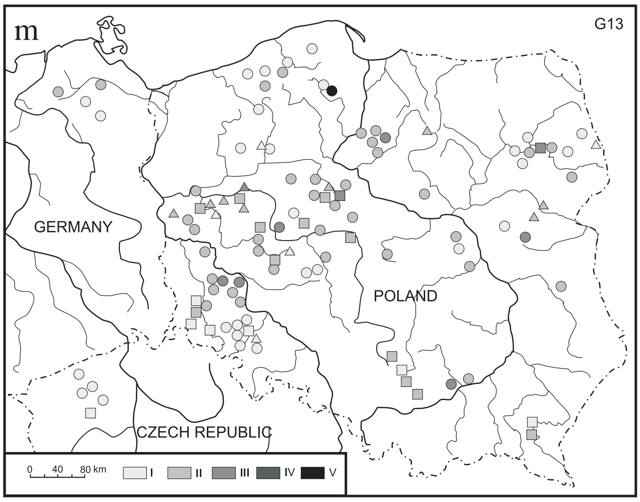

N=29, max=14.0, min=0.0, $\bar{x}$=3.8, σ=2.8



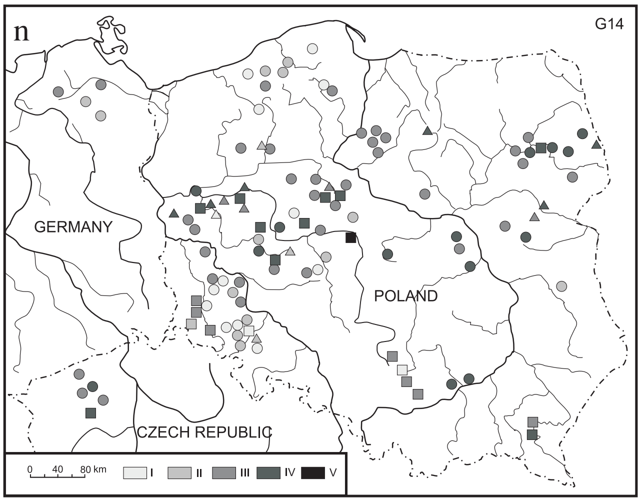

N=128, max=81.8, min=0.0, $\bar{x}$=24.1, σ=20.1

### 5.2.5. Floristic similarity of archaeological sites

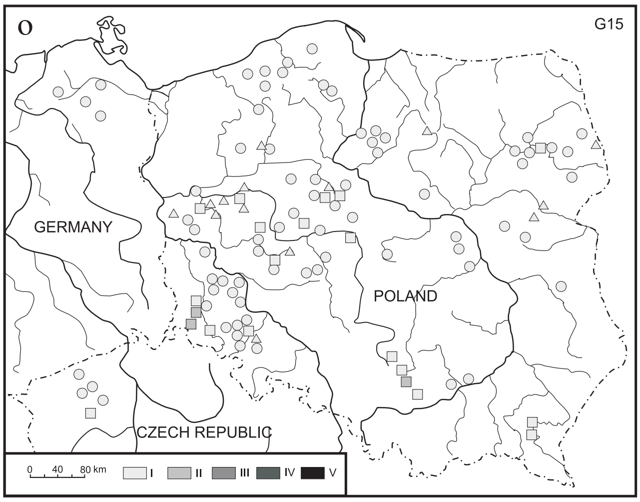
Indices of floristic similarity show which archaeological sites have most similar and most different species composition. Irrespective of the applied formulae (for Jaccard I, Jaccard II, or Steinhaus indices), values for 14 pairs of sites amount to 0.00 (Jaccard II, Steinhaus) or reach the maximum of 50.00 (Jaccard I). This indicates that no species are common to the the following pairs of sites: Myślibórz III versus Bonikowo, Błonie, and Jamno; Tykocin versus Bolkowice,



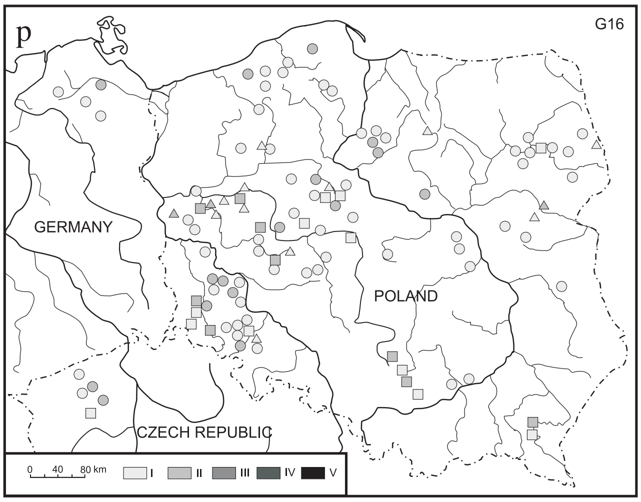

N=67, max=65.1, min=0.0, $\bar{x}$=4.8, σ=8.0




N=109, max=2.4, min=0.0, $\bar{x}$=0.1, σ=0.4




N=4, max=2.4, min=0.0, $\bar{x}$=0.1, σ=0.4




N=45, max=2.4, min=0.0, $\bar{x}$=0.1, σ=0.4

Chełmiec, Gołczewo, Laschendorf, Myślibórz I, Myślibórz III, and Siedmica; Jamno versus Chełmiec and Ostrowiec; Przytok versus Myślibórz II; and Zamczysk versus Laschendorf. These study sites vary greatly in size, chronology, site type, species richness, and geographic location.

The most similar sites (Steinhaus index over 0.60) are presented in Table 10. These include 5 concave settlements and a castle, covered completely or nearly completely with forest (Kczewo, Kociałkowa Górka, Laschendorf, Myślibórz I, Ociąż, and Ostrowiec); and 3 castles located in the Kraków-Częstochowa Upland, with ruins covered mostly by ruderal communities and thermophilous grasslands (Mirów, Olsztyn near Częstochowa, and Podzamcze). For most pairs (3081 of the 5995 pairs), the Steinhaus index ranges from 0.18 to 0.34, and the mean is 0.25. Values up to 0.17 were recorded for 1603 pairs, 0.35-0.51 for 1272 pairs, while over 0.51 for only 39 pairs.

In the dendrogram based on Steinhaus index, the most distinct is the site in Jamno (no. 11), which is nearly completely under cultivation (group A). The other for-

**Table 10.** Highest values of indices of floristic similarity between West Slavic sites

| Study site | Kociałkowa Górka | Kczewo | Olsztyn | Mirów | Ostrowiec |
|---|---|---|---|---|---|
| Ociąż | 41.18[1], 0.43[2], 0.60[3] | | | | |
| Myślibórz castle I | 40.27, 0.48, 0.65 | | | | |
| Ostrowiec | | 40.00, 0.50, 0.67 | | | |
| Mirów | | | 39.88, 0.51, 0.67 | | |
| Podzamcze | | | 39.75, 0.52, 0.68 | 40.00, 0.50, 0.67 | |
| Laschendorf | | | | | 41.22, 0.43, 0.60 |

Explanations: [1] – Jaccard index I, [2] – Jaccard index II, [3] – Steinhaus index

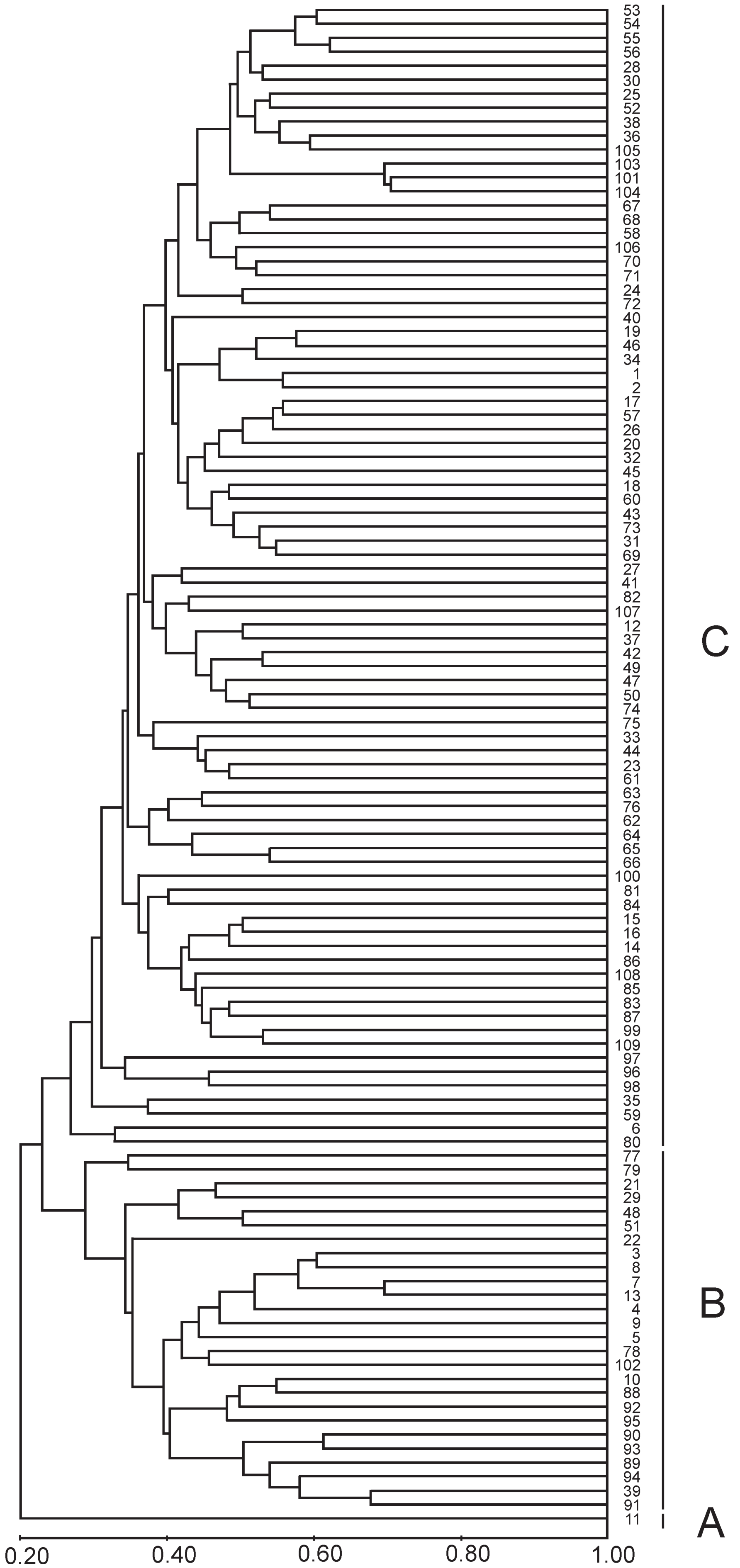



**Fig. 43.** Dendrogram of West Slavic sites, constructed on the basis of the Steinhaus index of floristic similarity (UPGMA method)

tified settlements form 2 large groups: B and C. Group B is composed of wooded sites, but these are not all the study sites covered with this vegetation type. This group includes 5 most similar sites. Group C is very heterogeneous, divided into many subgroups. The most distinct subgroup consists of 3 castles, very similar floristically to one another (sites 101, 103, and 104) (Fig. 43).

### 5.2.6. Floristic value and distinctness of archaeological sites

Floristic value of an archaeological site, defined as the sum of rarity coefficients of the species recorded there, depends on both the total number of species at that site and on the number of rare species found there. It varies from 22.3 (for Ostrowiec) to 213.6 (for Olsztyn). The mean value is 66.6. Values lower than the mean were recorded for 70 sites, while higher for 39 (Appendix 4). As many as 63 sites have a very low floristic value, whereas 3 sites (Olsztyn, Podzamcze, and Stradów) have the highest value. In most of the study sites, the distribution of floristic value is similar to the distribution of species number. Sites with a high number of species usually have a high floristic value, and the other way around.

The environmental value of a study site is also reflected in its floristic dissimilarity index, which is the mean of rarity coefficients of the species recorded there. The range of floristic dissimilarity of the studied archaeological sites is narrow: from 0.62 (for Ostrów and Połęcko) to 0.82 (for Jamno and Sławsko). The mean floristic dissimilarity is 0.72. Values lower than the mean were recorded for 55 sites, while higher for 45 (Appendix 4). Most of the study sites (72) have low or medium values (2-3).

### 5.2.7. Floristic variation depending on site type and chronology

Three types of archaeological sites were compared: concave fortified settlements, cone-shaped ones, and castles (see section 4.3). At 74 West Slavic fortified settlements, 784 species were recorded (i.e. 90% of the total flora of West Slavic sites). They belonged to 399 genera and 106 families (Fig. 44). In 14 cone-shaped settlements, 398 species were observed, while in 21 castles, 607 species. As many as 223 species were recorded exclusively in concave settlements (e.g. *Adonis aestivalis, Anthriscus cerefolium, Bromus secalinus, Carex humilis, Chrysanthemum segetum, Lathyrus tuberosus, Nonea pulla, Salvia nemorosa*), 10 species exclusively in cone-shaped settlements (e.g. *Asperugo procumbens, Carduus nutans, Chrysosplenium alternifolium, Thesium linophyllon*), and 74 species exclusively at castles (e.g. *Asplenium ruta-muraria, Cerinthe minor, Cymbalaria muralis, Diplotaxis muralis, D. tenuifolia, Marrubium vulgare, Parietaria officinalis,* and *Stachys germanica*).

Concave fortified settlements are dominated by non-synanthropic spontaneophytes and their contribution is higher there than in other site types. The ratio of non-synanthropic spontaneophytes to apophytes is 1.4, while *WN*=46.0% (Table 11). The flora of concave settlements has the lowest contribution of synanthropic species ($WS_t$=54.0%) and the lowest contribution of apophytes among spontaneophytes (*Wap*=42.4%). The flora of cone-shaped settlements is distinguished by the highest

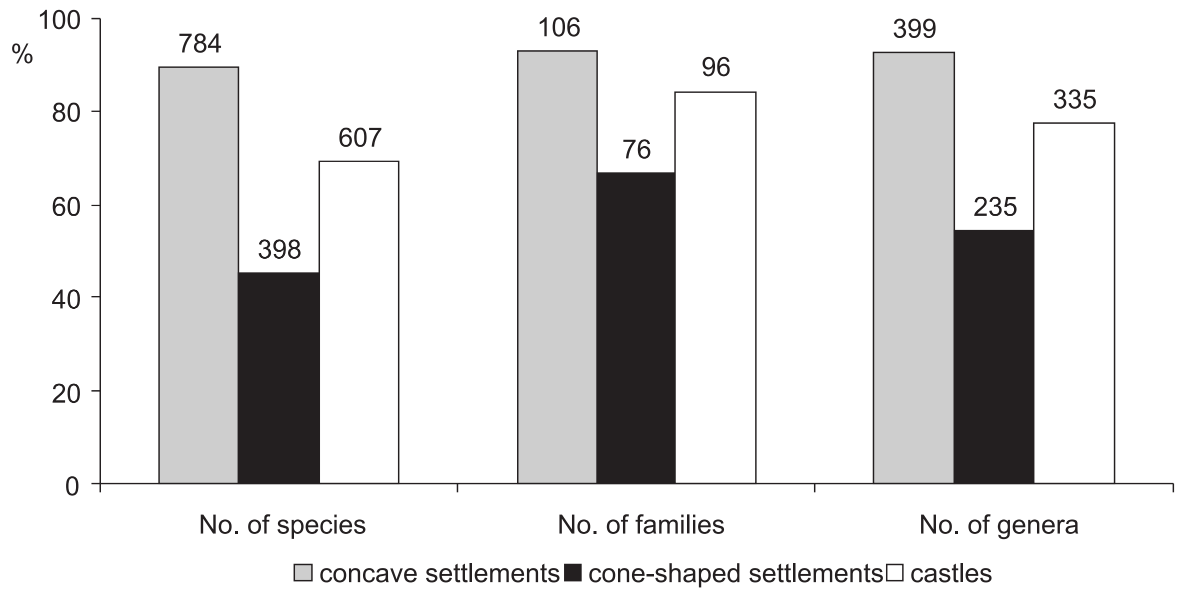



**Fig. 44.** Contributions of species, families, and genera recorded in the 3 types of West Slavic sites to the total number in West Slavic sites

**Table 11.** Indices of anthropogenic changes in the flora of the 3 types of West Slavic sites

| Index [%] | Concave settlements | Cone-shaped settlements | Castles |
|---|---|---|---|
| $WS_t$ | 54.0 | 65.8 | 61.4 |
| $WS_p$ | 52.2 | 65.5 | 60.1 |
| $WAp_t$ | 33.9 | 47.2 | 39.7 |
| $WAp_p$ | 35.2 | 47.7 | 41.3 |
| $Wap$ | 42.4 | 58.0 | 50.8 |
| $WAn_t$ | 20.0 | 18.6 | 21.9 |
| $WAn_p$ | 17.1 | 17.8 | 18.8 |
| $WAr_t$ | 11.9 | 13.1 | 11.4 |
| $WAr_p$ | 12.3 | 13.2 | 11.8 |
| $WKn_t$ | 4.6 | 4.5 | 6.8 |
| $WKn_p$ | 4.8 | 4.6 | 7.0 |
| $WM$ | 27.9 | 25.7 | 37.3 |
| $WF$ | 3.6 | 1.0 | 3.8 |
| $WN$ | 46.0 | 34.2 | 38.4 |
| $WT_a$ | 82.2 | 94.6 | 82.7 |
| $WT_t$ | 96.4 | 99.0 | 96.2 |

Explanations: index names – see Table 6

values of several indices of anthropogenic transformations of the flora (Table 11). Their flora is most synanthropic ($WS_t$=65.8%) and apophytes prevail there over anthropophytes ($WAp_t$ is about 2.5-fold higher than $WAn_t$). More than half of spontaneophytes are apophytes (*Wap*=58.0%). The highest is also the percentage contribution of archaeophytes to the total number of species ($WAr_t$=13.1), and to the number of permanent species ($WAr_p$=13.2). The flora of castles is distinguished by the highest contribution of kenophytes to the total flora ($WKn_t$=6.8) and to the group of metaphytes (*WM*=37.3) and of diaphytes to the total flora (*WF*=3.8). The spectrum of Raunkiaer life-forms in all site types is quite similar. Hemicryptophytes prevail, accompanied mostly by therophytes and geophytes.

Members of all socio-ecological groups are found only at castles. Concave settlements lack species of group G15, while cone-shaped ones lack species of group G2, and G15 (Table 12).

An analysis of flora in respect of site chronology (Fig. 45) showed that the sites inhabited only in the early Middle Ages were richest in species. Over 85% of the total number of species, 90% of families, and 88% of genera were recorded there. The other chronological groups are colonized by smaller numbers of taxa (Fig. 45, Table 13). However, early medieval sites were more numerous (63) than those of the other chronological groups (13, 14, and 15 sites). The smallest numbers of taxa were observed at the sites inhabited only in the late Middle Ages. This can be due to the relatively short time of their utilization (up to 200 years) as well as site size (the sites used only in that period are the smallest).

As many as 165 species were recorded exclusively at early medieval sites (e.g. *Allium angulosum, Anthemis tinctoria, Cerasus fruticosa, Chamomilla recutita, Datura stramonium, Draba nemorosa, Lappula squarosa, Serratula tinctoria*), compared to 27 species exclusively at the sites inhabited in the early and late Middle Ages (e.g. *Angelica archangelica, Cicuta virosa, Clematis vitalba, Geranium pyrenaicum*), 19 species exclusively at late medieval sites (*Cardamine impatiens*, *Gagea arvensis*, *Hesperis matronalis, Veronica montana*), and 50 species exclusively at the sites inhabited from late medieval to modern times (e.g. *Eragrostis minor, Galium cracoviense, Primula elatior, Reynoutria japonica, Salvia glutinosa, Vicia grandiflora*). Irrespective of the applied index, the floristic similarity of the compared chronological groups is quite high (Table 13). The least similar chronological groups were the sites inhabited

**Table 12.** Contributions of socio-ecological groups to the flora of the 3 types of study sites

| Group | Site type | | | | | |
|---|---|---|---|---|---|---|
| | Concave settlements | | Cone-shaped settlements | | Castles | |
| | N | % | N | % | N | % |
| G1 | 12 | 1.5 | 2 | 0.5 | 5 | 0.8 |
| G2 | 8 | 1.0 | 0 | 0.0 | 2 | 0.3 |
| G3 | 16 | 2.0 | 8 | 2.0 | 8 | 1.3 |
| G4 | 45 | 5.7 | 14 | 3.5 | 25 | 4.1 |
| G5 | 120 | 15.3 | 61 | 15.3 | 86 | 14.2 |
| G6 | 134 | 17.1 | 65 | 16.3 | 109 | 18.0 |
| G7 | 38 | 4.8 | 24 | 6.0 | 27 | 4.4 |
| G8 | 20 | 2.6 | 9 | 2.3 | 16 | 2.6 |
| G9 | 44 | 5.6 | 22 | 5.5 | 27 | 4.4 |
| G10 | 17 | 2.2 | 10 | 2.5 | 12 | 2.0 |
| G11 | 27 | 3.4 | 14 | 3.5 | 22 | 3.6 |
| G12 | 118 | 15.1 | 73 | 18.3 | 105 | 17.3 |
| G13 | 64 | 8.2 | 23 | 5.8 | 38 | 6.3 |
| G14 | 88 | 11.2 | 65 | 16.3 | 92 | 15.2 |
| G15 | 0 | 0.0 | 0 | 0.0 | 4 | 0.7 |
| G16 | 33 | 4.2 | 8 | 2.0 | 29 | 4.8 |

Explanations: N – no. of species, G1-G16 – see section 4.3.4

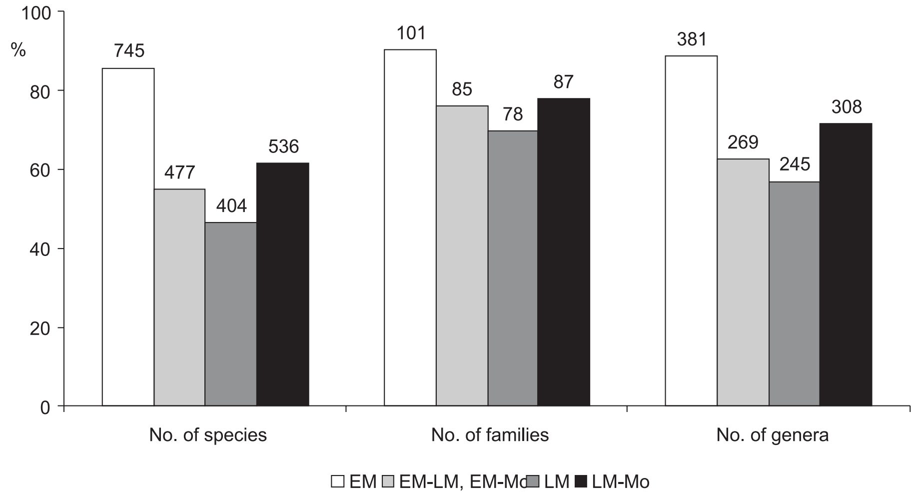



**Fig. 45.** Contributions of species, families, and genera within chronological groups of West Slavic sites
Explanations: EM – early medieval, EM-LM, EM-Mo – early medieval to late medieval or to modern era, LM – late medieval, LM-Mo – late medieval to modern era

only in the early Middle Ages and those inhabited only in the late Middle Ages.

In all chronological groups, native species prevail and their contribution is about 80%. At only early medieval sites, non-synanthropic spontaneophyte species are 1.3-fold more numerous than apophytes (*WN*=44.7%) (Table 14). Those sites are also distinguished by the smallest contribution of synanthropic species ($WS_t$=55.3%) and apophytes ($WAp_t$=34.6%), while the highest of diaphytes (*WF*=3.8%) (Table 14). The sites inhabited from early medieval to modern times and from late medieval to modern times have the lowest contribution of archaeophytes (11.5% and 11.6%, respectively), and the highest contribution of kenophytes (5.5% and 6.3%). The largest proportion of spontaneophytes are apophytes at the sites inhabited from early medieval to modern times (*Wap*=56.4%). Contributions of apophytes to the total and permanent flora are also the highest there ($WAp_t$=45.5%, $WAp_p$=46.6%).

**Table 13.** Comparison of the flora of study sites differing in chronology

| Chronology | EM | EM-LM, EM-Mo | LM | LM-Mo |
|---|---|---|---|---|
| EM | | 433[4] | 369 | 460 |
| (N=745) | | 790[5] | 780 | 821 |
| | | 357[6] | 411 | 361 |
| EM-LM, EM-Mo | 39.24[1] | | 309 | 363 |
| (N=477) | 0.55[2] | | 573 | 651 |
| | 0.71[3] | | 264 | 288 |
| LM | 40.44 | 39.38 | | 323 |
| (N=404) | 0.47 | 0.54 | | 617 |
| | 0.64 | 0.7 | | 294 |
| LM-Mo | 39.06 | 39.09 | 39.63 | |
| (N=536) | 0.56 | 0.56 | 0.52 | |
| | 0.72 | 0.72 | 0.69 | |

Explanations: [1] – Jaccard index I, [2] – Jaccard index II, [3] – Steinhaus index, [4] – no. of species in common, [5] – total no. of species, [6] – no. of different species, EM – early medieval, EM-LM – early to late medieval, EM-Mo – early medieval to modern era, LM – late medieval, LM-Mo – late medieval to modern era, N – no. of species

Late medieval sites have the highest contribution of archaeophytes (12.6%) and the smallest contributions of kenophytes (4.5%) and ergasiophytes (0.7%). Besides, apophytes prevail over anthropophytes most strongly in that chronological group ($WAp_t$ is 2.5-fold higher than $WAn_t$), while indices of anthropophyte permanence and total permanence reach the highest values (Table 14). The most synanthropic is the flora of sites inhabited from late medieval to modern times ($WS_t$=65.1%). This chronological group has also the highest contribution of anthropophytes ($WKn_t$=6.3), kenophytes among anthropophytes (*WM*=35.4), and the lowest of non-synanthropic spontaneophytes (Table 14).

Hemicryptophytes prevail in all chronological groups. Their contribution is about 50%. Also the contributions of phanerophytes and chamaephytes are very similar. The sites inhabited from late medieval to modern times have the lowest contribution of geophytes (9.9%), and a relatively low contribution of hydrophytes (jointly

**Table 14.** Indices of anthropogenic changes in the flora of chronological groups of West Slavic sites

| Index [%] | Chronology | | | |
|---|---|---|---|---|
| | EM | EM-LM, EM-Mo | LM | LM-Mo |
| $WS_t$ | 55.3 | 64.8 | 62.4 | 65.1 |
| $WS_p$ | 53.6 | 63.9 | 62.1 | 63.9 |
| $WAp_t$ | 34.6 | 45.5 | 44.6 | 43.8 |
| $WAp_p$ | 36.0 | 46.6 | 44.9 | 45.4 |
| *Wap* | 43.7 | 56.4 | 54.2 | 55.7 |
| $WAn_t$ | 20.7 | 19.3 | 17.8 | 21.3 |
| $WAn_p$ | 17.6 | 17.4 | 17.2 | 18.5 |
| $WAr_t$ | 12.2 | 11.5 | 12.6 | 11.6 |
| $WAr_p$ | 12.7 | 11.8 | 12.7 | 12.0 |
| $WKn_t$ | 4.7 | 5.5 | 4.5 | 6.3 |
| $WKn_p$ | 4.9 | 5.6 | 4.5 | 6.6 |
| *WM* | 27.8 | 32.1 | 26.1 | 35.4 |
| *WF* | 3.8 | 2.3 | 0.7 | 3.4 |
| *WN* | 44.7 | 35.2 | 37.6 | 34.9 |
| $WT_a$ | 81.8 | 88.0 | 95.8 | 84.2 |
| $WT_t$ | 96.2 | 97.7 | 99.3 | 96.6 |

Explanations: see Table 6

**Table 15.** Contributions of socio-ecological groups to the flora of chronological groups of West Slavic sites

| Socio-ecological group | Chronological group | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | EM | | EM-LM, EM-Mo | | LM | | LM-Mo | |
| | N | % | N | % | N | % | N | % |
| G1 | 7 | 0.9 | 7 | 1.5 | 1 | 0.2 | 3 | 0.6 |
| G2 | 7 | 0.9 | 3 | 0.6 | 0 | 0.0 | 1 | 0.2 |
| G3 | 14 | 1.9 | 13 | 2.7 | 8 | 2.0 | 6 | 1.1 |
| G4 | 43 | 5.8 | 26 | 5.5 | 9 | 2.2 | 17 | 3.2 |
| G5 | 117 | 15.7 | 80 | 16.8 | 54 | 13.4 | 86 | 16.0 |
| G6 | 130 | 17.4 | 60 | 12.6 | 60 | 14.9 | 106 | 19.8 |
| G7 | 35 | 4.7 | 17 | 3.6 | 27 | 6.7 | 26 | 4.9 |
| G8 | 19 | 2.6 | 12 | 2.5 | 8 | 2.0 | 16 | 3.0 |
| G9 | 38 | 5.1 | 27 | 5.7 | 26 | 6.4 | 22 | 4.1 |
| G10 | 15 | 2.0 | 11 | 2.3 | 10 | 2.5 | 10 | 1.9 |
| G11 | 27 | 3.6 | 21 | 4.4 | 15 | 3.7 | 17 | 3.2 |
| G12 | 112 | 15.0 | 81 | 17.0 | 91 | 22.5 | 79 | 14.7 |
| G13 | 64 | 8.6 | 34 | 7.1 | 21 | 5.2 | 35 | 6.5 |
| G14 | 84 | 11.3 | 65 | 13.6 | 64 | 15.8 | 86 | 16.0 |
| G15 | 0 | 0.0 | 4 | 0.8 | 3 | 0.7 | 3 | 0.6 |
| G16 | 33 | 4.4 | 16 | 3.4 | 7 | 1.7 | 23 | 4.3 |

Explanations: N – no. of species, other abbreviations – see Table 13 and section 4.3.4

only 11.4%). Late medieval sites have the lowest contribution of hydrophytes and therophytes (jointly 16.8%). The contribution of therophytes is highest at early medieval sites (over 19%). Members of all socio-ecological groups are found at the sites inhabited in both the early and late Middle Ages, or from late medieval to modern times. Species of group G15 are absent at early medieval sites, while G2 at late medieval ones. It is noteworthy that a high contribution (over 22%) of species of group G12 was recorded at late medieval sites, and of species of group G6 (nearly 20%) at sites inhabited till the modern era (Table 15).

## 5.3. Comparison of the current and subfossil flora of archaeological sites

The present vascular flora in the Lednica region includes 720 species, whereas the subfossil flora from early medieval deposits consists of 335 taxa (249 of them identified to species level). In the geographical-historical spectrum, native species and archaeophytes dominate, obviously, in the subfossil flora. The modern flora comprises also kenophytes, and the contribution of naturalized cultivated species is higher (Fig. 46). Currently 80 archaeophytes are observed there, including 31 found also in medieval deposits. Besides, 6 species present in archaeological deposits are absent in the modern flora (Table 16). These include 3 species that are endangered in Wielkopolska (*Anthemis cotula*, *Bromus secalinus*, and *Lolium temulentum*), whereas the others are likely to be found in further investigations in that region. Contributions of life-forms to both floras are very similar. The only exception were hydrophytes, which were more numerous in the subfossil flora, probably because some of the subfossil materials

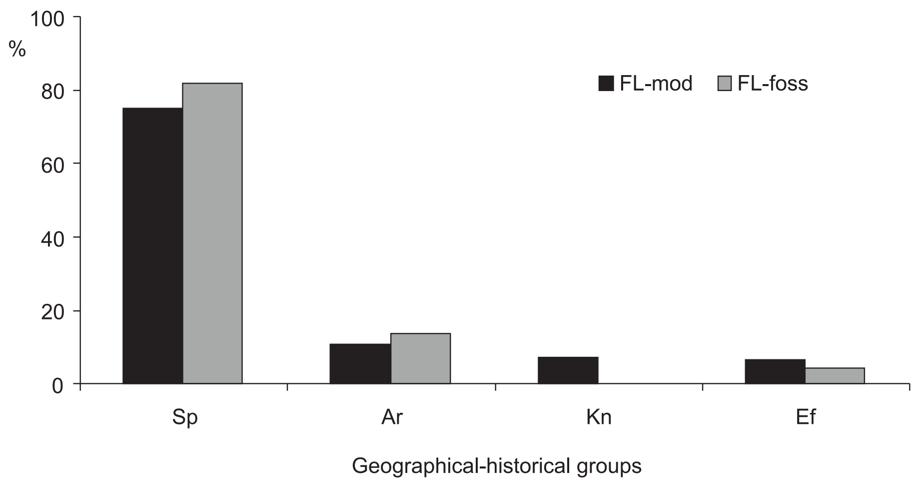



**Fig. 46.** Contributions of geographical-historical groups to the modern flora (FL-mod), and subfossil flora (FL-foss) of the Lednica region
Explanations: see Fig. 14; subfossil data from Tobolski & Polcyn (1993), and Polcyn (2003)

**Table 16.** Archaeophytes in cultural deposits of the Lednica region and their occurrences in the region's modern flora

| Species | Subfossil flora | | Modern flora (author's observations) |
|---|---|---|---|
| | Tobolski & Polcyn 1993 | Polcyn 2003 | |
| *Agrostemma githago* | + | + | + |
| *Anagallis arvensis* | - | + | + |
| *Anthemis cotula* | - | + | - |
| *Ballota nigra* | + | + | + |
| *Bromus secalinus* | + | + | - |
| *Capsella bursa-pastoris* | + | + | + |
| *Centaurea cyanus* | + | + | + |
| *Chenopodium ficifolium* | + | - | + |
| *Chenopodium hybridum* | - | + | + |
| *Cichorium intybus* | + | + | + |
| *Descurainia sophia* | + | + | + |
| *Echinochloa crus-galli* | - | + | + |
| *Fallopia convolvulus* | + | + | + |
| *Fumaria officinalis* | - | + | + |
| *Galium spurium* | - | + | + |
| *Hyoscyamus niger* | - | + | + |
| *Leonurus cardiaca* | - | + | + |
| *Lithospermum arvense* | - | + | + |
| *Lolium temulentum* | - | + | - |
| *Malva alcea* | + | + | + |
| *Malva neglecta* | - | + | + |
| *Malva sylvestris* | - | + | + |
| *Melandrium noctiflorum* | - | + | + |
| *Nepeta cataria* | - | + | - |
| *Neslia paniculata* | + | + | - |
| *Onopordum acanthium* | - | + | + |
| *Scleranthus annuus* | + | - | + |
| *Senecio vulgaris* | + | - | + |
| *Setaria glauca* | + | + | - |
| *Sinapis arvensis* | + | - | + |
| *Sisymbrium officinale* | + | - | + |
| *Solanum nigrum* | + | + | + |
| *Sonchus asper* | - | + | + |
| *Spergula arvensis* | - | + | + |
| *Thlaspi arvense* | - | + | + |
| *Urtica urens* | + | + | + |
| *Viola arvensis* | + | +? | + |

originate from submerged archaeological deposits (Fig. 47). The socio-ecological spectrum has changed considerably (Fig. 48). The subfossil flora has higher contributions of species associated with aquatic habitats and meadows (G1, G3-G5) as well as ruderal plants (G14). The modern flora is dominated by species typical for xerothermic and sandy grasslands (G6), thermophilous oak forests, mesophilous deciduous forests,

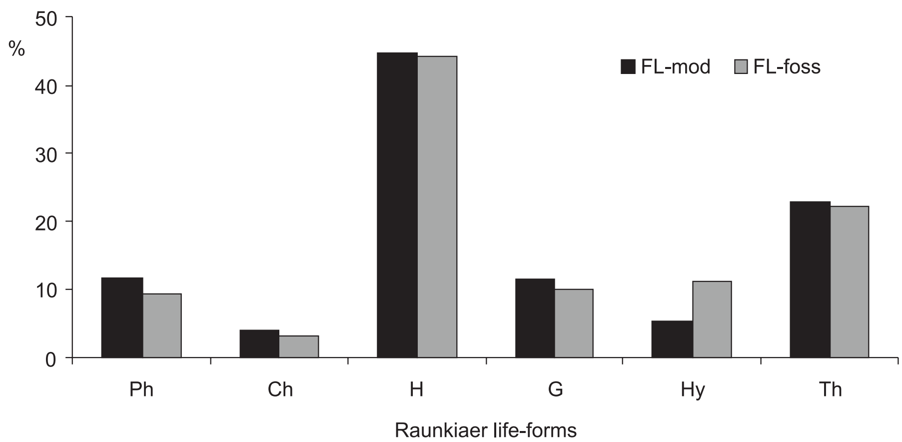



**Fig. 47.** Contributions of Raunkiaer life-forms to the modern flora (FL-mod) and subfossil flora (FL-foss) of the Lednica region
Explanations: see Fig. 16; subfossil data from Tobolski & Polcyn (1993), and Polcyn (2003)

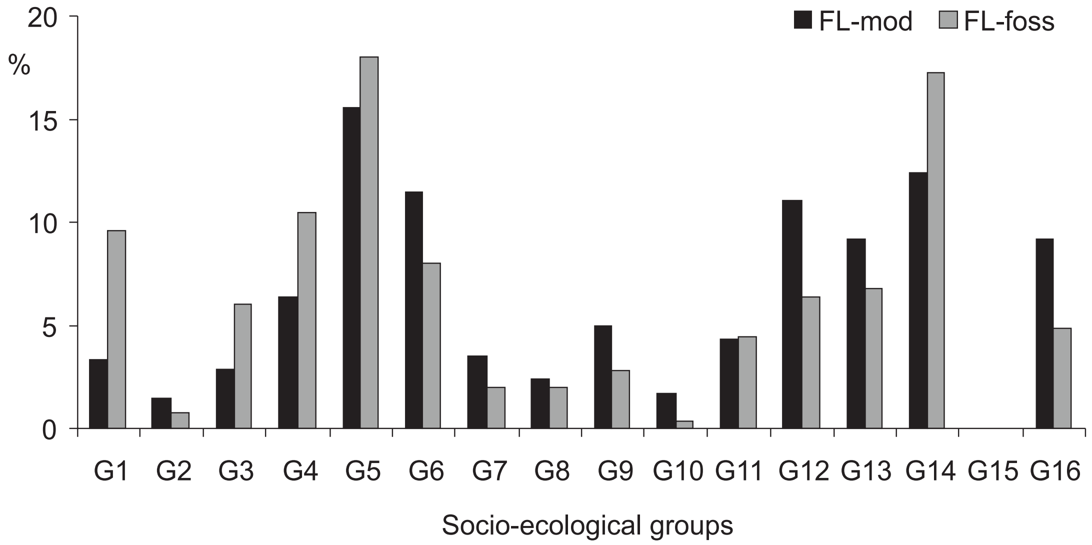



**Fig. 48.** Contributions of socio-ecological groups to the modern flora (FL-mod) and subfossil flora (FL-foss) of the Lednica region
Explanations: see section 4.3.4; subfossil data from Tobolski & Polcyn 1993; Polcyn 2003

**Table 17.** Plant species found in subfossils of a flax bundle at the fortified settlement in Wrześnica (Pomerania, north-western Poland) and their occurrences in the modern flora of this area

| Species found in flax bundle* | This study | Species found in flax bundle* | This study |
|---|---|---|---|
| *Agrostemma githago* | z | *Mentha* cf. *arvensis* | g |
| *Alisma plantago-aquatica* | z | *Myosotis palustris* | g |
| *Alnus glutinosa* | g | *Myosoton aquaticum* | g |
| *Bidens cernua* | z | *Panicum miliaceum* | n |
| *Bidens tripartita* | z | *Pedicularis palustris* | n |
| *Camelina alyssum* | n+ | *Picirs hieracioides* | z |
| *Camelina microcarpa* subsp. *sylvestris* | n | *Plantago major* | g |
| *Capsella bursa-pastoris* | z | *Polygonum aviculare* | g |
| *Carex elata* | z | *Polygonum hydropiper* | g |
| *Carex ovalis* | g | *P. lapathifolium* subsp. *lapathifolium* | z |
| *Carex nigra* | g | *P. lapathifolium* subsp. *pallidum* | z |
| *Carex* cf. *paniculata* | z | *Potentilla argentea* | z |
| *Carex pseudocyperus* | z | *Potentilla erecta* | g |
| *Carex rostrata* | z | *Prunella vulgaris* | z |
| *Carex vesicaria* | g | *Ranunculus acris* | g |
| *Cerastium holosteoides* | g | *Ranunculus repens* | g |
| *Chelidonium majus* | z | *Ranunculus sardous* | n |
| *Chenopodium album* | z | *Ranunculus sceleratus* | g |
| *Cirsium arvense* | g | *Rubus idaeus* | g |
| *Cuscuta epilinum* | n+ | *Rumex acetosella* | g |
| *Echinocloa crus-galli* | z | *Rumex obtusifolius* | g |
| *Eleocharis* cf. *palustris* | z | *Scirpus sylvaticus* | z |
| *Eleocharis* cf. *uniglumis* | z | *Scleranthus annuus* | z |
| *Fallopia convolvulus* | g | *Setaria pumila* | z |
| *Filipendula ulmaria* | g | *Solanum nigrum* | z |
| *Fragaria vesca* | z | *Sonchus asper* | z |
| *Galeopsis ladanum* | n | *Sorbus aucuparia* | g |
| *Galium* cf. *aparine* | g | *Sorbus* cf. *torminalis* | n |
| *Galium spurium* | n | *Spergula maxima*** | n |
| *Glyceria maxima* | g | *Spergula sativa*** | n |
| *Juncus effusus* | g | *Spergula vulgaris*** | n |
| *Lamium album* | z | *Stellaria graminea* | g |
| *Lapsana communis* | g | *Stellaria media* | z |
| *Leontodon autumnalis* | g | *Triglochin maritimum* | n |
| *Linaria vulgaris* | g | *Urtica dioica* | g |
| *Linum catharticum* | z | *Vaccinium myrtillus* | z |
| *Luzula pilosa* | g | *Vaccinium vitis-idaea* | z |
| *Lychnis flos-cuculi* | g | *Vicia hirsuta* | z |

Explanations: * – according to Latałowa & Rączkowski (1999a), ** – names according to Kowal (1966) and Latałowa (1998), g – found within the fortified settlement in this study, n – not recorded in this study, n+ – not recorded in this study, extinct in Poland, z – found close to, but not within the fortified settlement in this study

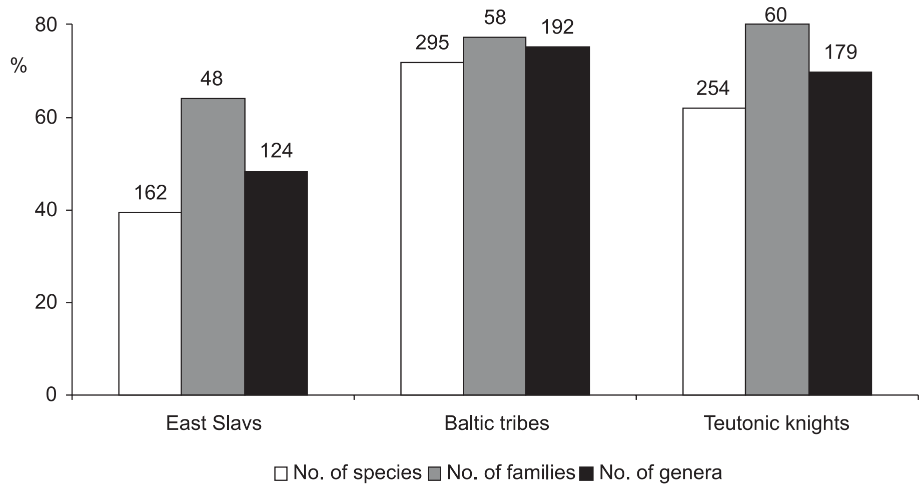



**Fig. 49.** Contributions of species, families, and genera at archaeological sites of other tribes and groups to their total flora

and nitrophilous shrub communities (G12), field and garden weeds (G13), and species of undetermined phytosociological affiliation (G16).

Changes in the flora of a single archaeological site and its vicinity are most conspicuous when comparing the modern flora of the early medieval settlement in Wrześnica with the plant species found in a flax bundle (*Linum usitatissimum*). The bundle was discovered in one of the archaeological excavations near the rampart, close to the river (Latałowa 1998; Latałowa & Rączkowski 1999a, 1999b). Among flax stems, diaspores of 92 plant taxa were found. These include 76 taxa indentified to species or subspecies level (Table 17). Currently at that site, 32 species of this list are found, and another 31 in its immediate vicinity. These include, e.g., field and garden weeds (G13), which at the fortified settlement could be present as late as in the 1930s, when the inner depression was still cultivated (Łosiński *et al*. 1971). Only 13 species of this list are not recorded currently in that region. They can be divided into 5 groups: (*i*) plants that still exist in Pomerania and are very likely to be rediscovered in the Wrześnica settlement complex: *Galeopis ladanum* and *Pedicularis palustris*; (*ii*) currently very rare in Pomerania: *Camelina microcarpa*, *Galium spurium*, *Ranunculus sardous*, *Sorbus torminalis*, and *Triglochin maritimum*; (*iii*) crop species, which could be cultivated together with flax: *Panicum miliaceum* and *Spergula sativa*; (*iv*) formerly distinguished species of the genus *Spergula* (*S. maxima* and *S. vulgaris*), which are currently considered as synonyms of *Spergula arvensis* (this species is recorded in the Wrześnica settlement complex); (*v*) weeds typical of flax fields: *Cuscuta epilinum* and *Camelina alyssum*. The last two species are particularly noteworthy because they are now classified as extinct in Poland (Mirek *et al*. 2001; Zając & Zając 2001). In the geographical-historical spectrum of the plant species found in the flax bundle, archaeophytes are numerous (17 species, 22.4%), but currently this group is represented at that site by only one species: *Fallopia convolvulus*. The dominant life-forms are hemicryptophytes (nearly 40%) and therophytes (about 37%). In the synecological spectrum, the major groups are field and garden weeds (G13, over 21%), meadow plants (G5, over 18%), ruderal weeds (G14, nearly 12%), and marsh plants (G4, nearly 12%).

### 5.4. Comparison of floras of medieval settlements and castles of West Slavs with those of East Slavs, Baltic tribes, and Teutonic knights

For comparison, floristic investigations were conducted in 21 archaeological sites inhabited by East Slavs, Baltic tribes, and Teutonic knights in the same historical period as those used by West Slavs. This group included 2 castles and a fortified settlement located in an area colonized at that time by East Slavs (now Ukraine), 12 Old Prussian and Yotvingian fortified settlements (now north-eastern Poland), and 6 Teutonic castles in the Chełmno region (northern Poland).

Jointly at those sites 411 species of 256 genera and 75 families were recorded. Currently the most species-rich are the sites located in the areas colonized by Baltic tribes (Fig. 49). At the 21 study sites, the local floras include 14 species that were not recorded at West Slavic archaeological sites (Table 18).

As many as 479 species were found exclusively at West Slavic fortified settlements. Over 95% of the species are extremely rare, very rare, or rare at the study sites. Only 22 species are frequent, including 21 native taxa and only one archaeophyte: *Vicia hirsuta*. Interestingly, 10 of these species are absent or relatively rare in north-eastern Poland (e.g. *Fallopia dumetorum*, *Heracleum sphondylium* or *Quercus petraea*), while 6 are associated with wetlands, which are rare or absent

**Table 18.** List of species recorded in this study only at historical sites located outside the region colonized by West Slavs

| Species | Baltic settlements | East Slavic settlements | Teutonic castles |
|---|---|---|---|
| *Alcea rosea* | - | - | • |
| *Arabis planisiliqua* | • | - | - |
| *Artemisia annua* | - | • | - |
| *Aster lanceolatus* | - | - | • |
| *Geranium sibiricum* | - | • | - |
| *Iva xanthiifolia* | - | • | - |
| *Onobrychis viciifolia* | • | - | - |
| *Orobanche alba* | - | • | - |
| *Potentilla supina* | - | • | - |
| *Rosa sherardii* | • | - | - |
| *Rosa tomentosa* | - | • | - |
| *Sambucus ebulus* | - | • | - |
| *Verbascum thapsus* | • | • | - |
| *Virga pilosa* | - | - | • |

at the study sites, e.g. *Carex acutiformis*, *Filipendula ulmaria*, *Galium palustre*, *Iris pseudoacorus*, and *Lemna minor*.

An analysis of the geographical-historical spectrum shows that mostly native species are found at the 21 sites (Fig. 50a). Their contribution is the highest at the Baltic sites (over 85%). At those sites, contributions of kenophytes and ergasiophytes were the lowest. The Old Prussian and Yotvingian settlements were abandoned as early as in the 12th to 13th century (and since then they were mostly penetrated only sporadically. The contribution of anthropophytes is the highest in Teutonic castles (over 30%). They were inhabited until the 17th or 18th century, and some of them are still strongly influenced by human activity. The spectrum of Raunkiaer life-forms is similar for all the sites (Fig. 50b). Because of the lack of aquatic habitats, hydrophytes are absent (except *Polygonum amphibium* at the settlement in Mieruniszki). The lack of some habitat types excluded the presence of some socio-ecological groups. At all the sites, there is no aquatic and flush vegetation, and no plants of raised bogs and bog meadows (G1 and G2). Additionally, East Slavic sites lack waterside therophytes (G3), species of reedbeds and sedge communities (G4), and epilithic species (G15), whereas Old Prussian and Yotvingian settlements lack species of group G15, and Teutonic castles lack species representing G4 (Fig. 50c).

The dendrogram based on species diversity and abundance at the total of 130 study sites (Fig. 51) shows that the sites located outside the area controlled by West Slavs are assigned to subgroups B and C. Subgroup B, including West Slavic archaeological sites with a high contribution of synanthropic communities, comprises also 6 Teutonic castles, 2 East Slavic sites, and a Yotvingian site. They belong to group B1, composed of sites dominated by synanthropic species. In subgroup C, linking archaeological sites dominated by xerothermic species, the addition of 12 sites resulted in separation of 2 subgroups: C1 and C2. Subgroup C1 includes 4 Yotvingian settlements, some of them with a high contribution of forest species. The other 8 sites (7 Yotvingian settlements and a Ukrainian castle) are within subgroup C2.

In the dendrogram based on the Steinhaus index of floristic similarity for the 130 sites, all the sites located outside the area controlled by West Slavs are assigned to a large, heterogeneous group C (Fig. 52). Some Teutonic castles form a small subgroup (sites 125, 127, 129, and 130). Four Yotvingian settlements are also aggregated in a separate small subgroup (sites 112-114 and 119), while Ukrainian sites constitute another subgroup (sites 122-124). The most similar (Steinhaus index 0.6) are Teutonic castles in Kowalewo Pomorskie and Wąbrzeźno. No species are common to fortified settlements Myślibórz III and Boże. The mean Steinhaus index for 21 sites located outside the area controlled by West Slavs is 0.32.

Detailed research was conducted at 12 Baltic fortified settlements (7 concave, 4 cone-shaped, and one with a transverse rampart) and 6 Teutonic castles in the Chełmno region. To compare them with floras of West Slavic archaeological sites, 12 West Slavic fortified settlements were randomly selected (7 concave ones: Błonie, Dziedzice, Grodzisk, Kałdus, Ostrowo, Sławsko, Starý Plzenec; 4 cone-shaped ones: Czaple Szlacheckie, Drohiczyn, Połęcko, Pszczew; and one with a transverse rampart: Stary Kraków), as well as 6 castles (Dzierznica, Koło, Odrzykoń, Rząsiny, Wenecja, Wleń).

The flora of the 12 randomly selected West Slavic settlements differs from that of 12 Baltic settlements in number of species (405 and 295, respectively). This can be due to the greater habitat diversity in the selected West Slavic settlements (including all major habitat

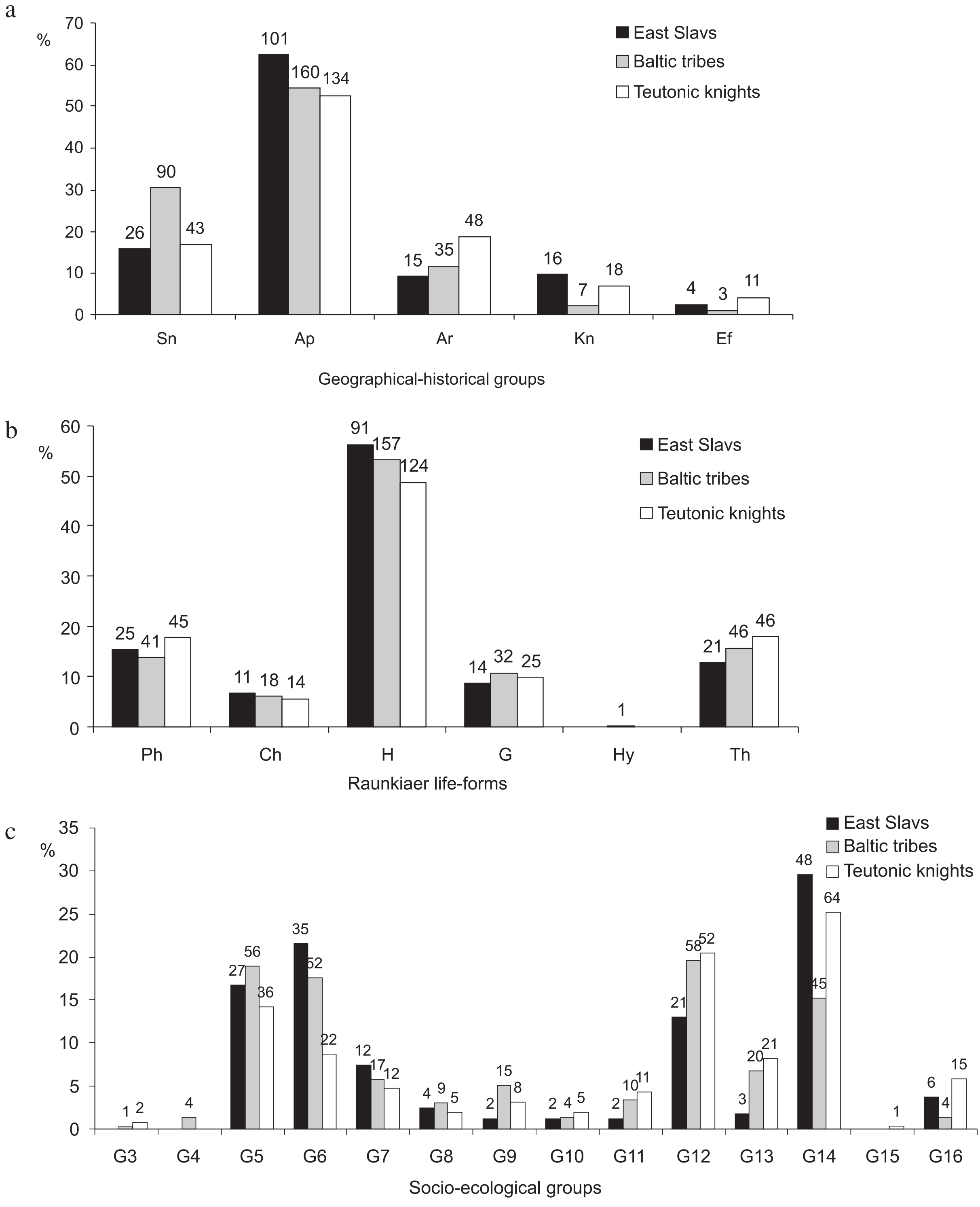



**Fig. 50.** Contributions of geographical-historical groups (a), life-forms (b), and socio-ecological groups (c) to the flora of archaeological sites of other tribes and groups
Explanations: see Figs. 14, 16 and section 4.3.4

types: dry grasslands, meadows, arable fields, ruderal habitats, shrublands, and forests). In fortified Baltic settlements, which were not been inhabited after the early Middle Ages, the dominant habitat types are dry grasslands as well as shrub and forest communities, while synanthropic habitats are relatively small and infrequent. In the geographical-historical spectrum, native plants prevail and their contribution is slightly higher in Baltic settlements. Among anthropophytes, kenophytes and ergasiophytes slightly prevail at West Slavic sites, while contributions of archaeophytes are similar in both groups (Fig. 53a). The flora of Baltic settlements is more synanthropic than the flora of 12 selected West Slavic settlements ($WS_t$=69.5%, $WS_p$=69.2%). In the flora of Baltic settlements, apophytes clearly prevail over anthropophytes ($WAp_t$

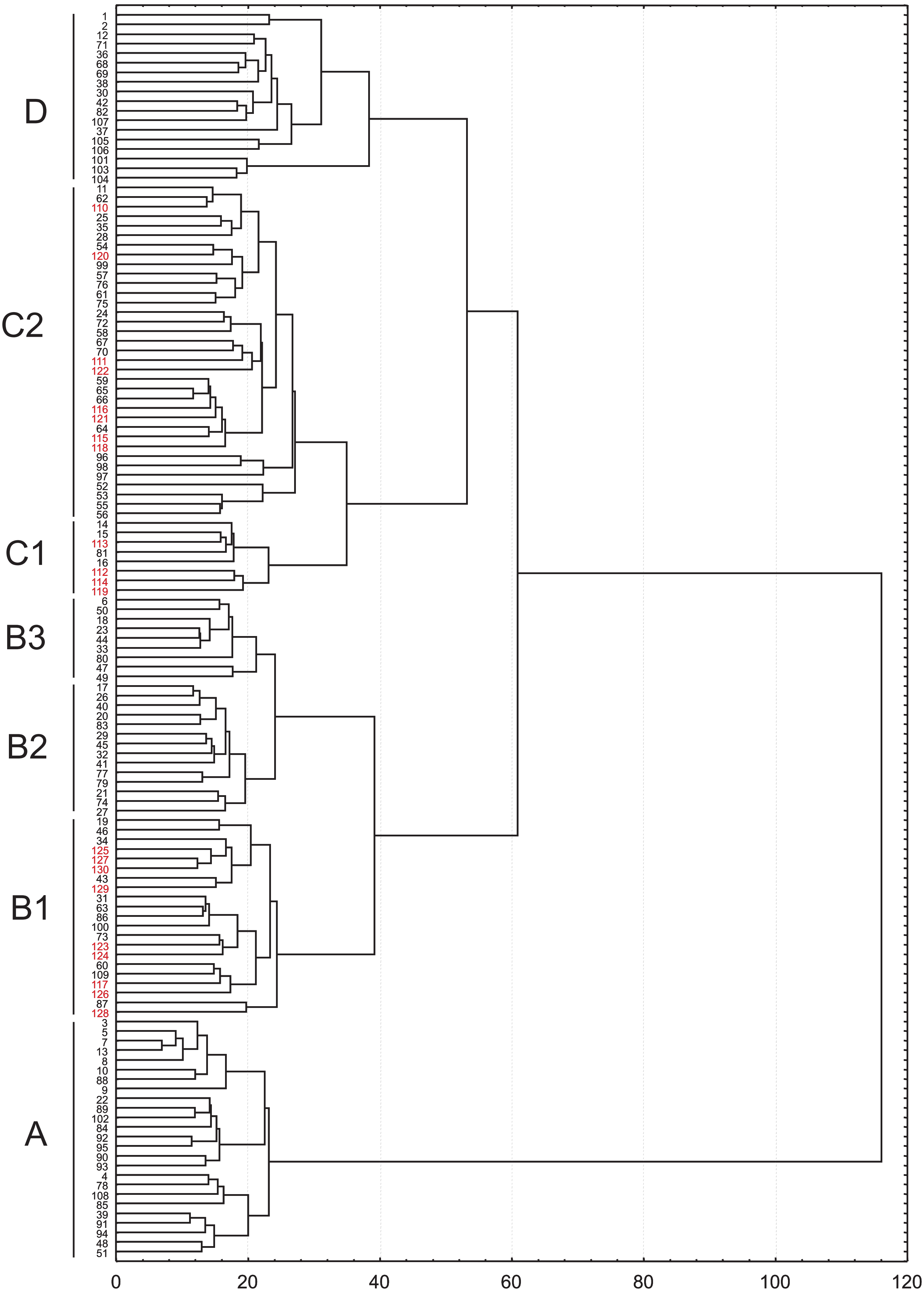



**Fig. 51.** Dendrogram of species number and abundance at individual sites, constructed on the basis of Euclidean distances by agglomerative clustering (Ward metod) for 130 sites

Explanations: site numbers correspond to those in Appendix 1 (sites 1-109) and 2 (sites 110-130), red denotes the sites located outside the area colonized by West Slavs

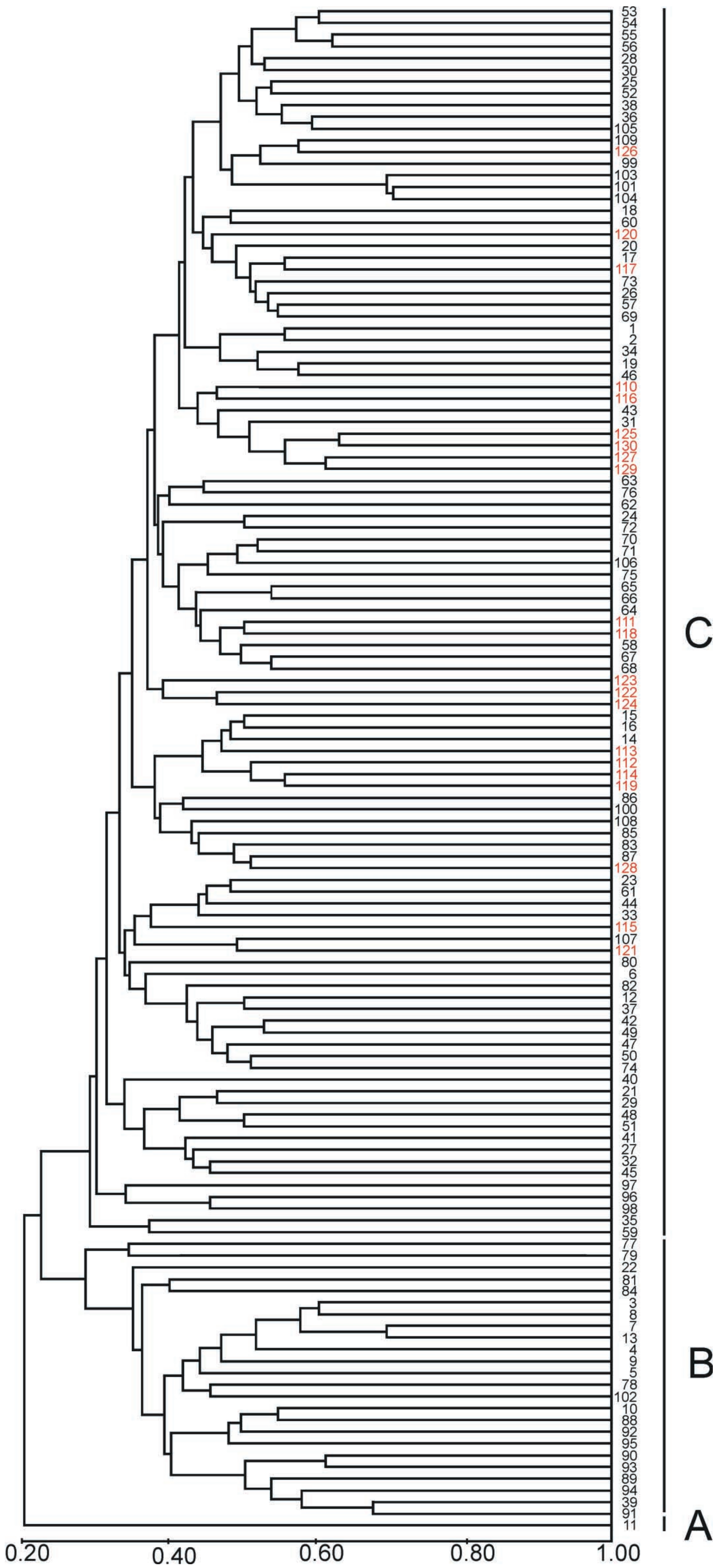



**Fig. 52.** Dendrogram of the 130 study sites constructed on the basis of the Steinhaus index of floristic similarity (UPGMA method)
Explanations: see Fig. 51

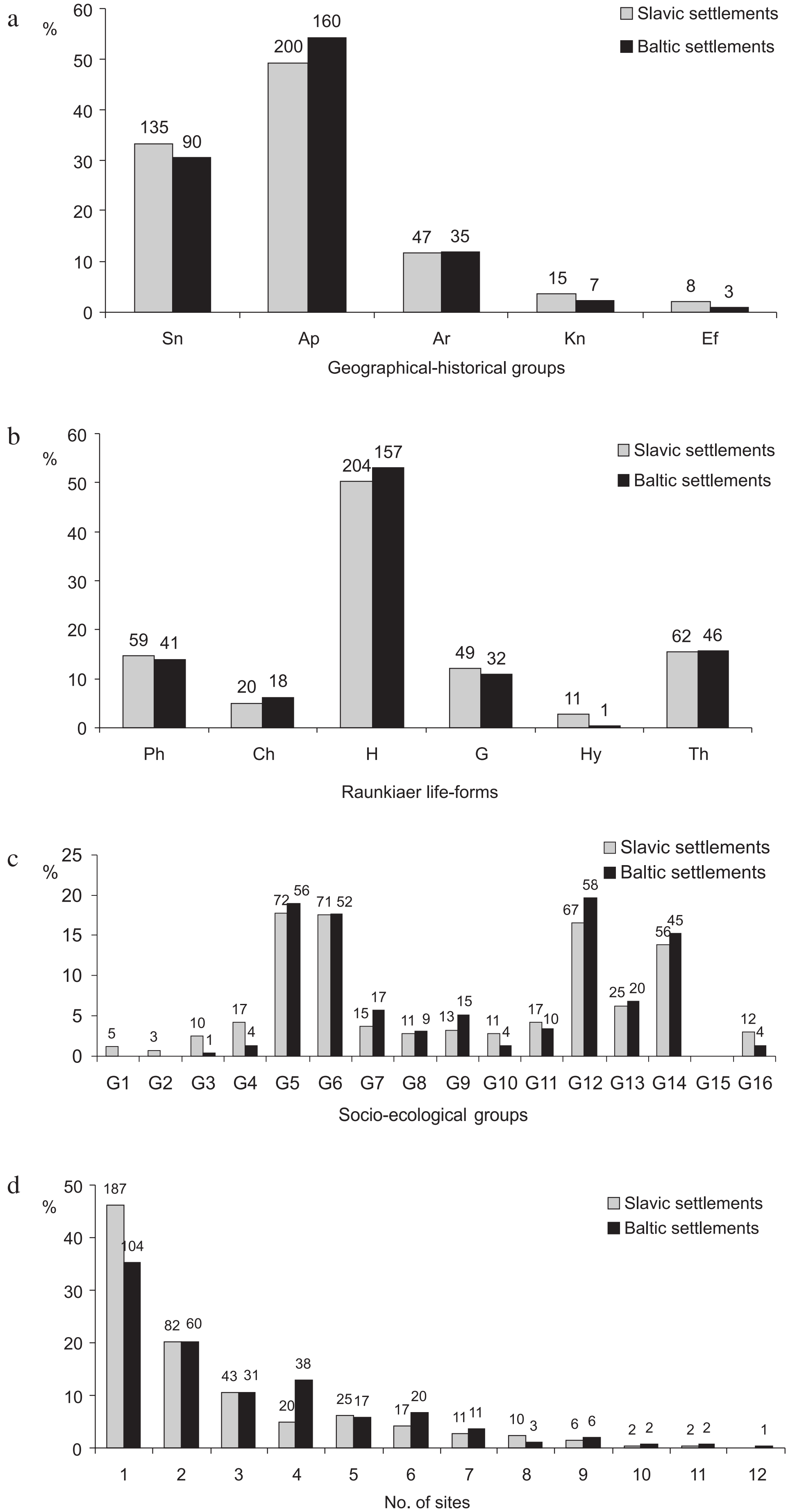



**Fig. 53.** Contributions of geographical-historical groups (a), life-forms (b), socio-ecological groups (c), and frequency classes of species (d) to the flora of 12 Baltic and 12 selected West Slavic fortified settlements

Explanations: see Figs. 14, 16 and section 4.3.4

**Table 19.** Indices of anthropogenic changes in the flora of 12 Baltic and 12 selected West Slavic fortified settlements

| Index [%] | West Slavic settlements | Baltic settlements |
|---|---|---|
| $WS_t$ | 66.7 | 69.5 |
| $WS_p$ | 66.0 | 69.2 |
| $WAp_t$ | 49.4 | 54.2 |
| $WAp_p$ | 50.4 | 54.8 |
| *Wap* | 59.7 | 64.0 |
| $WAn_t$ | 17.3 | 15.3 |
| $WAn_p$ | 15.6 | 14.4 |
| $WAr_t$ | 11.6 | 11.9 |
| $WAr_p$ | 11.8 | 12.0 |
| $WKn_t$ | 3.7 | 2.4 |
| $WKn_p$ | 3.8 | 2.4 |
| *WM* | 24.2 | 16.7 |
| *WF* | 2.0 | 1.0 |
| *WN* | 33.3 | 30.5 |
| $WT_a$ | 88.6 | 93.3 |
| $WT_t$ | 98.0 | 99.0 |

Explanations: index names – see Table 6

**Table 20.** Indices of anthropogenic changes in the flora of 6 Teutonic and 6 selected West Slavic castles

| Index [%] | West Slavic castles | Teutonic castles |
|---|---|---|
| $WS_t$ | 76.1 | 83.1 |
| $WS_p$ | 75.5 | 82.3 |
| $WAp_t$ | 55.0 | 52.8 |
| $WAp_p$ | 56.4 | 55.1 |
| *Wap* | 69.7 | 75.7 |
| $WAn_t$ | 21.1 | 30.3 |
| $WAn_p$ | 19.1 | 27.2 |
| $WAr_t$ | 12.8 | 18.9 |
| $WAr_p$ | 13.1 | 19.8 |
| $WKn_t$ | 5.9 | 7.1 |
| $WKn_p$ | 6.0 | 7.4 |
| *WM* | 31.5 | 27.3 |
| *WF* | 2.4 | 4.3 |
| *WN* | 33.3 | 16.9 |
| $WT_a$ | 23.9 | 85.7 |
| $WT_t$ | 88.5 | 95.7 |

Explanations: index names – see Table 6

is about 3.5-fold higher than $WAn_t$), about 65% of spontaneophytes are apophytes, and the flora naturalness index is only 30% (Table 19). Indices of apophytization, kenophytization, modernization, and floristic fluctuations are higher for West Slavic settlements. Indices of flora archaeophytization are slightly higher for Baltic settlements (Table 19).

Among plant life-forms in Baltic settlements, there are no hydrophytes, while contributions of geophytes and hemicryptophytes are relatively small (Fig. 53b). The greatest differences were observed in the socio-ecological spectrum. At the Baltic settlements, there are no species of groups G1, G3, and G15, while the contribution of G3 is small. By contrast, contributions of 4 dominant groups (over 10% each: G5, G6, G12, and G14) were higher (Fig. 53c). Among species frequency classes, in both groups of sites, species found at single sites are most numerous (Fig. 53d). Only few species are found at 10-12 sites. In West Slavic settlements, these include *Cirsium arvense*, *Dactylis glomerata*, *Sambucus nigra*, and *Urtica dioica*, while in Baltic settlements: *Achillea millefolium*, *Agrostis capillaris*, *Dactylis glomerata*, *Urtica dioica*, and *Galium mollugo*. The last mentioned species was found at all the 12 sites. Relics of cultivation in Baltic settlements are represented at 5 sites by *Anthemis tinctoria* and *Malva alcea*, at 2 sites by *Artemisia absinthium* and *Leonurus cardaica*, and at single sites by *Origanum vulgare* and *Viola odorata.* Those species could be cultivated there by Balic tribes or the presence of Slavic relics of cultivation may be due to the use of these sites also by Slavic people in the Middle Ages (which was the case at 3 sites) or due to a later expansion of those species, associated with human activity in the modern era. In the group of 12 selected West Slavic settlements, 11 relics of cultivation were observed at 11 sites: *Allium scorodoprasum* (1 site), *Artemisia absinthium* (3), *Chaerophylum bulbosum* (1), *Lavatera thuringiaca* (4), *Leonurus cardiaca* (3), *Lithospermum officinale* (1), *Lycium barbarum* (1), *Malva alcea* (6), *Origanum vulgare* (1), and *Viola odorata* (4).

West Slavic castles and Teutonic castles are colonized by similar numbers of species (289 and 254 species, respectively). In both groups of castles, ruderal and shrub communities prevail. Considering the geographical-historical groups, a majority of species are native, mostly apophytes (Fig. 54a). In Teutonic castles, the contribution of non-synanthropic spontaneophytes was much lower (23.9% vs. 16.9%). The contribution of anthropophytes is much larger in Teutonic castles, where it reaches over 30%. Most of them are archaeophytes (18.9%). The flora of Teutonic castles is more synanthropic ($WS_t$=83.1% and $WS_p$=82.3%) than the flora of the selected West Slavic castles (Table 20). In the flora of the latter group, apophytes prevail over anthropophytes ($WAp_t$ is about 2.5-fold higher than $WAn_p$). In Teutonic castles, over ¾ spontaneophytes are apophytes, and the contribution of non-synanthropic spontaneophytes is very low (*WN*=16.9%). Also indices of anthropophytization, kenophytization, and archaeophytization are higher for Teutonic castles (Table 20).

Among plant life-forms, there are no hydrophytes in Teutonic castles, and their percentage contribution in West Slavic castles is negligible (Fig. 54b). In the socio-ecological spectrum of Teutonic castles, no species represent groups G1, G2, and G4. At these sites, contributions of G13, G14, and G16 are higher. In Slavic castles, no species represent groups G1 and G2, while more species belong to groups G5, G6, G9, and G12 (Fig. 54c). In Teutonic castles, the only epilithic species is *Cymbalaria muralis*, whereas in Slavic castles,

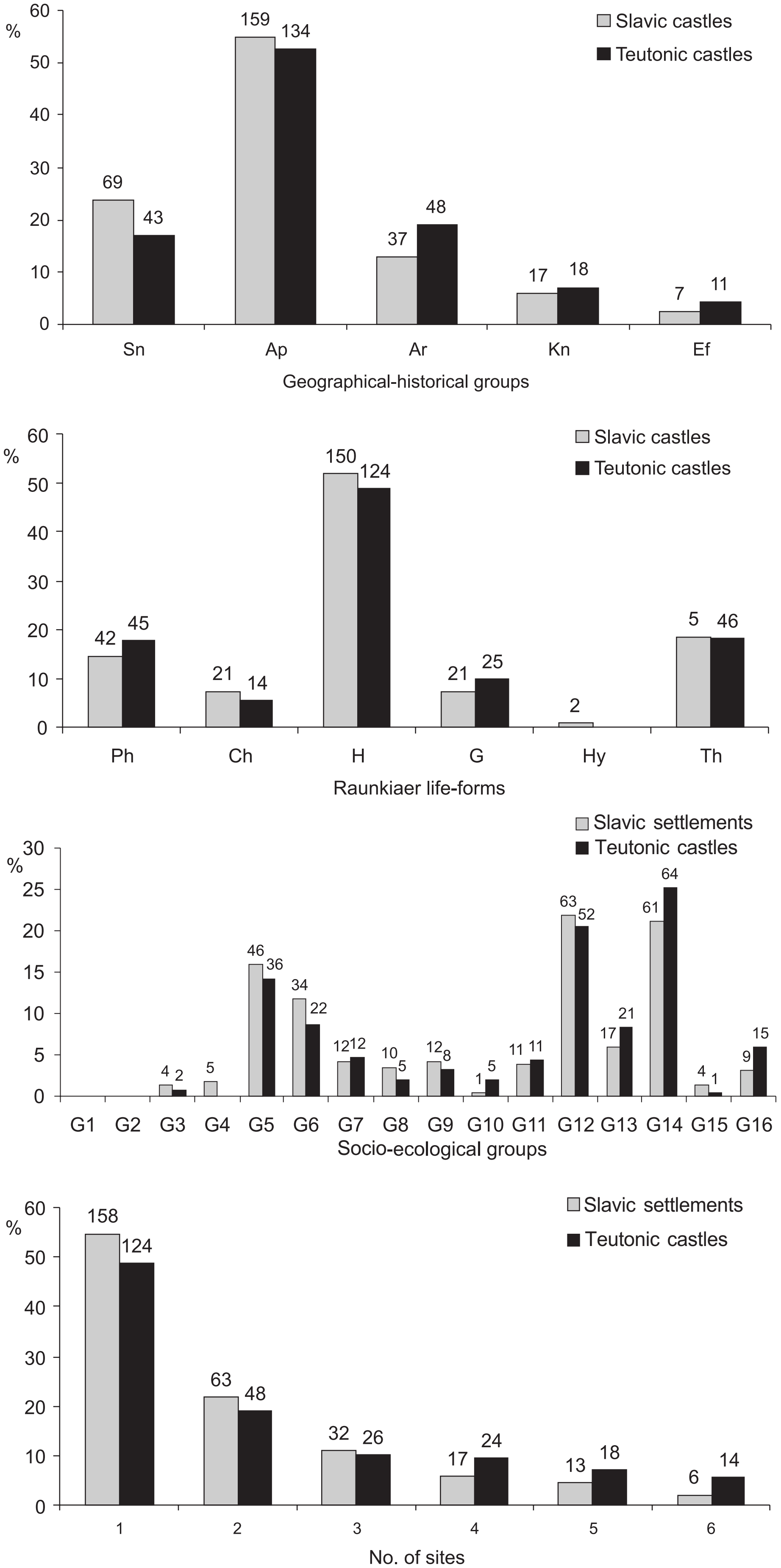



**Fig. 54.** Contributions of geographical-historical groups (a), life-forms (b), socio-ecological groups (c), and frequency classes of species (d) to the flora of 6 Teutonic castles and 6 selected West Slavic castles

Explanations: see Figs. 14, 16 and section 4.3.4

this group was represented also by *Asplenium ruta-muraria, A. trichomanes*, and *Cystopteris fragilis*. Among species frequency classes, in both groups of sites, species found at single sites are most numerous (Fig. 54d). The contribution of species found at all the 6 sites is relatively large. This frequency class includes 6 species in Slavic castles: *Arrhenatherum elatius, Conyza canadensis, Lolium perenne, Plantago major, Sambucus nigra*, and *Urtica dioica*; and 8 species in Teutonic castles: *Achillea millefolium*, *Dactylis glomerata*, *Plantago major, Poa annua, Poa compressa, Polygonum aviculare, Taraxacum officinale*, and *Urtica dioica*. In West Slavic castles, 8 relics of cultivation were found: *Artemisia absinthium* (2 sites), *Chaerophyllum bulbosum* (1), *Cymbalaria muralis* (1), *Leonurus cardiaca* (2), *Malva alcea* (2), *Nepeta cataria* (2), *Origanum vulgare* (1), and *Viola odorata* (1). In the 6 Teutonic castles, this group is represented by 11 species: *Anthemis tinctoria* (1), *Cymbalaria muralis* (1), *Chaerophyllum bulbosum* (2), *Leonurus cardiaca* (1), *Lycium barbarum* (1), *Malva alcea* (1), *Origanum vulgare* (2), *Pastinaca sativa* (1), *Saponaria officinalis* (1), *Vinca minor* (1), and *Viola odorata* (6).

### 5.5. Specificity of the current flora of West Slavic archaeological sites and its distinctness from the surrounding natural environment

Archaeological sites are distinguished from the surrounding landscape by their specific vegetation. This is a result of secondary succession initiated after the Slavic settlements were abandoned. However, floristic traces of human activity at that time can still be found there. Fortified settlements and castles were built, as a rule, in places that were not easily accessible: on hills, at river bends, on lake islands, and on wetlands (Figs. 55-57). Out of the total of 109 sites, 48 are now located in farmland, 32 in woodlands, 27 in built-up areas, and 2 on lake islands. In the Middle Ages, many of them were situated in isolated places. Currently they form a mosaic of habitats varying in history and naturalness, and are refuges of plant diversity.

Even at a single archaeological site, covering a small area, a great variety of habitats can be found, such as sandy or xerothermic grassland on slopes of ramparts and cone-shaped mounds, a meadow patch and an aquatic habitat in the moat, a species-rich shrub community in the central depression, and/or some fields and ruderal habitats. That is why, within a small area, a high diversity of species coexist. They are diagnostic for various plant communities: xerothermic grasslands (e.g. *Thalictrum minus* and *Filipendula vulgaris*), meadows (*Avenula pubescens* and *Briza media*), aquatic communities (*Batrachium trichophyllum* and *Potamogeton crispus*), forests and shrub communities (*Anemone nemorosa* and *Gagea lutea*), and synanthropic communities (*Consolida regalis* and *Ballota nigra*).

**Fig. 55.** Concave settlement in Stara Łomża, in the Narew valley (eastern Poland)

**Fig. 56.** Concave settlement in Jaguszewice near Toruń, located at the edge of a valley (northern Poland)

**Fig. 57.** Castle in Mirów near Częstochowa, located on a steep hill (southern Poland)

A lower plant diversity is observed at archaeological sites located within extensive woodlands, because they are covered mostly by forest and shrub communities, while rarely by other vegetation types. The vegetation of fortified settlements usually positively differs

**Fig. 58.** Monumental oaks (*Quercus robur*) on a rampart of the fortified settlement of Laschendorf near Malchow (north-eastern Germany)

**Fig. 59.** *Galium cracoviense* on the castle in Olsztyn near Częstochowa (southern Poland, photo by R. Sajkiewicz)

from their surroundings, partly because of the relatively high species richness and higher level of naturalness. This results from the difficult access to such sites and, consequently, lower human impact. In fortified settlements and castles located in extensive woodlands, many veteran trees have been preserved, e.g. *Fagus sylvatica* and *Quercus robur* at the fortified settlement in Laschendorf, *Quercus robur* in Jeżewo, *Sorbus torminalis* in Kociałkowa Górka, or *Acer campestre* in the castle in Czudec (Figs. 58, 60). The specificity and floristic diversity of the studied archaeological sites is confirmed by the presence of a large number of species of old deciduous forests (see section 5.1.8).

The environmental value of archaeological sites is increased by the presence of many species that are protected by Polish law or classified as endangered, vulnerable, or rare, both on the national and regional scale. At the 100 West Slavic archaeological sites located in Poland, 27 plant species that are threatened in Poland were recorded (i.e. 3.2% of their total flora), including 5 endangered, 18 vulnerable, and 4 rare species (Table 21, Fig. 59).

**Fig. 60.** Veteran oak trees (*Quercus robur*, bird's eye view) at the fortified settlement in Jeżewo near Gostyń (western Poland, photo by W. Rączkowski)

**Table 21.** Threatened and protected species in Poland recorded at West Slavic archaeological sites

| Species | Threat category in Poland[1] | Protection status in Poland[2] |
|---|---|---|
| *Adonis aestivalis*[Ar] | V | - |
| *Allium angulosum* | V | - |
| *Allium scorodoprasum*[Ar] | V | - |
| *Allium ursinum* | [V] | PP |
| *Anemone sylvestris* | - | SP |
| *Angelica archangelica* subsp. *archangelica* | - | SP |
| *Asarum europaeum* | - | PP |
| *Asperugo procumbens*[Ar] | E | - |
| *Asperula tinctoria* | V | - |
| *Batrachium trichophyllum* | - | SP |
| *Botrychium multifidum** | E | SP |
| *Bromus secalinus*[Ar] | V | - |
| *Campanula bononiensis* | - | SP |
| *Campanula latifolia* | V | SP |
| *Carex praecox* | V | - |
| *Carlina acaulis* | - | SP |
| *Centaurium erythraea* subsp. *erythraea* | - | SP |
| *Cephalanthera longifolia* | V | SP |
| *Cerasus fruticosa* | V | SP |
| *Chimaphila umbellata* | - | SP |
| *Cnidium dubium* | V | - |
| *Convallaria majalis* | - | PP |
| *Daphne mezereum.* | - | SP |
| *Dianthus superbus* | V | SP |
| *Diphasiastrum complanatum** | - | SP |
| *Elymus hispidus* subsp. *hispidus* | R | - |
| *Epipactis helleborine* | -- | SP |
| *Frangula alnus* | - | PP |
| *Gagea arvensis*[Ar] | E | - |
| *Gagea minima* | V | - |
| *Gagea pratensis* | V | - |
| *Galanthus nivalis* | - | SP |
| *Galium cracoviense* | R | SP |
| *Galium odoratum* | - | PP |
| *Gentiana cruciata* | - | SP |
| *Hedera helix* | - | PP |
| *Helichrysum arenarium* | - | PP |
| *Hepatica nobilis* | - | SP |
| *Hieracium echioides* | V | - |
| *Jovibarba sobolifera* | - | SP |
| *Lilium martagon* | - | SP |
| *Lycopodium annotinum** | - | SP |
| *Lycopodium clavatum** | - | SP |
| *Marrubium vulgare*[Ar] | E | - |
| *Melittis melissophyllum* | - | SP |
| *Ononis arvensis* | - | PP |
| *Ononis spinosa* | - | PP |
| *Ophioglossum vulgatum* | V | SP |
| *Orobanche bartlingii* | R | SP |
| *Orobanche caryophyllacea* | - | SP |
| *Polypodium vulgare* | - | SP |
| *Primula elatior* | - | PP |
| *Primula veris* | - | PP |
| *Ribes nigrum* | - | PP |
| *Saxifraga paniculata* | - | SP |
| *Sorbus torminalis* | - | SP |
| *Stipa capillata* | V | SP |
| *Thymus kosteleckyanus* | R | - |
| *Triglochin maritimum* | [E] | - |
| *Valerianella locusta*[Ar] | V | - |
| *Viburnum opulus* | - | PP |

Explanations: [1] – according to the list of Zarzycki and Szeląg (2006), [2] – according to the Regulation of the Minister of Environment (2004), E – critically endangered, [E] – critically endangered at isolated localities, V – vulnerable, [V] – vulnerable at isolated localities, R – rare (potentially endangered), SP – strictly protected, PP – partly protected, * – not recorded during this study, [Ar] – archaeophyte

At archaeological sites, also many species from regional red lists are found. However, this phenomenon is difficult to analyse statistically because (*i*) lists of threatened and rare species are not available for all physiographic regions of Poland; and (*ii*) the lists are not always created according to the same principles and criteria. For example, in fortified settlements in the Wielkopolska region, apart from the taxa endangered on the national scale, also 30 species included in the red list for this region are found (Jackowiak *et al.* 2007). These include e.g. *Actaea spicata*, *Chenopodium bonus-henricus*, *Draba nemorosa*, *Libanotis pyrenaica*, *Melittis melissophyllum*, *Parnassia palustris*, *Stachys recta*, *Thesium linophyllon*, and *Veronica catenata*. In 4 castles in the Kraków-Częstochowa Upland, 24 of the recorded taxa are threatened or rare in that region (Bernacki *et al.* 2000). These include e.g. *Allium montanum, Anthericum ramosum, Corydalis solida, Cynoglossum officinale, Denataria enneaphyllos, Gypsophila fastigiata, Inula salicina, Libanotis pyrenaica, Potentilla recta, Stachys recta*, and *Veronica teucrium* (Fig. 61). In 3 fortified settlements in the South Podlasie Lowland, *Allium oleraceum*, *Lavatera thuringiaca*, and *Stachys recta* are found (Głowacki *et al.* 2003). At the fortified settlement in Tum near Łęczyca, species of the "Red List of Flora of Central Poland" (Jakubowska-Gabara & Kucharski 1999) are represented by *Arabis glabra*, *Cuscuta europaea*, *Phleum phleoides*, *Salvia pratensis, S. verticillata*, and *Thalictrum minus.*

It is noteworthy that *Galium cracoviense* was found in wall crevices of the castle in Olsztyn (Fig. 59). It is an endemic species included in the world list of endangered plants (Mirek 2001a) covered also by the Bern Convention of 1979. The only population of *Galium cracoviense* in the world reported so far was found on Jurassic rock outcrops covered with dry grassland east of Olsztyn near Częstochowa (Mirek 2001a).

At the studied archaeological sites in Poland, 44 of the recorded species are protected by Polish law (i.e. 5.2% of the flora). Among them, 31 are strictly protected and 13 are partly protected (Table 21). This statistical analysis excludes *Sorbus intermedia*, *Taxus baccata*, and *Vinca minor*, i.e. the species whose presence at the study sites is associated with plants cultivated in the vicinity.

In fortified settlements and castles, some archaeophytes have survived, although they disappear from the fields and ruderal sites located nearby (see Fig. 37c). The scale of their decline is evidenced by the inclusion of some of them in the "Red List of Polish Vascular Plants" (Table 21). Except for the relatively widely distributed *Allium scorodoprasum*, these species are classified in the present study as extremely rare (*Adonis aestivalis*, *Asperugo procumbens*, *Bromus secalinus*, *Gagea arvensis*, *Marrubium vulgare*) or very rare (*Valerianella locusta*).

The special role of archaeological sites as refuges of plant diversity is evident in the agricultural landscape. The flora of 45 sites surrounded by farmland includes 666 species, which constitute 76% of the total number of species recorded at West Slavic sites. Their geographical-historical spectrum differs slightly from that of the total flora. Non-synanthropic spontaneophytes prevail but their contribution is very similar to that of apophytes (Fig. 62). Among alien species, the prevalence of archaeophytes over the other group is more

**Fig. 61.** *Stachys recta* at the fortified settlement in Stradów near Kraków (south-eastern Poland)

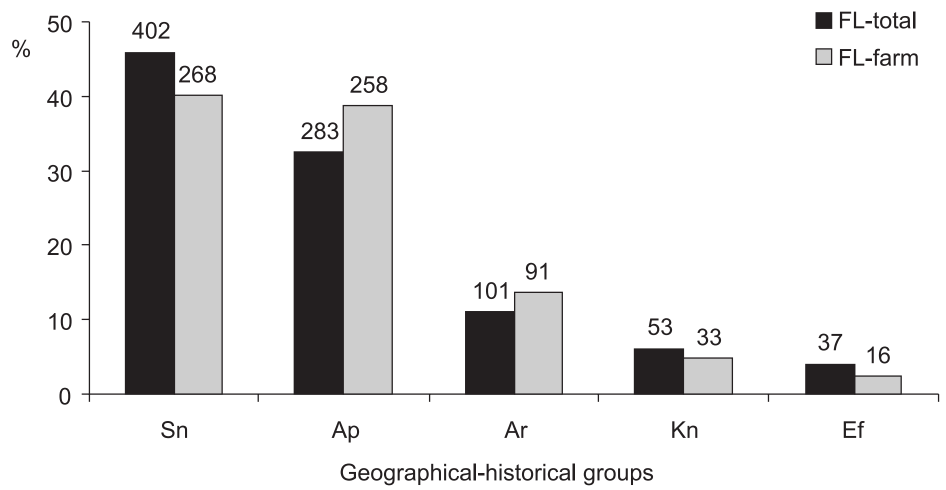



**Fig. 62.** Contributions of geographical-historical groups to the total flora (FL-total) and to the flora of West Slavic sites located in farmland (FL-farm)
Explanations: see Fig. 14

conspicuous. The surrounding farmland only slightly affects the spectrum of plant life-forms of archaeological sites (Fig. 63), but strongly affects socio-ecological groups (Fig. 64). At the study sites located in farmland all the groups are represented, but contributions of groups G5 and G13 are higher than in the total flora, while those of groups G6, G9, and G12 are markedly lower. It is noteworthy that in ruins of the castle in Rząsiny, 2 epilithic species (G15) were found: *Asplenium ruta muraria* and *A. trichomanes*.

The mean floristic value (*Wf*), calculated according to Loster's (1985) formula, is 70.7 for the study sites located in farmland, so it is higher than for the total flora of West Slavic sites (*Wf*=66.6). By contrast, their floristic dissimilarity indices are nearly the same. The floristic distinctness of fortified settlements and castles from the surrounding farmland is mostly due to the high variation and fragmentation of habitats (mean area 0.9 ha) and is manifested mostly by the presence of relics of cultivation (see section 6.4). The role of archaeological sites as plant refuges is greater in the agricultural landscape because they are specific habitat islands. In many cases they are the only wooded patches in otherwise monotonous agricultural landscapes. Results of this study show that sites of medieval settlements and castles play a major role of refuges of plant diversity, for native species as well as archaeophytes.

## 6. Discussion and conclusions

### 6.1. General remarks on the current flora of archaeological sites in Central Europe

On the basis of the present study and published data from Germany (Brandes 1996a; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), Austria (Hübl & Scharfetter 2008), and Poland (Buliński 1993; Celka 1999, 2004; Kamiński 2006a, 2006b), a general picture

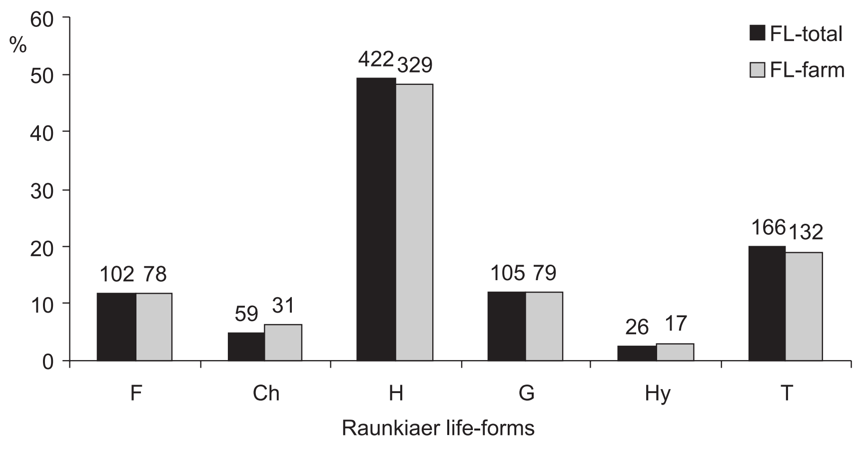



**Fig. 63.** Contributions of Raunkiaer life-forms to the total flora (FL-total) and to the flora of West Slavic study sites located in farmland (FL-farm)
Explanations: see Fig. 16

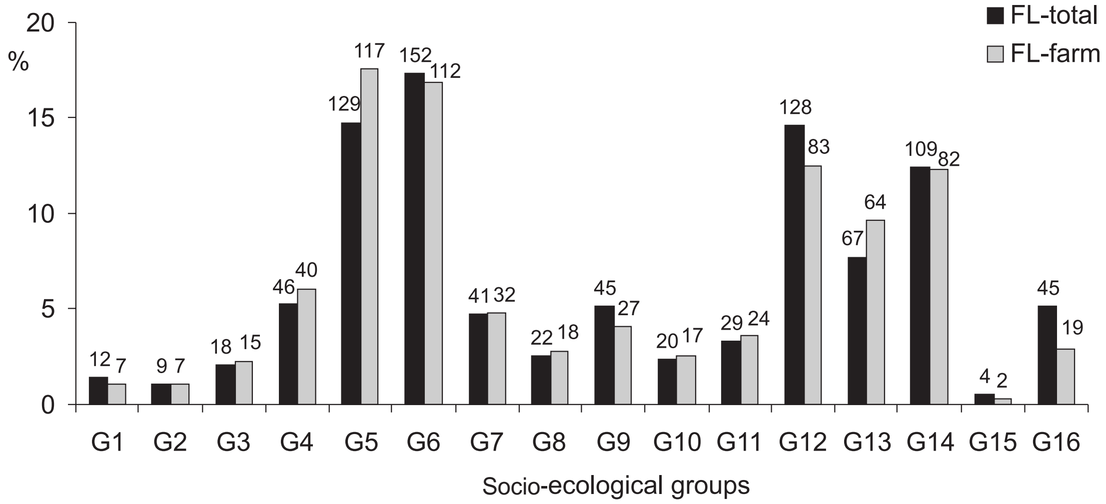



**Fig. 64.** Contributions of socio-ecological groups to the total flora (FL-total) and to the flora of West Slavic study sites located in farmland (FL-farm)
Explanations: see section 4.3.4

of the flora of archaeological sites in Central Europe can be put together. The number of species recorded at concave settlements (over 150 analysed sites) is close to 800, while at castles, both in southern Poland and Lower Austria, it slightly exceeds 600. The flora of castles of southern Germany seems to be much poorer, as it includes 371 species (Fig. 65). It should be noted, however, that at those sites, botanical explorations focused on plants growing on rocks and walls and – to a lesser extent – on xerothermic shrub communities.

On the basis of various criteria, Central European archaeological sites can be divided into groups represented by several to about a dozen sites each. About 300-400 species are recorded in individual groups. The number of recorded species depends to a large extent on the number of sites and their total area, and thus it can be treated only as a background for a discussion of the factors that determine plant diversity.

Among the Central European sites, the richest in species are those classified as large or medium-sized (Appendix 1 and 4). This applies mostly to castles and concave settlements with a high variety of habitats (dry grasslands, meadows, shrublands, and ruderal habitats) and those surrounded by various habitats, usually dry grasslands, meadows, fields, wetlands, and ruderal habitats. Plant diversity is much lower at wooded sites and those surrounded by woodland or by fields and meadows only.

It is interesting to compare the groups of archaeological sites in respect of e.g. indices of flora anthropophytization (Fig. 66). The contribution of alien

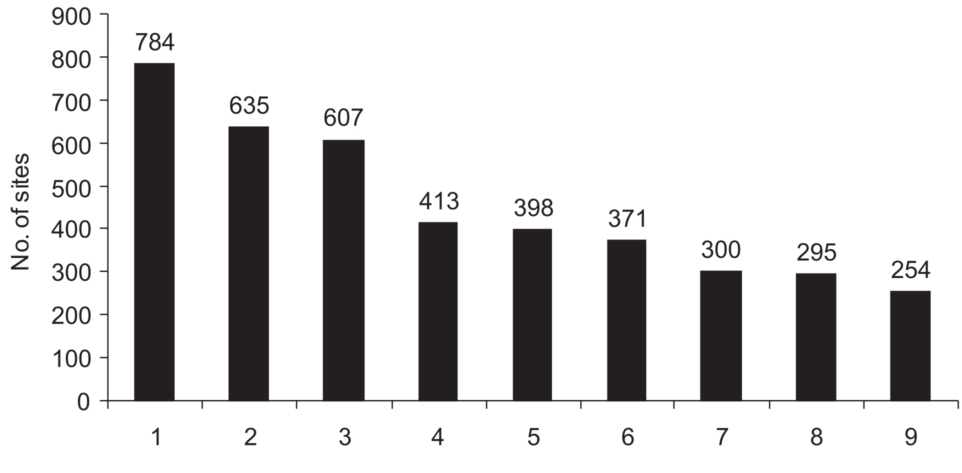



**Fig. 65.** Total numbers of species in the compared floras of fortified settlements and castles of Central Europe
Explanations: 1 – concave West Slavic settlements in this study (74 sites), 2 – castles in Lower Austria (55 sites, Hübl & Scharfetter 2008), 3 – West Slavic castles in this study (21 sites), 4 – castles in south-western Germany (10 sites, Schneider & Fleschutz 2001), 5 – cone-shaped West Slavic settlements in this study (14 sites), 6 – castles in southern Germany (56 sites, Dehnen-Schmutz 2000), 7 – castles in the Harz Mts. (16 sites, Brandes 1996b), 8 – fortified settlements of Baltic peoples in this study (12 sites), 9 – Teutonic castles in this study (6 sites)

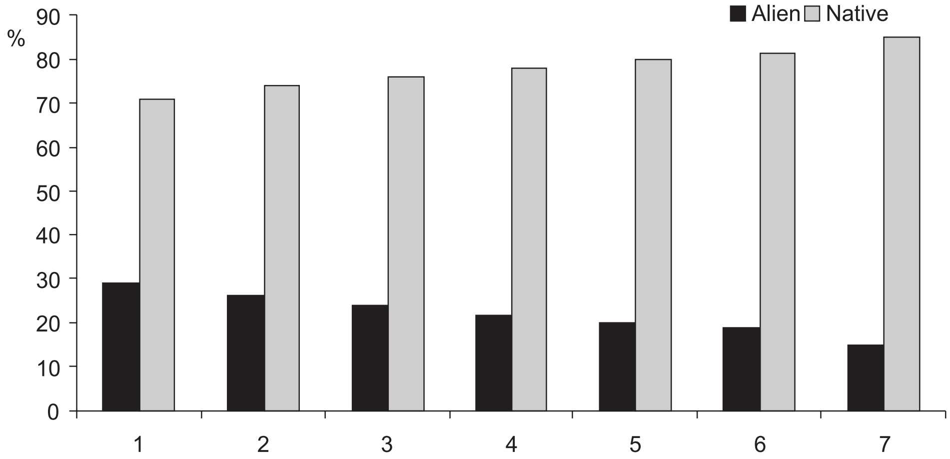



**Fig. 66.** Gegraphical-historical spectrum of the flora of fortified settlements and castles in Central Europe
Explanations: 1 – Teutonic castles in this study (6 sites), 2 – castles in southern Germany (56 sites, Dehnen-Schmutz 2000), 3 – castles in south-western Germany (10 sites, Schneider & Fleschutz 2001), 4 – castles in this study (21 sites), 5 – concave settlements in this study (74 sites), 6 – cone-shaped settlements in this study (14 sites), 7 – fortified settlements of Baltic peoples in this study (12 sites)

species does not exceed 20% in 3 groups of fortified settlements but reaches nearly 30% in floras of castles. Anthropophytization index is the lowest in Baltic settlements, which are usually located in wooded areas and were abandoned over 800 years ago. The higher contribution of anthropophytes in floras of castles is probably due to the fact that some of them played defensive and representative roles until modern times, and some of them still are subject to human disturbance.

Percentage contributions of anthropophytes in the 4 best-studied groups of sites, i.e. West Slavic settlements as well as castles located in Poland, southern Germany, and Lower Austria (Tables 22-23) show that the species composition of archaeophytes is more stable than that of kenophytes. Over 52% of the 101 archaeophytes are found at 3-4 groups of sites, while the others are associated with 1-2 groups (Table 22). By contrast, among the 53 kenophytes recorded in West Slavic settlements and castles, 47% are found in 3-4 groups of sites (Table 23).

Castle walls are specific habitats. Initially they are not colonized by plants, but in the course of time the walls are weathered and become favourable habitats for both bryophytes (see Sonnensberg & Röller 1999) and vascular plants. The most favourable for plant growth are the crevices between bricks and stones of the walls, filled with mortar. At castles built a few hundred years ago, the old walls (often damaged, falling apart, and damp) are very good habitats for the specific epilithic flora.

Numbers of species in floras of castle walls vary from 47 to 207, and are comparable with floras of walls in built-up areas, including 77-231 species (Fig. 67). The mean number of species for castles is lower (105.6) than for walls in built-up areas (164.3). All these floras are dominated by apophytes. The mean contribution of apophytes at castles is about 80%, while on urban walls, about 67%. In floras of castle walls, the contribution of alien species is slightly lower than in floras of walls in urban areas. This is due to the smaller influx of anthropophytes from neighbouring gardens and fields (Fig. 68). Alien species found on walls of castles are mostly archaeophytes. The most common in all the floras are: *Ballota nigra*, *Bromus sterilis*, *Hordeum murinum*, *Sisymbrium officinale* (Weretelnik 1982; Brandes 1996a; Duchoslav 2002). Many of the plants found on walls are species that used to be cultivated and have persisted there since then (i.e. *Anthemis tinctoria*, *Cymbalaria muralis, Lycium barbarum*) or are modern garden escapes (e.g. *Aesculus hippocastanum*, *Arabis caucasica, Solidago canadensis, Taxus baccata*). Among plant life-forms, hemicryptophytes rank first in all the compared floras, whereas chamaephytes and therophytes rank second and third, respectively. Phanerophytes are usually represented only by seedlings and saplings. The contribution of geophytes is very low (several per cent).

Constant components of the floras of walls are ferns of the genera *Asplenium* and *Dryopteris,* as well as *Cystopteris fragilis* and *Gymnocarpium robertianum.* Accompanied by flowering plants, like *Cymbalaria muralis,* as well as bryophytes, they form specific communities reported from many urban and castle walls (e.g. Brandes 1987b, 1992a, 1992b; Weretelnik 1982; Świerkosz 1993; Láníková & Sádlo 2009; Sádlo & Chytrý 2009). In Polish lowlands, *Asplenium ruta-muraria* and *A. trichomanes* are quite frequent. Their local populations on walls of castles and towns or cities are often distant from the main distribution range (see Buliński 2000; Zając & Zając 2001). Out of the group of species reported as frequent on walls of castles in southern Germany (Dehnen-Schmutz 2000), *Lotus*

**Table 22.** Numbers of sites of archaeophytes in this study (A, B) and in other groups of historical sites (C, D)

| Species | A | B | C | D | A-D |
|---|---|---|---|---|---|
| *Artemisia absinthium* | 13 | 4 | 6 | 6 | 4 |
| *Ballota nigra* | 31 | 13 | 20 | 27 | 4 |
| *Berteroa incana* | 12 | 7 | 1 | 10 | 4 |
| *Bromus sterilis* | 7 | 4 | 22 | 4 | 4 |
| *Bromus tectorum* | 7 | 6 | 2 | 10 | 4 |
| *Camelina microcarpa* subsp. *sylvestris* | 6 | 3 | 1 | 2 | 4 |
| *Capsella bursa-pastoris* | 19 | 11 | 12 | 5 | 4 |
| *Carduus acanthoides* | 27 | 11 | 4 | 9 | 4 |
| *Chenopodium hybridum* | 8 | 9 | 2 | 1 | 4 |
| *Hordeum murinum* | 2 | 4 | 2 | 2 | 4 |
| *Hyoscyamus niger* | 3 | 2 | 2 | 2 | 4 |
| *Lactuca serriola* | 23 | 11 | 8 | 11 | 4 |
| *Lamium album* | 11 | 8 | 9 | 1 | 4 |
| *Lamium purpureum* | 5 | 7 | 4 | 3 | 4 |
| *Malva neglecta* | 4 | 5 | 3 | 4 | 4 |
| *Malva sylvestris* | 5 | 1 | 6 | 1 | 4 |
| *Myosotis arvensis* | 16 | 4 | 2 | 3 | 4 |
| *Nepeta cataria* | 2 | 4 | 6 | 5 | 4 |
| *Onopordum acanthium* | 12 | 4 | 3 | 3 | 4 |
| *Papaver rhoeas* | 13 | 1 | 1 | 1 | 4 |
| *Pastinaca sativa* | 9 | 6 | 6 | 3 | 4 |
| *Senecio vulgaris* | 4 | 5 | 4 | 1 | 4 |
| *Sisymbrium officinale* | 7 | 8 | 2 | 2 | 4 |
| *Solanum nigrum* | 2 | 1 | 1 | 2 | 4 |
| *Sonchus asper* | 7 | 2 | 5 | 1 | 4 |
| *Sonchus oleraceus* | 6 | 1 | 3 | 6 | 4 |
| *Vicia hirsuta* | 15 | 1 | 2 | 3 | 4 |
| *Viola odorata* | 8 | 8 | 7 | 15 | 4 |
| *Allium scorodoprasum* | 6 | 1 | 1 | - | 3 |
| *Anchusa officinalis* | 20 | 7 | - | 5 | 3 |
| *Atriplex nitens* | 1 | 2 | - | 2 | 3 |
| *Carduus nutans* | 1 | - | 2 | 1 | 3 |
| *Chenopodium bonus-henricus* | 1 | 2 | 2 | - | 3 |
| *Cichorium intybus* subsp. *intybus* | 14 | 2 | 1 | - | 3 |
| *Conium maculatum* | 2 | 1 | - | 1 | 3 |
| *Descurainia sophia* | 10 | 5 | 4 | - | 3 |
| *Euphorbia helioscopia* | 2 | 3 | 1 | - | 3 |
| *Fallopia convolvulus* | 15 | 5 | - | 2 | 3 |
| *Geranium molle* | 4 | 1 | 1 | - | 3 |
| *Geranium pusillum* | 14 | 4 | 2 | - | 3 |
| *Lamium amplexicaule* | 3 | 1 | 2 | - | 3 |
| *Leonurus cardiaca* | 10 | 3 | - | 1 | 3 |
| *Lithospermum arvense* | 10 | - | 1 | 2 | 3 |
| *Malva alcea* | 38 | 9 | 4 | - | 3 |
| *Parietaria officinalis* | - | 1 | 1 | 4 | 3 |
| *Saponaria officinalis* | 5 | 2 | 3 | - | 3 |
| *Setaria viridis* | 6 | 3 | - | 2 | 3 |
| *Thlaspi arvense* | 5 | 1 | 1 | - | 3 |
| *Valerianella locusta* | 3 | - | 3 | 3 | 3 |
| *Veronica arvensis* | 7 | - | 3 | 2 | 3 |
| *Vicia angustifolia* | 8 | 3 | 4 |  | 3 |
| *Vicia tetrasperma* | 9 | 1 | - | 1 | 3 |
| *Viola arvensis* | 18 | 4 | - | 4 | 3 |
| *Anagallis arvensis* | 3 | - | 1 | - | 2 |
| *Anthemis arvensis* | 2 | 2 | - | - | 2 |
| *Anthemis tinctoria* | 2 | - | 14 | - | 2 |
| *Anthriscus cerefolium* | 1 | - | - | 9 | 2 |
| *Apera spica-venti* | 10 | 3 | - | - | 2 |
| *Armoracia rusticana* | 8 | 6 | - | - | 2 |
| *Bunias orientalis* | 1 | 1 | - | - | 2 |
| *Camelina sativa* | 1 | - | 1 | - | 2 |
| *Centaurea cyanus* | 11 | 1 | - | - | 2 |
| *Chaerophyllum bulbosum* | 5 | 1 | - | - | 2 |
| *Consolida regalis* | 15 | 1 | - | - | 2 |
| *Euphorbia peplus* | 1 | 3 | - | - | 2 |
| *Fumaria officinalis* subsp. *officinalis* | 2 | 4 | - | - | 2 |
| *Lavatera thuringiaca* | 15 | 2 | - | - | 2 |
| *Lepidium campestre* | 1 | - | 2 | - | 2 |

| Species | A | B | C | D | A-D |
|---|---|---|---|---|---|
| *Matricaria maritima* subsp. *inodora* | 16 | 3 | - | - | 2 |
| *Melandrium noctiflorum* | 1 | 1 | - | - | 2 |
| *Odontites verna* | 1 | - | 1 | - | 2 |
| *Papaver argemone* | 1 | - | 2 | - | 2 |
| *Papaver dubium* | 7 | - | 7 | - | 2 |
| *Polygonum lapathifolium* subsp. *pallidum* | 7 | 1 | - | - | 2 |
| *Scleranthus annuus* | 1 | 1 | - | - | 2 |
| *Setaria pumila* | 2 | - | - | 1 | 2 |
| *Sinapis arvensis* | 4 | 2 | - | - | 2 |
| *Spergula arvensis* subsp. *arvensis* | 1 | 1 | - | - | 2 |
| *Urtica urens* | 4 | 2 | - | - | 2 |
| *Vicia villosa* | 5 | 2 | - | - | 2 |
| *Adonis aestivalis* | 1 | - | - | - | 1 |
| *Agrostemma githago* | 3 | - | - | - | 1 |
| *Anchusa arvensis* | 4 | - | - | - | 1 |
| *Aphanes arvensis* | 1 | - | - | - | 1 |
| *Asperugo procumbens* | 1 | - | - | - | 1 |
| *Avena fatua* | 5 | - | - | - | 1 |
| *Bromus secalinus* | 1 | - | - | - | 1 |
| *Chamomilla recutita* | 3 | - | - | - | 1 |
| *Chrysantheum segetum* | 1 | - | - | - | 1 |
| *Digitaria ischaemum* | 1 | - | - | - | 1 |
| *Echinochloa crus-galli* | 7 | - | - | - | 1 |
| *Gagea arvensis* | 1 | - | - | - | 1 |
| *Galeopsis ladanum* | 1 | - | - | - | 1 |
| *Geranium dissectum* | - | 1 | - | - | 1 |
| *Lathyrus tuberosus* | 3 | - | - | - | 1 |
| *Lepidium ruderale* | 2 | - | - | - | 1 |
| *Marrubium vulgare* | - | 1 | - | - | 1 |
| *Neslia paniculata* | 2 | - | - | - | 1 |
| *Raphanus raphanistrum* | 2 | - | - | - | 1 |
| *Stachys annua* | 2 | - | - | - | 1 |
| *Veronica triphyllos* | 3 | - | - | - | 1 |

Explanations: A – fortified settlements in this study, B – castles in this study, C – castles in southern Germany (after Dehnen-Schmutz 2000 and Schneider & Fleschutz 2001), D – castles in Lower Austria (after Hübl & Scharfetter 2008), A-D – total number of groups of historical sites

*corniculatus* and *Taxus baccata* were not observed in my study. Among the remaining species of that group, *Poa compressa* was most frequent. In Polish castles, apart from the ferns, also *Arenaria serpyllifolia, Glechoma hederacea*, and *Betula pendula* are common, while they are relatively rare at castles in southern Germany.

Wooded archaeological sites, often located within extensive woodlands, are good sites for research on species of old deciduous forests. According to Dzwonko & Loster (2001), these forests are defined as remnants of primeval forests and secondary forests. The concept of old deciduous forests assumes their continuity as forest habitats. In Poland many old deciduous forests are fragments of prehistoric primeval forests, often transformed to some extent. However, very often, the forest communities found in fortified settlements and castle ruins have persisted there for many centuries. Land relief in the fortified settlements (ramparts, cone-shaped mounds, moats), resulting from medieval human activity, in many cases make forest management difficult. Consequently, many forest species may have persisted there for hundreds of years.

The list of plant indicators of old deciduous forests in Poland includes 155 species (Dzwonko and Loster 2001). At the studied archaeological sites, 98 species of them were recorded (i.e. as much as 64% of the total). They account for 11.2% of the flora of the studied archaeological sites. By contrast, in the Polish flora, including 2029 species (Zając & Zając 2003), the species of old deciduous forests constitute only 5.3% of the total.

As emphasized by Dzwonko & Loster (2001), their list of species of old deciduous forests is not complete. Because of the shortage of comparative field data, those authors did not list *Acer campestre, Lonicera xylosteum, Tilia cordata, Ulmus laevis*, and *Viburnum opulus*. Regionally, such species could be good plant indicators of old deciduous forests. The botanical research at archaeological sites confirms this opinion. The species listed above are associated generally with wooded archaeological sites, often found within extensive woodlands. For example, in the castle in Czudec (near Rzeszów), a large local population of *Acer campestre* was observed, which is rare in the whole Strzyżów Forest District (oral communication, forest ranger Roman Kula).

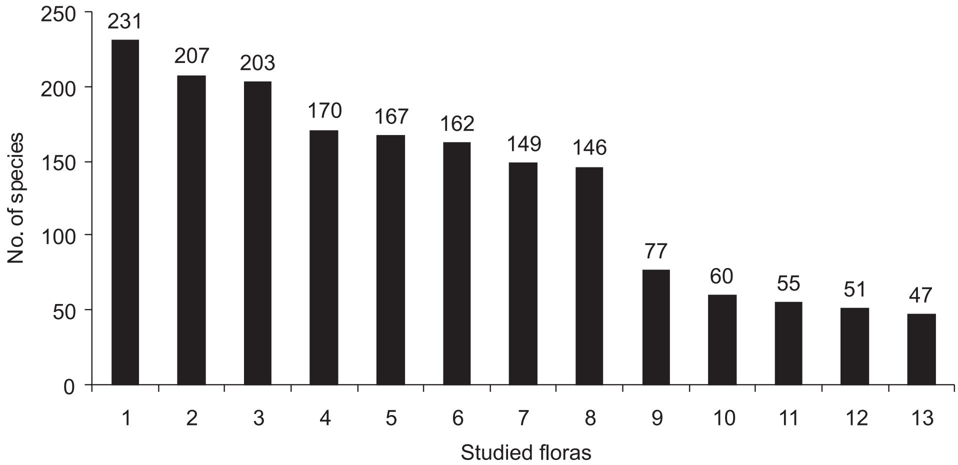



**Fig. 67.** Numbers of species in the compared floras of old walls
Explanations: 1 – town walls in southern and western Moravia (Czech Republic, Simonová 2008), 2 – castles in southern Germany (Dehnen-Schmutz 2000), 3 – town walls in East Bohemia (Czech Republic, Duchoslav 2002), 4 – castles in Lower Silesia (Poland, Weretelnik 1982), 5 – old walls in villages in southern and western Moravia (Czech Republic, Simonová 2008), 6 – Braunschweig town walls (Germany, Brandes *et al.* 1998), 6 – castles in the Harz mountains (Germany, Brandes 1996b), 8 – Wrocław city walls (Poland, Świerkosz 1993), 9 – old town walls and cemetery walls in Lower Silesia (Poland, Weretelnik 1982), 10 – West Slavic castles in this study (Poland and Czech Republic), 11 – Teutonic castles in this study (Poland), 12 – castles in southern and western Moravia (Czech Republic, Simonová 2008), 13 – castles in East Bohemia (Czech Republic, Duchoslav 2002)

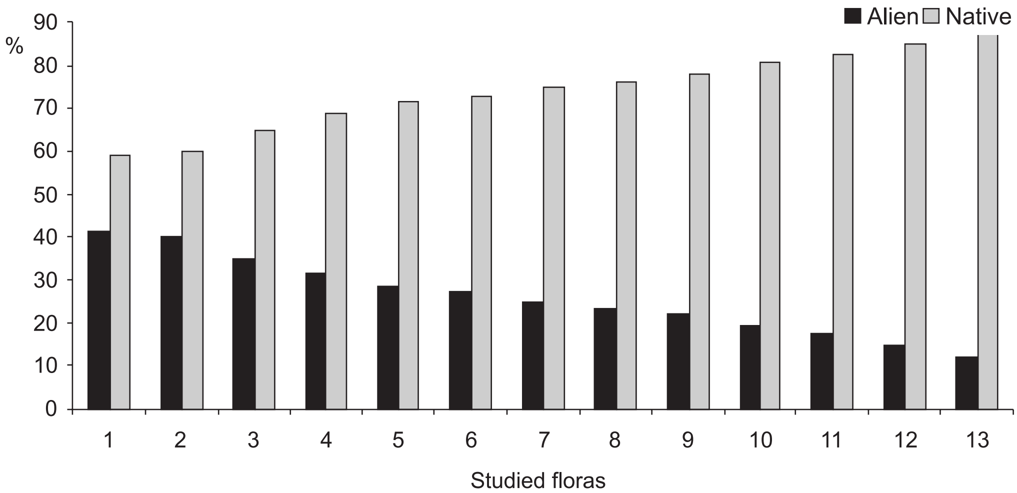



**Fig. 68.** Contributions of native and alien species to the compared floras of old walls
Explanations: 1 – town walls in southern and western Moravia (Czech Republic, Simonová 2008), 2 – old walls in villages in southern and western Moravia (Czech Republic, Simonová 2008), 3 – Braunschweig town walls (Germany, Brandes *et al.* 1998), 4 – Wrocław city walls (Poland, Świerkosz 1993), 5 – old town walls and cemetery walls in Lower Silesia (Poland, Weretelnik 1982), 6 – castles in southern Germany (Dehnen-Schmutz 2000), 7 – West Slavic castles in this study (Poland and Czech Republic), 8 – Teutonic castles in this study (Poland), 9 – town walls in East Bohemia (Czech Republic, Duchoslav 2002), 10 – castles in the Harz mountains (Germany, Brandes 1996b), 11 – castles in Lower Silesia (Poland, Weretelnik 1982), 12 – castles in East Bohemia (Czech Republic, Duchoslav 2002), 13 – castles in southern and western Moravia (Czech Republic, Simonová 2008),

### 6.2. West Slavic fortified settlements and castles as sites of concentration and sources of dispersal of alien species

At the 109 study sites, 191 anthropophytes were found. They account for nearly 22% of the total flora of West Slavic fortified settlements and castles. Alien species were recorded at 103 sites (nearly 95% of the total). On average, there are nearly 12 anthropophytes per site, but their maximum contribution exceeds 58% of the flora. This applies to the study sites that are still used for plant cultivation.

A characteristic feature of archaeological sites is a high concentration of earlier immigrants. Archaeophytes (101 species in total) are observed at all the site types, irrespective of their chronology. They are absent only at wooded early medieval sites (16 fortified settlements and a castle), located within or at the edges of extensive woodlands. Only at some of them, small patches of meadows and dry grasslands have been preserved. Archaeophytes are the dominant group of anthropophytes at 81 sites (Fig. 69), but their percentage contribution varies greatly between sites: from 0.0 to 57.1% (see Fig. 37c). The mean number of archaeophytes per site is 8.4. Their number is the highest at the sites covered to a large extent by arable fields (e.g. Jamno), ruderal communities (e.g. Wenecja), and dry grasslands

**Table 23.** Numbers of sites of kenophytes in this study (A, B) and in other groups of historical sites (C, D)

| Species | A | B | C | D | A-D |
|---|---|---|---|---|---|
| *Aesculus hippocastanum* | 5 | 6 | 5 | 5 | 4 |
| *Cardaria draba* | 1 | 1 | 1 | 2 | 4 |
| *Conyza canadensis* | 29 | 14 | 6 | 6 | 4 |
| *Echinops sphaerocephalus* | 3 | 1 | 1 | 1 | 4 |
| *Impatiens glandulifera* | 1 | 1 | 3 | 2 | 4 |
| *Impatiens parviflora* | 17 | 4 | 6 | 18 | 4 |
| *Ligustrum vulgare* | 5 | 2 | 20 | 24 | 4 |
| *Lycium barbarum* | 6 | 3 | 7 | 1 | 4 |
| *Robinia pseudoacacia* | 12 | 5 | 5 | 13 | 4 |
| *Solidago canadensis* | 3 | 4 | 4 | 5 | 4 |
| *Amaranthus retroflexus* | 4 | 2 | 0 | 2 | 3 |
| *Bryonia alba* | 1 | 4 | 0 | 1 | 3 |
| *Chamomilla suaveolens* | 6 | 8 | 0 | 1 | 3 |
| *Clematis vitalba* | 0 | 1 | 21 | 27 | 3 |
| *Cymbalaria muralis* | 0 | 1 | 14 | 1 | 3 |
| *Diplotaxis tenuifolia* | 0 | 1 | 3 | 2 | 3 |
| *Epilobium ciliatum* | 4 | 3 | 0 | 1 | 3 |
| *Erigeron annuus* | 3 | 0 | 6 | 7 | 3 |
| *Lupinus polyphyllus* | 1 | 2 | 1 | 0 | 3 |
| *Medicago varia* | 1 | 4 | 2 | 0 | 3 |
| *Parthenocissus inserta* | 0 | 2 | 4 | 3 | 3 |
| *Senecio vernalis* | 5 | 4 | 1 | 0 | 3 |
| *Sisymbrium loeselii* | 5 | 2 | 1 | 0 | 3 |
| *Symphoricarpos albus* | 5 | 5 | 3 | 0 | 3 |
| *Veronica persica* | 6 | 2 | 1 | 0 | 3 |
| *Acer negundo* | 6 | 1 | 0 | 0 | 2 |
| *Acorus calamus* | 6 | 1 | 0 | 0 | 2 |
| *Bidens frondosa* | 4 | 1 | 0 | 0 | 2 |
| *Bromus carinatus* | 1 | 2 | 0 | 0 | 2 |
| *Echinocystis lobata* | 1 | 1 | 0 | 0 | 2 |
| *Elodea canadensis* | 2 | 1 | 0 | 0 | 2 |
| *Galinsoga parviflora* | 3 | 5 | 0 | 0 | 2 |
| *Geranium pyrenaicum* | 0 | 1 | 5 | 0 | 2 |
| *Medicago sativa* | 6 | 3 | 0 | 0 | 2 |
| *Quercus rubra* | 3 | 1 | 0 | 0 | 2 |
| *Salsola kali* subsp. *ruthenica* | 1 | 1 | 0 | 0 | 2 |
| *Solidago gigantea* | 1 | 2 | 0 | 0 | 2 |
| *Amaranthus chlorostachys* | 0 | 1 | 0 | 0 | 1 |
| *Cannabis ruderalis* | 2 | 0 | 0 | 0 | 1 |
| *Cannabis sativa* | 3 | 0 | 0 | 0 | 1 |
| *Datura stramonium* | 1 | 0 | 0 | 0 | 1 |
| *Diplotaxis muralis* | 0 | 1 | 0 | 0 | 1 |
| *Eragrostis minor* | 0 | 1 | 0 | 0 | 1 |
| *Galinsoga ciliata* | 1 | 0 | 0 | 0 | 1 |
| *Hesperis matronalis* subsp. *matronalis* | 1 | 0 | 0 | 0 | 1 |
| *Juncus tenuis* | 1 | 0 | 0 | 0 | 1 |
| *Oxalis fontana* | 2 | 0 | 0 | 0 | 1 |
| *Padus serotina* | 5 | 0 | 0 | 0 | 1 |
| *Reynoutria japonica* | 0 | 2 | 0 | 0 | 1 |
| *Rosa rugosa* | 0 | 1 | 0 | 0 | 1 |
| *Sisymbrium altissiumum* | 1 | 0 | 0 | 0 | 1 |
| *Vicia grandiflora* | 0 | 1 | 0 | 0 | 1 |
| *Xanthium albinum* | 1 | 0 | 0 | 0 | 1 |

Explanations: A – fortified settlements in this study, B – castles in this study, C – castles in southern Germany (after Dehnen-Schmutz 2000 and Schneider & Fleschutz 2001), D – castles in Lower Austria (after Hübl & Scharfetter 2008), A-D – total number of groups of historical sites

with a high contribution of ruderal species (e.g. Drohiczyn). Nearly 50% of archaeophytes are classified in this study as rare, frequent or very frequent. The very frequent archaeophytes include *Ballota nigra, Capsella bursa-pastoris, Carduus acanthoides, Lactuca serriola*, and *Malva alcea*.

Kenophytes are represented by 53 species observed at 83 sites. At 48 of them, only 1-2 species of this group were recorded. Their mean contribution was 2.4%, while the maximum was in Kruszwica: 13.3%. These later arrivals are most numerous at cone-shaped settlements and at castles inhabited from late medieval to modern times, because many of them are still subject to a strong human impact. They are located within modern cities, towns, and villages or close to them (e.g. Krobia and Wleń) or are partly used for plant cultivation (e.g.

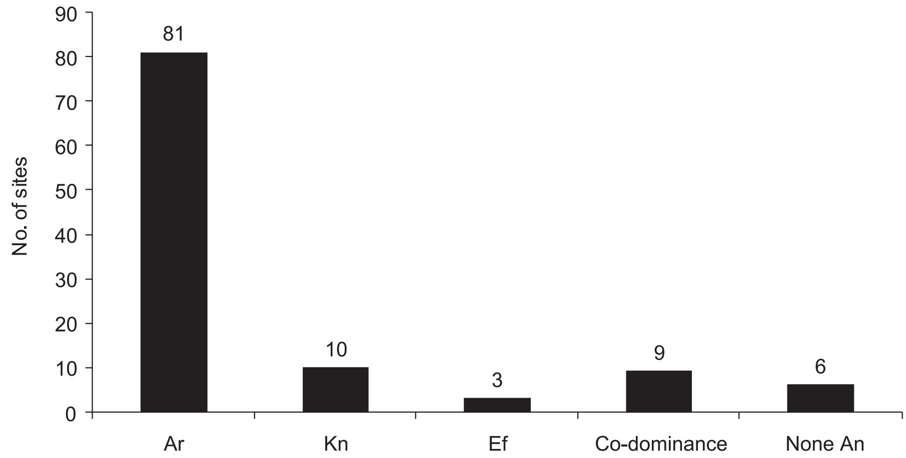



**Fig. 69.** Dominant groups of anthropophytes at West Slavic sites
Explanations: Ar – archaeophytes, Kn – kenophytes, Ef – ergasiophytes, None An – no anthropophytes found

Stradów), or are subject to human impact associated with tourism (e.g. Mirów and Teterow). The group of kenophytes is dominated by species classified as extremely rare, very rare and rare (95% of the group), and their abundance at individual sites is generally also low. Ergasiophytes play a minor role in the modern flora of medieval West Slavic settlements and castles. They are recorded at 49 sites, but at 34 sites this group is represented by only 1-2 species with a low abundance. They are often single individuals. The most frequent ergasiophytes include *Juglans regia* and *Syringa vulgaris*. The mean contribution of this group was 0.9% of the total number of species recorded at a site. The largest numbers of species of ergasiophytes were observed at the castles inhabited from late medieval to modern times, located within or close to modern human settlements, e.g. in Stęszew, Olsztyn, and Podzamcze (Ogrodzieniec).

Castles are specific sources of dispersal of alien species. Used by people not only in the Middle Ages, but also in modern times, they significantly affect the surrounding natural environment. The change of the major role of castles (now representative instead of defensive) and their utilization for many centuries caused also changes in species composition of cultivated plants. Ornamental and food plants were replaced to a large extent by ornamentals, including many trees and shrubs (Table 24). Formerly cultivated species, now naturalized, are found not only within castles, but also in their immediate neighbourhood. Specific plant communities are formed by e.g. *Aesculus hippocastanum, Clematis vitalba, Hedera helix, Syringa vulgaris, Lycium barbarum, Symphoricarpos albus*, and *Vinca minor*. In Międzyrzecz (Wielkopolska), castle walls are partly covered by *Clematis vitalba* and *Hedera helix*, while thickets around them are composed of e.g. *Aesculus hippocastanum, Lycium barbarum, Robinia pseudoacacia*, and *Symhoricarpos albus* (Figs. 70-71). In the castle in Gościszów (Silesia), a very old specimen of *Hedera helix* climbs on a wall. Its trunk near the ground has a

**Table 24.** Occurrence of decorative woody species in selected West Slavic castles

| Species | Gościszów | Międzyrzecz | Wleń | Total no. of sites | No. of castles |
|---|---|---|---|---|---|
| *Aesculus hippocastanum* | + | + | - | 11 | 6 |
| *Clematis vitalba* | - | + | - | 1 | 1 |
| *Hedera helix* | +* | + | +* | 13 | 5 |
| *Juglans regia* | + | - | - | 9 | 4 |
| *Ligustrum vulgare* | - | - | + | 7 | 2 |
| *Lycium barbarum* | - | + | - | 9 | 3 |
| *Philadelphus coronarius* | + | - | + | 3 | 3 |
| *Robinia pseudacacia* | - | + | - | 17 | 5 |
| *Symphoricarpos albus* | - | + | - | 10 | 5 |
| *Syringa vulgaris* | ++ | - | - | 12 | 3 |
| *Vinca minor* | ++ | - | - | 2 | 1 |

Explanations: * flowering and fruiting, + not abundant, ++ moderately abundant (see section 4.2)

**Fig. 70.** *Clematis vitalba* on a wall of the castle in Międzyrzecz near Gorzów Wielkopolski (western Poland)

circumference of over 80 cm (!). The trunk clings to the wall and has no lateral branches up to the height of over 10 m. Only above the wall it is profusely branched, flowering abundantly, and bringing fruit. Besides, *Aesculus hippocastanum*, *Philadelphus coronarius*, *Syringa vulgaris*, and *Vinca minor* grow around the castle. Similarly, in Wleń (Silesia), the castle walls and tower are partly covered by flowering and fruiting shoots of *Hedera helix*, and the castle is surrounded by *Ligustrum vulgare* and *Philadelphus coronarius*.

On the stone walls of the castles, secondary habitats are formed and utilized by plants that are naturally associated with rock crevices. On walls of 13 of the 21 studied castles, 60 vascular plant species were recorded, and 75.0% of them are apophytes. The dominant group of anthropophytes are archaeophytes (15.0%), while kenophytes account for 8.3% and ergasiophytes for 1.7% of the total number of species. In the spectrum of Raunkiaer life-forms, hemicryptophytes prevail, but their contribution is lower than in the total flora

**Fig. 71.** *Lycium barbarum* near a wall of the castle in Korets (western Ukraine)

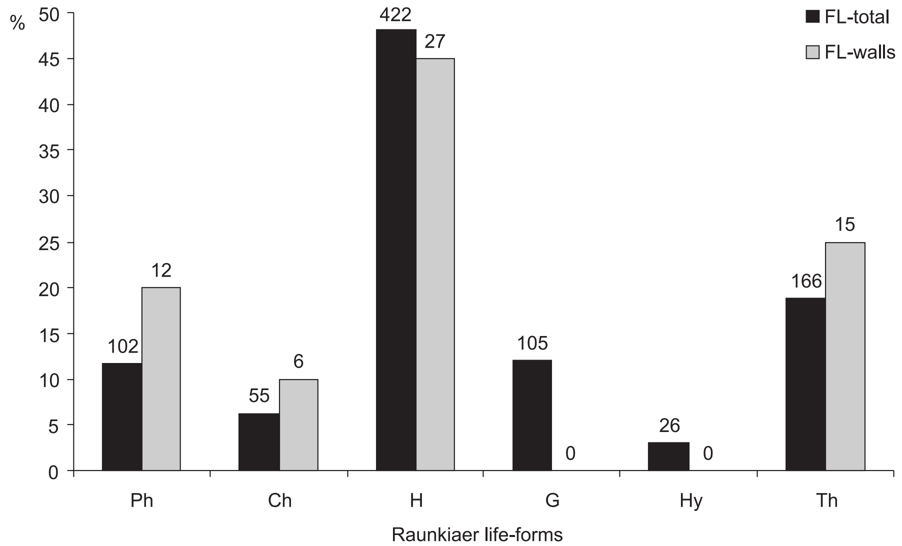



**Fig. 72.** Spectrum of Raunkiaer life-forms on walls (FL-walls) and in the total flora (FL-total)
Explanations: see Fig. 16

(Fig. 72). By contrast, the contributions of phanerophytes, chamaephytes, and therophytes are higher.

Crevices and top parts of walls are colonized by e.g. the ferns *Asplenium ruta-muraria, A. trichomanes*, and *Cystopteris fragilis*, as well as by *Cymbalaria muralis,* which was cultivated till the mid-19th century (Table 25). These species grow only in such habitats at the study sites (Figs. 73-74). For epilithic ferns of the genus *Asplenium*, such secondary habitats are important for them particularly in the Polish lowlands, in central and northern Poland (e.g. in the castle in Wenecja near Żnin in the Wielkopolska region).

An analysis of the potential uses of anthropophytes shows that over 67% of archaeophyte species could be used in the Middle Ages (Table 26). Most of the early immigrants were used as medicinal plants and food (51%), and only rarely they were ornamentals. This is due to the medieval functions of those sites (mostly defensive, rarely representative). Medicinal plants include *Chamomilla recutita, Malva sylvestris* and *Parietaria officinalis*, while *Allium scorodoprasum, Armoracia rusticana*, and *Anthriscus cerefolium* were used as spices, and *Anchusa officinalis* and *Leonurus cardiaca* were useful as dyeing plants. Among kenophytes, a majority of species are used as ornamentals (over 43%), or medicinal and forage plants (18.8%). Some of the ornamentals are woody, e.g. *Aesculus hippocastanum, Lycium barbarum, Clematis vitalba, Ligustrum vulgare* or *Symphoricarpus albus*; but some others are herbaceous plants, which spread from cultivation throughout Central Europe, e.g. *Echinocystis lobata, Solidago canadensis*, and *S. serotina*. Among ergasiophytes, which are recent garden escapes at the study sites, a majority of species are ornamental and food plants, e.g. *Caragana arborescens, Iberis umbellata, Prunus domestica*, and *Secale cereale*.

Over centuries, the functions of fortified settlements and castles have changed. Till the late Middle Ages, these were mostly defensive functions, whereas in modern times, representative functions started to dominate. These changes are reflected also in the uses of anthropophytes found there. Among archaeophytes associated mostly with early medieval sites, medicinal properties are most common, while among kenophytes, a larger proportion of species are ornamental.

Archaeological sites, because of their numerous functions in the Middle Ages (administrative, judiciary, fiscal, military, trade, services), have become sources of dispersal of alien species, especially those associated with medieval plant cultivation. The species composition of the immediate vicinity of archaeological sites reflects to a large extent the flora of that site. Research

**Table 25.** Rock plants in the flora of selected West Slavic castles

| Species | Mirów | Olsztyn | Ostrężnik | Podzamcze | Wleń | Total no. of sites |
|---|---|---|---|---|---|---|
| *Asplenium ruta-muraria* | ++ | +++ | ++ | +++ | ++ | 10 |
| *Asplenium trichomanes* | + | ++ | + | ++ | + | 7 |
| *Cymbalaria muralis* | - | - | - | - | + | 1 |
| *Cystopteris fragilis* | + | + | + | ++ | + | 6 |

Explanations: + not abundant, ++ moderately abundant, +++ very abundant (see section 4.2)

**Fig. 73.** *Asplenium ruta-muraria* in crevices of a wall of the castle in Wenecja near Żnin (western Poland)

**Fig. 74.** *Cymbalaria muralis* on bricks of a damaged wall of a Teutonic castle in Pokrzywno near Grudziądz (northern Poland)

on the spread of species from medieval settlements in the Lednica, Łekno, and Wrześnica regions, confirm these hypotheses.

In the Lednica region, 10 relics of cultivation were recorded. *Malva alcea* is present at all the study sites in that region: Imiołki, Ledniczka, Łubowo, Moraczewo, and Ostrów Lednicki (Fig. 75). It grows also in the immediate vicinity of archaeological sites and near some transportation routes, both medieval and modern, along which it is spreading. This is most conspicuous near the western limit of Lake Lednica, where in the early Middle Ages a bridge linked the lake shore with the island, and near the road from Dziekanowice to the main road Poznań-Gniezno, as well as in the north, along the road Kiszkowo-Łubowo. The abundance of *M. alcea* is highly variable. At some archaeological sites, e.g. fortified settlements in Moraczewo and Imiołki, there are several dozen clumps, which flower and bear fruit abundantly. At the remaining sites and on roadsides, its abundance is lower: several to about a dozen clumps. Ostrów Lednicki (i.e. the largest island on Lake Lednica) is a well-known historical site open to visitors. The abundance of *M. alcea* is changing continuously because of human interference (e.g. mowing). *Allium scorodoprasum* was recorded in the Lednica region at 4 localities, in habitats associated with transportation routes: roadsides, ditches, and thickets along roads, often in connection with parks surrounding historical manor houses. The population near Latalice is the smallest, composed of only several individuals. Its populations in Myszki and Zakrzewo are larger, consisting of up to several dozen individuals. *Leonurus cardiaca* is found only in 2 small populations at the archaeological site in Imiołki and in the village of Kamionek. *Artemisia absinthium*, *Chaerophyllum bulbosum*, and *Pasinaca sativa* also form small populations at the sites of medieval settlements (Łubowo, Moraczewo, Ostrów Lednicki) and in ruderal habitats in some villages in the Lednica region. *Viola odorata* was recorded both at archaeological sites (Ostrów Lednicki, Łubowo) and in several parks and cemeteries. It is also currently cultivated in gardens near houses. *Lycium barbarum, Saponaria officinalis*, and *Vinca minor* were not observed in fortified settlements. They are currently associated with cemeteries, parks, and ruderal habitats in villages in the Lednica region.

**Table 26.** Comparison of potential uses* of anthropophytes found at West Slavic sites

| Potential use | Archaeophytes | | Kenophytes | | Ergasiophytes | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| Medicinal | 46 | 45.5 | 6 | 11.3 | 1 | 2.7 |
| Food | 6 | 5.9 | 1 | 1.9 | 12 | 32.4 |
| Seasonings | 3 | 3.0 | 0 | 0.0 | 1 | 2.7 |
| Pigments | 4 | 4.0 | 0 | 0.0 | 0 | 0.0 |
| Forage | 3 | 3.0 | 4 | 7.5 | 0 | 0.0 |
| Decorative | 1 | 1.0 | 23 | 43.4 | 21 | 56.8 |
| Cosmetic | 2 | 2.0 | 0 | 0.0 | 0 | 0.0 |
| Others | 3 | 3.0 | 2 | 3.8 | 2 | 5.4 |
| No use | 33 | 32.7 | 17 | 32.1 | 0 | 0.0 |

Explanations: N – no. of species, * – based on Broda & Mowszowicz (2000), Podbielkowski & Sudnik-Wójcikowska (2003), Jäger *et al.* (2008)

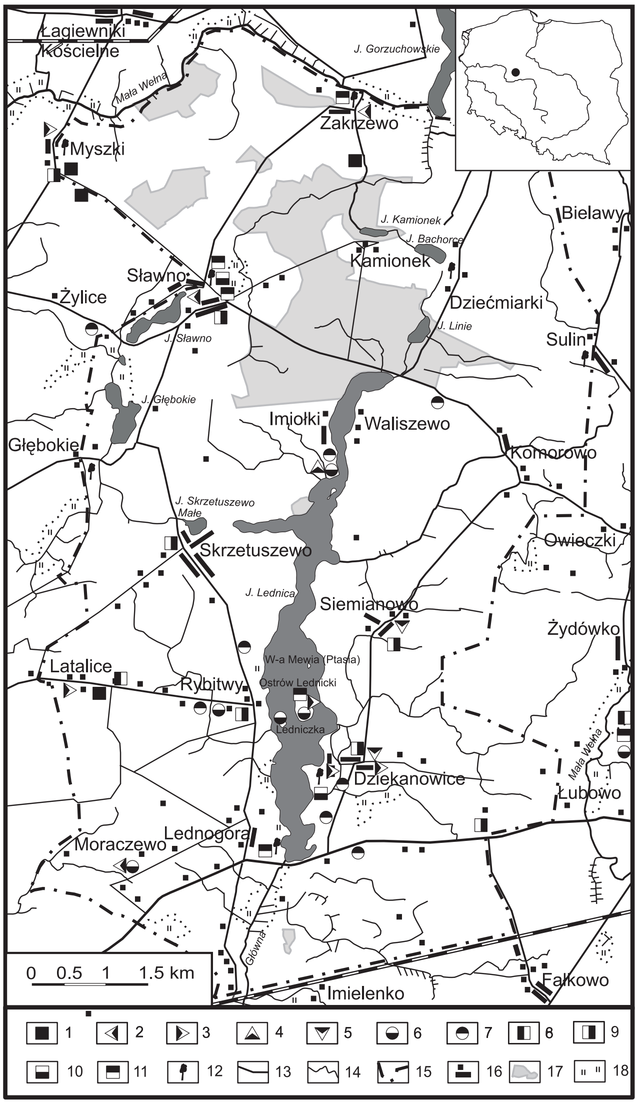



**Fig. 75.** Distribution of relics of cultivation in the Lednica settlement complex near Gniezno (after Celka *et al.* 2008, modified and supplemented)

Explanations: 1 – *Allium scorodoprasum*, 2 – *Artemisia absinthium*, 3 – *Chaerophyllum bulbosum*, 4 – *Leonurus cardiaca*, 5 – *Lycium barbarum*, 6-7 – *Malva alcea* (at the fortified settlement, on a roadside), 8 – *Pastinaca sativa*, 9 – *Saponaria officinalis*, 10 – *Vinca minor*, 11 – *Viola odorata*, 12 – old parks, 13 – roads, 14 – watercourses, 15 – boundary the Lednica Landscape Park, 16 – buildings, 17 – forests, 18 – meadows

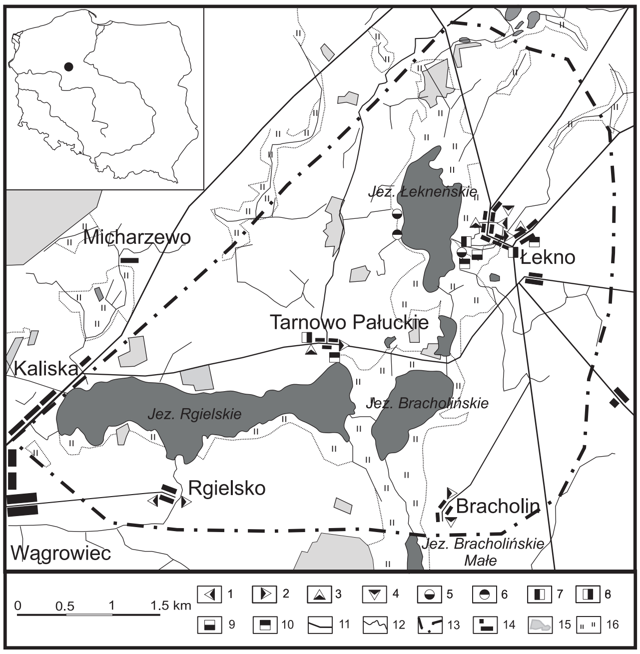



**Fig. 76.** Distribution of relics of cultivation in the Łekno settlement complex near Wągrowiec (mid-western Poland)

Explanations: 1 – *Artemisia absinthium*, 2 – *Chaerophyllum bulbosum*, 3 – *Leonurus cardiaca*, 4 – *Lycium barbarum*, 5-6 – *Malva alcea* (at the fortified settlement, on a roadside), 7 – *Pastinaca sativa*, 8 – *Saponaria officinalis*, 9 – *Vinca minor*, 10 – *Viola odorata*, 11 – roads, 12 – watercourses, 13 – boundary of the study area, 14 – buildings, 15 – forests, 16 – meadows

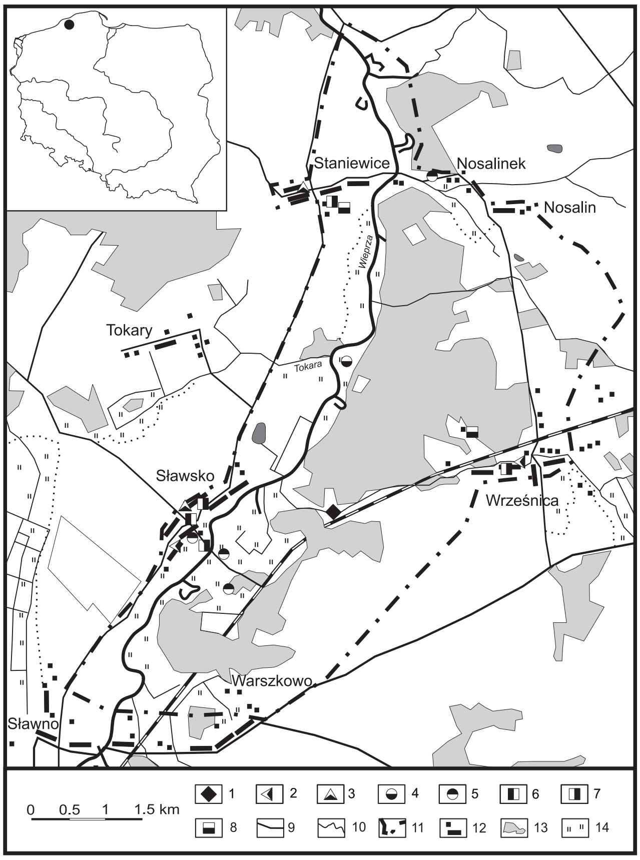



**Fig. 77.** Distribution of relics of cultivation in the Wrześnica settlement complex near Sławno (north-western Poland)

Explanations: 1 – *Anthemis tinctoria*, 2 – *Artemisia absinthium*, 3 – *Leonurus cardiaca*, 4-5 – *Malva alcea* (at the fortified settlement, on a roadside), 6 – *Pastinaca sativa*, 7 – *Saponaria officinalis*, 8 – *Vinca minor*, 9 – roads, 10 – watercourses, 11 – boundary of the study area, 12 – buildings, 13 – forests, 14 – meadows

In the Łekno region, 9 relics were recorded. *Malva alcea* is found only in 3 localities (Fig. 76): 2 medieval fortified settlements in Łekno (Ł2 and Ł3), and on a small hill south of Ł3. This hill, currently surrounded by dense reeds, in the Middle Ages was a shelter for boats used on Lake Łekneńskie. At the archaeological site located at the eastern edge of the lake, only several clumps of this species are present, while the population on the western shore is much larger. That is an area where a Cistercian monastery was built in the Middle Ages, on an earlier fortified settlement. (In the 14$^{th}$ century, the Cistercians moved to the nearby town of Wągrowiec.) The abundance of *M. alcea*, which forms about a dozen clumps there, is changing continuously because of archaeological excavations. Close to them, a large population of *Allium scorodoprasum* is found. This species was recorded also on the eastern edges of the nearby Lake Durowskie. *Vinca minor* forms only a small population at site Ł2. *Viola odorata* and *Pastinaca sativa* are found at archaeological sites and several villages in that region. The other relics of cultivation (*Artemisia absinthium*, *Chaerophyllum bulbosum*, *Leonurus cardiaca*, *Lycium barbarum*, and *Saponaria officinalis*) are found in ruderal habitats in villages in the Łekno region (Fig. 76).

In the Wrześnica region, 7 relics of cultivation were found. *Malva alcea* forms several clumps at the site of the fortified settlement in Wrześnica, on a roadside, and in a shrubland near the archaeological site in Sławsko (now intensively used as a meadow), and on a roadside in Nosalin (Fig. 77). In the shrubland near the archaeological site in Sławsko, several dozen clumps of this species are present, while about a dozen grow along the road to the village. In Nosalin, there is only one but large clump of this species. *Saponaria officinalis* is recorded in Staniewice at the cemetery, in Sławsko near the archaeological site (beside *Malva alcea*) and near the medieval church, and in Wrześnica near the church. The other relics of cultivation (*Anthemis tinctoria*, *Artemisia absinthium*, *Leonurus cardiaca*, and *Vinca minor*) are found in ruderal habitats in villages, near the forester's lodge, and near railway tracks. These plants are most numerous near the medieval church in Sławsko (Fig. 77).

### 6.3. West Slavic settlements and castles as refuges of relics of cultivation

Medieval West Slavic archaeological sites are specific refuges for relics of cultivation (German *Kulturreliktpflanzen*), i.e. species that were cultivated by various groups and tribes in the past for various purposes, but now are no longer cultivated or cultivated only sporadically (Celka 1999). They were used at that time as medicinal plants, seasonings, food, pigments, forage, rituals, cosmetics, ornamentals, and for other purposes. Currently, people generally do not associate most of them with crop plants. Relics of cultivation are also termed relicts of cultivation, relics of former cultivation, relict crops, relics of cultivated plants, and old cultural plants. They are classified as plant indicators (phytoindicators) of medieval or earlier human settlements, because their presence is usually associated with various archaeological sites (e.g. medieval earthworks, which are noticeable as "lumps and bumps" in the landscape).

This group of species is often subdivided depending on the period of their cultivation and their area of origin, but it is not always possible to determine these characteristics precisely. Anyway, in various historical periods, people used either native plants (sometimes termed *ekiophytes* or *ekiolypophytes*) collected for cultivation from nearby sites, or alien species (sometimes termed *ergasiolypophytes*) introduced into cultivation from distant regions. Plant cultivation started in prehistoric times but only the Neolithic Revolution initiated

**Table 27.** Relics of cultivation recorded at West Slavic sites

| Species | Cultivation period | | | Major use | | | | |
|---|---|---|---|---|---|---|---|---|
| | prehistoric | medieval | modern era | M | F | P | D | O |
| *Allium scorodoprasum* | + | + | + | + | + | - | - | - |
| *Anthemis tinctoria* | +? | + | + | + | - | + | + | - |
| *Anthriscus cerefolium* | - | + | + | + | + | - | - | - |
| *Artemisia absinthium* | + | + | + | + | + | + | - | + |
| *Bunias orientalis* | - | + | +? | - | + | - | + | + |
| *Camelina sativa* | + | + | +? | + | + | - | - | + |
| *Chaerophyllum bulbosum* | + | + | - | - | + | - | - | - |
| *Cymbalaria muralis* | - | - | + | - | - | - | + | - |
| *Lavatera thuringiaca* | +? | + | + | + | + | + | + | + |
| *Leonurus cardiaca* | - | + | +? | + | - | + | + | + |
| *Lithospermum officinale* | + | + | - | + | + | + | - | + |
| *Lycium barbarum* | - | - | + | + | - | - | + | + |
| *Malva alcea* | + | + | + | + | + | + | + | + |
| *Marrubium vulgare* | - | + | + | + | + | + | - | + |
| *Nepeta cataria* | - | + | + | + | + | - | - | + |
| *Origanum vulgare* | +? | + | + | + | + | + | - | + |
| *Parietaria officinalis* | - | + | - | + | - | - | - | + |
| *Pastinaca sativa* | + | + | + | + | + | - | - | + |
| *Saponaria officinalis* | +? | + | + | + | - | + | + | + |
| *Vallerianella locusta* | - | + | +? | - | + | - | - | - |
| *Vinca minor* | + | + | + | + | - | - | + | + |
| *Viola odorata* | + | + | + | + | - | - | + | + |

Explanations: M – medicinal, F – food and seasonings, P – pigments, D – decorative, O – others, major uses based on many sources: Marcin z Urzędowa (1595, after Furmanowa *et al*. 1959), Jundziłł (1791), Kluk (1805, 1808), Waga (1847, 1848), Rostafiński (1900), Maurizio (1926), Nowiński (1977, 1983), Ożarowski (1982), Broda & Mowszowicz (2000), Kraepelin (2000), Simon (2000), Podbielkowski & Sudnik-Wójcikowska (2003), Jäger *et al*. (2008)

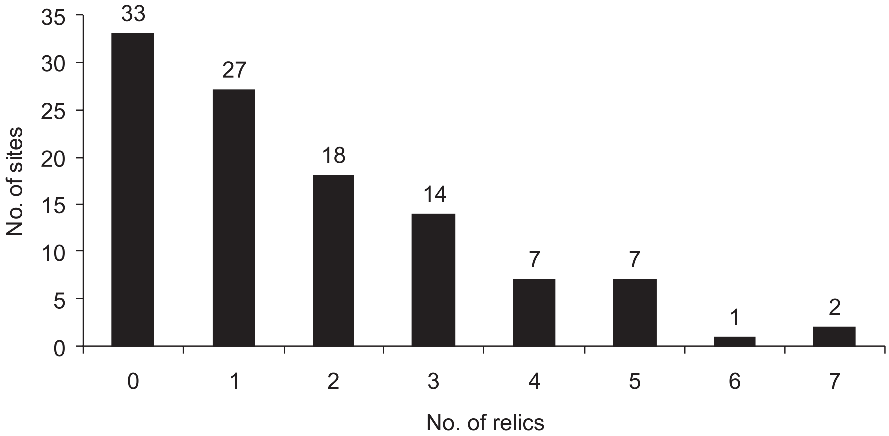



**Fig. 78.** Distribution of numbers of relics of cultivation at West Slavic sites

the transfer of crop plants over long distances. Many of them stopped to be used as late as in the 20th century (e.g. *Avena strigosa*). In the Middle Ages, during the migrations of various tribes, the species cultivated by them were transported to new areas. These were initially anthropogenic habitats within their natural ranges of distribution, but later also outside their natural ranges. Because of the great dynamics of these processes, it is extremely difficult to determine even which species are truly relics of cultivation. A basic problem is the time that has passed since their cultivation was stopped. Some species were introduced into cultivation several times or continue to be cultivated for many centuries. For example, *Viola odorata* was cultivated in the Middle Ages and is still widely cultivated. There are no sources that unambiguously indicate the origin and period of utilization of many species. Archival sources, old books about plants, and herbaria are highly valued, but rare and incomplete reference sources (see Furmanowa *et al.* 1959 and Chodurska 2003).

Important contributions to identification of relics of cultivation are provided by floristic research conducted at archaeological sites (particularly at medieval fortified settlements and their surroundings, castle ruins, suburbia, and other abandoned settlements), near old monasteries, and in former manor parks. Relics of cultivation are not always found there, but usually their contribution is much higher there than outside such sites. In total, at the studied sites in Central Europe, 22 relics of cultivation were recorded (Table 27). Some of them were cultivated in the Middle Ages, while the others in later periods. The latter are most frequent at the late medieval sites that were inhabited until modern times. Most of the plants cultivated in the Middle Ages were old medicinal plants (e.g. *Malva alcea, Leonurus cardiaca*, *Marrubium vulgare* or *Parietaria officinalis*),

**Table 28.** West Slavic sites with the largest numbers (≥4) of relics of cultivation

| Study site | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Drohiczyn | - | - | + | - | - | - | + | - | + | + | - | - | - | - | - | - | - | + |
| Kałdus | + | - | - | - | + | + | - | + | - | - | - | - | + | - | - | - | - | + |
| Kórnik | + | - | + | - | - | + | - | - | + | - | - | - | - | - | + | + | - | + |
| Kruszwica | - | - | - | - | - | + | - | - | + | - | - | - | - | - | + | - | - | + |
| Ląd | - | - | - | - | + | + | - | + | - | + | - | - | - | - | - | - | - | - |
| Mietlica | - | + | + | - | - | + | - | - | + | - | - | - | - | - | - | + | - | - |
| Międzyrzecz | - | - | - | - | - | - | - | - | + | + | - | - | - | + | + | - | - | + |
| Mirów | - | - | - | - | - | - | - | - | - | + | + | + | - | - | + | + | - | - |
| Obrzycko | - | - | - | - | - | - | - | - | + | + | - | - | - | - | - | + | + | - |
| Olsztyn | + | - | + | - | - | - | - | - | - | + | - | - | - | - | - | + | - | + |
| Piersko | + | - | - | - | + | - | - | + | - | + | - | + | + | - | - | - | - | + |
| Podzamcze | - | - | - | - | - | - | - | - | - | + | - | + | + | - | + | - | - | - |
| Stara Warka | - | - | - | - | - | + | - | + | - | + | - | - | + | - | - | - | - | - |
| Stradów | - | - | - | - | - | + | + | - | + | - | - | - | - | - | + | + | - | - |
| Szarlej | - | - | + | - | + | + | - | + | - | - | - | - | + | - | - | - | - | - |
| Tum | - | - | - | + | - | - | + | - | - | + | - | - | - | - | - | - | - | + |
| Wiślica | - | - | - | - | - | + | + | - | + | - | - | - | - | - | + | - | - | - |

Explanations: 1 – *Allium scorodoprasum*, 2 – *Anthriscus cerefolium*, 3 – *Artemisia absinthium*, 4 – *Bunias orientalis*, 5 – *Chaerophyllum bulbosum*, 6 – *Lavatera thuringiaca*, 7 – *Leonurus cardiaca*, 8 – *Lithospermum officinale*, 9 – *Lycium barbarum*, 10 – *Malva alcea*, 11 – *Marrubium vulgare*, 12 – *Nepeta cataria*, 13 – *Origanum vulgare*, 14 – *Parietaria* officinalis, 15 – *Pastinaca sativa*, 16 – *Saponaria officinalis*, 17 – *Valerianella locusta*, 18 – *Viola odorata*

**Fig. 79.** Clumps of *Malva alcea* and *Lavatera thuringiaca* at the fortified settlement in Chlebnia near Warsaw (central Poland)

spice plants (*Allium scorodoprasum*), rarely ornamentals (*Lavatera thuringiaca*). Plants cultivated in modern times are ornamentals (e.g. *Cymbalaria muralis* and *Lycium barbarum*), rarely spice plants (e.g. *Anthriscus cerefolium*). Some of the relics were cultivated in various periods, some of them till the present time (e.g. *Origanum vulgare*, *Saponaria officinalis*, *Viola odorata*). The current distribution of relics is connected with remnants of various archaeological sites. Some relic species, making use of favourable environmental conditions, have spread from the sites where they were cultivated in the past, into neighbouring habitats, mostly along transportation routes.

Relics of cultivation are found at 76 study sites (Fig. 78), but at 27 of the sites, this group was represented by only one species. Their largest numbers (7 species each) were recorded at 2 fortified settlements: on the Szyja peninsula in Kórnik, and on the island of Piersko on Lake Bytyńskie (Table 28).

At the study sites, relics of cultivation were usually not abundant or moderately abundant. Only exceptionally they were very abundant. A more complete picture of this phenomenon was drawn below on the basis of detailed population research at 3 fortified settlements: in Błonie and Chlebnia near Warsaw and in Kórnik near Poznań.

In 2004, at the fortified settlement in Błonie, 783 individuals of *Lavatera thuringiaca* were recorded, while in Chlebnia, 28 individuals and additionally 138 of *Malva alcea* (Fig. 79). In Błonie, *L. thuringiaca* grows at the centre of the site, forming a dense stand in the northern part of the central depression, on its south-facing slope. Smaller patches and single individuals of this species were found in the southern part and on ramparts. Outside the archaeological site, no specimens of *L. thuringiaca* were found on roadsides, in ruderal habitats, and meadows. At the second fortified settlement, in Chlebnia, *L. thuringiaca* forms several patches only on the cone-shaped mound, which is the most elevated part of the site. This species grows on southern slopes of the cone. Similarly, *Malva alcea* grows at the fortified settlement only on the central cone, on its south-facing slopes. In the neighbourhood, single clumps were observed along the road to Grodzisk Mazowiecki, ca. 150 ha from the archaeological site.

At the archaeological site in Kórnik, 323 individuals of *L. thuringiaca* grew in 2005 at the fortified settlement and 6 at the cone-shaped settlement located nearby. Clumps of *L. thuringiaca* growing on sunny ramparts with a southern exposure, were composed of individuals that flowered and bore fruit abundantly.

### 6.4. Relics of cultivation in the flora of Central Europe and the world

The problem of West Slavic relics of cultivation, being important components of the present flora of sites of their fortified settlements and castles in Central Europe, needs to be discussed in the context of similar ethnobotanical phenomena all over the world.

In many parts of Africa, when fields are abandoned in an area (usually because of soil degradation), the plants that were cultivated there often persist at the sites there as relics in the vicinty or at the places where they were cultivated in the past (Blay 2003). These include e.g. *Veronica montana*, *Euphorbia milii*, and *E. pulcherrima* (Hyde & Wursten 2010a, 2010b). On the islands of New

Zealand, relics of cultivation include some species that are still cultivated in some other parts of the world, e.g. *Colocasia esculenta*, *Cordyline fruticosa*, *Citrus limon*, *Echeveria* sp., *Eriobotrya japonica*, *Nerium oleander*, and *Prunus persica* (Harris & Heenan 1992; West 2002; Sykes 1977, 2004). In Australia, the same applies to *Moringa oleifera* (Navie & Csurhes 2010). In Asia, on the island of Sulawesi (Celebes), relics of cultivation include the palms *Areca catechu*, *Arenga pinnata*, and *Cocos nucifera* (Powling 2009), while on the island of Tioman in Malaysia, they are represented by *Colocasia esculenta* and *Manihot esculenta* (Latiff *et al.* 1999). In North America, some *Agave* species (e.g. *A. murpheyi* and *A. delamateri*) are regarded as relics of pre-Columbian cultivation (Adams & Adams 1998; Hodgson 1999, 2006; Parker *et al.* 2007).

On the European continent, into which alien crop plants were introduced from all over the world for hundreds of years, a large number of relics of cultivation have been identified. Some of them are completely naturalized and widespread, so that it is difficult to identify traces of their cultivation in the past. In France e.g. *Allium ampeloprasum* is regarded as a relic of cultivation, rather than a modern garden escape (Damania 1998). In Italy, *Vicia articulata* was cultivated for centuries for forage, green manure, and human consumption. Today it remains only as a relic of cultivation in some populations on Sardinia (Laghetti *et al.* 2000). A detailed list of relics of cultivation for Ireland was presented by Reynolds (2002). It includes the range of species from many plant families, cultivated for various purposes. The most interesting is the group of relics of ancient cultivation. It consists of species cultivated in ancent times for human consumption (e.g. *Allium scorodoprasum*, *Chenopodium bonus-henricus*, *Smyrnium olusatrum*) or as medicinal plants (e.g. *Inula helenium*, *Sambucus ebulus*, *Silybum marianum*, and *Tanacetum parthenium*). They are currently observed near old churches, monasteries, and their ruins (Reynolds 2002). In the Middle Ages, monasteries played an important role in medicine, as many monks were renowned herbalists at that time (Roth 2000; Thoms 2000; Mayer 2010). Numerous species cultivated by them persist there to this day as relics (Kornaś 1949-1950, 1959; Simon 2000).

Many relics of cultivation are observed also in the extensive woodlands of the Białowieża Forest, which is nearly free from human interference (Faliński 1966) or in areas abandoned after the 2nd World War and still inhabited by very few people, e.g. in the Magura National Park (Dubiel *et al.* 1998). In the Białowieża Forest, relic plants are found mostly in ruderal habitats (e.g. *Melissa officinalis*, *Mentha niliaca*, *Pastinaca sativa*), rarely on forest roadsides (*Elsholtzia citrina*, *Rudbeckia laciniata*), or in clear-cut areas and transformed forest communities (*Lupinus polyphyllus*, *Sambucus racemosa*, *Sarothamnus scoparius*) (Faliński 1966). In the Magura National Park, relics of old gardens were identified, i.e. old ornamental plants: *Centaurea mollis*, *Phalaris arundinacea* var. *picta*, *Rosa* ×*centifolia*, *Scopolia carniolica*, *Telekia speciosa*, *Vinca minor*; as well as fruit trees: *Cerasus avium*, *Malus domestica*, *Prunus domesitca*, *P. insititia*, *Pyrus communis*. They persist near remnants of old buildings, cemeteries, wayside shrines, and roadside crosses (Dubiel *et al.* 1998). In the Tatra National Park, a group of species that are the relics of experimental meadow cultivation, carried out over 100 years ago, was distinguished. It includes: *Crepis aurea*, *Bellardiochloa violacea*, *Festuca rupicaprina*, *Phleum rhaeticum* and *Plantago serpentina* (Mirek 1995).

A characteristic feature of Central Europe is the presence of Slavic relics of cultivation, which was noted by German botanists in the 19th and early 20th century (see Bauch 1937a, 1953). It still arouses the interest of researchers (e.g. Hanelt & Hammer 1985; Pivarci & Behm 2001; Russow & Schulz 2001; Russow 2002; Celka 2000b, 2005). The area of eastern Germany was colonized by Slavic people till the 12th century. Since then, remnants of their fortified settlements and the species cultivated at those sites and close to them persist to this day. Research conducted by Bauch (1937a, 1953) in Mecklenburg allowed him to distinguish a large group of Slavic relics of cultivation. Also in other parts of Germany (Brandes 1996a; Pivarci & Behm 2001; Russow 2000, 2002) or Poland (Celka 2000b, 2005), many species are apparently remnants of medieval cultivation. Some of them were given specific names, which are used in local languages, e.g. *pflanzliche Kulturrelikte, Burgpflanzen, Burggartenpflanzen, Burgwallpflanzen, Reliktpflanzen, Stinzenplanten* (Bakker 1986; Brandes 1996b; Russow 2002).

Russow (2002) divided relics of cultivation in Germany with regard to their distribution into 3 groups: general relics, regional relics, and local relics. General relics are species whose natural range is distant from the studied area, or subspecies (varieties) that do not have any natural range. The natural range of any regional relic borders on the area where it is regarded as a relic of cultivation, so that this is a secondary extension of its range. Local relics are species which outside archaeological sites grow also in natural and semi-natural plant communities, and are components of the wild flora of the studied area (Russow 2002). In the present study, general relics correspond to ergasiolypophytes, while regional relicts and local relicts, to ekiolypophytes. Russow (2002), on the basis of various sources, classified 20 species as general relics (*Antirrhinum majus*, *Artemisia absinthium*, *Artemisia maritima*, *Cannabis sativa*, *Cheiranthus cheiri*, *Conium maculatum*,

**Table 29.** List of species associated with castles according to Brandes (1996b) and their occurrence in this study

| Species | Brandes (1996b) | West Slavic | | Baltic settlements | Teutonic castles |
|---|---|---|---|---|---|
| | | settlements | castles | | |
| *Anthemis tinctoria* | + | + | - | + | + |
| *Anthriscus caucalis* | + | - | - | - | - |
| *Anthriscus cerefolium* | + | + | - | - | - |
| *Artemisia absinthium* | + | + | + | + | - |
| *Artemisia pontica* | + | - | - | - | - |
| *Asperugo procumbens* | + | + | - | - | + |
| *Asplenium ruta-muraria* | + | - | + | - | - |
| *Asplenium trichomanes* | + | + | + | - | - |
| *Ballota nigra* | + | + | + | + | + |
| *Cheiranthus cheiri* | + | - | - | - | - |
| *Chenopodium bonus-henricus* | + | + | + | - | - |
| *Conium maculatum* | + | + | + | + | - |
| *Cymbalaria muralis* | + | - | + | - | + |
| *Cystopteris fragilis* | + | - | + | - | - |
| *Datura stramonium* | + | + | - | - | - |
| *Diplotaxis muralis* | + | - | + | - | - |
| *Echium vulgare* | + | + | + | + | + |
| *Hyoscyamus niger* | + | + | + | - | + |
| *Iris germanica* | + | - | - | - | - |
| *Isatis tinctoria* | + | - | - | - | - |
| *Lappula squarrosa* | + | + | - | - | - |
| *Leonurus cardiaca* | + | + | + | + | + |
| *Malva neglecta* | + | + | + | - | + |
| *Malva sylvestris* | + | + | + | - | + |
| *Medicago minima* | + | + | - | - | - |
| *Nepeta cataria* | + | + | + | - | - |
| *Onopordum acanthium* | + | + | + | + | + |
| *Parietaria judaica* | + | - | - | - | - |
| *Ruta graveolens* | + | - | - | - | - |
| *Sempervivum tectorum* | + | - | - | - | - |
| *Sisymbrium austriacum* | + | - | - | - | - |
| *Tanacetum parthenium* | + | - | - | - | - |
| *Verbena officinalis* | + | - | - | - | - |
| Total | 31 | 18 | 16 | 7 | 10 |

*Dianthus gratianopolithanus flore pleno*, *Hyoscyamus niger*, *Hyssopus officinalis*, *Malva alcea**, *Marrubium creticum*, *Marrubium vulgare*, *Melissa officinalis*, *Nepeta cataria*, *Rosa majalis flore pleno*, *Rumex scutatus* var. *hortensis*, *Ruta graveolens*, *Verbascum nigrum**, *Vinca minor*, *Viola odorata**), 6 as regional relics (*Allium ursinum**, *Gentiana lutea*, *Helleborus foetidus*, *Helleborus viridis*, *Origanum vulgare**, *Petasites hybridus*), and 12 as local relics (*Agrimonia eupatoria**, *Allium oleraceum**, *Allium scorodoprasum**, *Anthemis tinctoria**, *Atropa bella-donna*, *Chelidonium maius**, *Hedera helix*, *Hypericum perforatum**, *Lilium martagon*, *Lithospermum officinale*, *Primula veris**, *Serratula tinctoria**). The 13 species marked with asterisks above were classified by him as cultivated by Slavs from the 7th to 12th century (Russow 2002).

Some of the species regarded as Slavic relics of cultivation in Mecklenburg have the same status also in other parts of the area controlled by West Slavs in that period (e.g. *Allium scorodoprasum*, *Malva alcea*, *Origanum vulgare*, *Viola odorata*). Some species classified as local relics (e.g. *Agrimonia eupatoria*, *Allium oleraceum*, *Chelidonium majus*, *Hypericum perforatum*, *Primula veris*, *Serratula tinctoria*) or general relics (*Verbascum nigrum*) arouse more doubts. Their utilization (and perhaps also cultivation) throughout the area inhabited by West Slavs in that period cannot be excluded. However, this problem requires further research.

A list of plant species associated with castles (so-called *Burgenpflanzen*) was compiled by Brandes (1996b). It includes 31 species (Table 29). As many as 22 of them were recorded in the present study, both in Slavic settlements (18 species) and at castles (16 species).

Relics of cultivation persist in places where they were formerly cultivated. Local populations of the relic species (e.g. *Allium scorodoprasum*, *Malva alcea*, *Origanum vulgare*) recorded in the 19th and early 20th century (Koch 1897; Krause 1897; Bauch 1937a) on an island of Teterower See in Mecklenburg, are still present there. The island in the early Middle Ages was inhabited by Slavs who built there a fortified settlement (gord) and an adjacent less fortified settlement (suburbium). The island was linked with the lake shore by a wooden bridge, which was 750 m long (Hermann & Donat 1979). Currently it is linked by a ferry, and near its terminal, single specimens of *Malva alcea* are found.

Hollnagel (1953a, 1953b) conducted interesting investigations on islands in the former Neustrelitz District (Kreis Neustrelitz), where remnants of Slavic settlements were found. He recorded there many relics of cultivation, well preserved in such isolated places. Research carried out on islands after 50 years, i.e. in 2000 by Russow & Schulz (2001, 2002), confirmed the presence of most of the relics of cultivation, but numbers of their localities usually decreased. For example, *Malva alcea* was recorded by Hollnagel (1953a, 1953b) on 17 islands, but currently it grows only on 6 islands (Russow & Schulz 2001, 2002). However, it should be remembered that at some sites, only repeated botanical exploration in several growing seasons enable determination of a complete list of species. Numerous examples are provided by an earlier study of the flora of fortified settlements in Wielkopolska (Celka 1999). At some sites, small populations of relics persist for many years at the vegetative stage, so they are difficult to notice.

Out of the group of relics of cultivation reported by Bauch (1937a) and Russow (2002) and found in the present study, I will discuss below the status of 22 species whose cultivation in the past is the best documented. Various authors showed that research on plant indicators of medieval or earlier human settlements has not been completed (see Russow 2002). Among the species found at the sites of medieval fortified settlements and castles, many could be used, planted, and cultivated (see Kruk 1994). Current knowledge does not provide any evidence to confirm their medieval cultivation. However, good examples are *Salvia glutinosa, S. nemorosa, S. verticillata*, and *Nepeta pannonica*, which at some archaeological sites are probably relics of cultivation (see Bartoszek & Siatka 2008; Suder 2010), as they were found also in archaeological deposits (e.g. Trzcińska-Tacik & Wieserowa 1976; Trzcińska-Tacik & Wasylikowa 1982).

Considering the time of cultivation, I divided relics of cultivation into 3 groups: (*i*) relics of medieval cultivation (cultivated before the late 15th century), (*ii*) relics of cultivation in the modern era (cultivated since the 16th century), and (*iii*) relics of cultivation in both the Middle Ages and the modern era.

### Relics of medieval cultivation

This group includes 13 species cultivated mostly in the Middle Ages. In prehistoric times and in modern times they were cultivated only sporadically, and currently people do not associate them with cultivated plants: *Allium scorodoprasum*, *Anthemis tinctoria*, *Bunias orientalis*, *Camelina sativa*, *Chaerophyllum bulbosum*, *Lavatera thuringiaca*, *Leonurus cardiaca*, *Lithospermum officinale*, *Malva alcea*, *Marrubium vulgare*, *Nepeta cataria*, *Parietaria officinalis*, and *Vallerianella locusta*.

***Allium scorodoprasum*** – a European-Pontic-Pannonian species (Zając & Zając 2009), rare or widely distributed in Central Europe (Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001; Krahulec 2002). Listed as a relic of cultivation by Bauch (1937a) and Russow (2002). Found at sites of fortified settlements in north-eastern Germany (Bauch 1934a, 1937a), the western part of Polish Carpathians, and Małopolska (Bartoszek & Siatka 2008; Suder & Towpasz 2010; Suder 2010), at the castles of Sachsenburg in northern Thuringia (Barthel *et al.* 1997), and Burgscheidungen in Saale-Unstrut (Dehnen-Schmutz 2000). In the area occupied by West Slavs, it forms large populations at 7 fortified settlements and castles, most of them constituting isolated habitats (e.g. on 2 lake islands: Piersko and Teterow).

***Anthemis tinctoria*** – a Euro-Siberian-Mediterranean-Irano-Turanian species (Meusel & Jäger 1992; Zając & Zając 2009), widely distributed in Central Europe (Dostál 1989; Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001). In Poland and in the Czech Republic regarded as a native species (Mirek *et al.* 2001; Zając & Zając 2001; Pyšek *et al.* 2002), while in Germany, as an archaeophyte (Lohmeyer & Sukopp 1992; Rothmaler *et al.* 2005). Regarded as a relic of cultivation by Brandes (1996a), Pivarci & Behm (2001), and Russow (2002). Found at sites of fortified settlements in Mecklenburg (Bauch 1937a), frequent at castle sites in southern and central Germany (Vollrath 1958-1960; Janssen 1990; Brandes 1996b; Barthel *et al.* 1997; Dehnen-Schmutz 2000), Estonia (Brandes 1996b), and at 4 castles in Lower Austria (Hübl & Scharfetter 2008). In the area colonized by West Slavs, found at 2 early medieval West Slavic settlements, 5 Yotvingian ones, and at the Teutonic castle in Papów Biskupi. Reported from archaeological deposits of many sites from various periods of the Iron Age, including the early Middle Ages (Trzcińska-Tacik & Wieserowa 1976; Alsleben 1991, 1997; Tobolski & Polcyn 1993; Rösch 1998; Rösch & Fischer 1999; Latałowa 1999a; Polcyn 2003; Latałowa *et al.* 2003; Lityńska-Zając 2005b).

***Bunias orientalis*** – a species originating from eastern Europe and Asia. In Central Europe usually regarded as a kenophyte (Pyšek *et al.* 2002; Celka 2004; Rothmaler *et al.* 2005; Tokarska-Guzik 2005), introduced in the 19th century and spreading eastwards. Observed earlier at the castles of western Germany (Lohmeyer 1975b, 1984). In the present study it was recorded at the fortified settlement in Tum near Łęczyca. This is interesting because many fruits of *B. orientalis* were found long ago in early medieval archaeological

**Fig. 80.** *Bunias orientalis* on a rampart of the fortified settlement in Tum near Łęczyca (central Poland)

deposits at that site (Klichowska 1955, 1972; Sychowa 1985) and on the island of Wolin (Latałowa 1999a). That is why, in spite of the doubts of Zając and Zając (1975) and Tokarska-Guzik (2005), it was classified as an archaeophyte. Currently, *B. orientalis* is abundant on ramparts and in the inner depression of the fortified settlement in Tum and near the road from the site to the village of Tum, as well as in the village itself, near the medieval collegiate church. Every year it flowered and bore fruit abundantly (Fig. 80). It is noteworthy that out of the 109 West Slavic sites, Tum near Łęczyca played the most important role in the Polish state in the 12$^{th}$ and 13$^{th}$ centuries. The fortified settlement itself was created in the 8$^{th}$ century and was a stronghold surrounded by a system of ramparts and moats. It was the capital of the senior district assigned for life to the Princess Mother Salomea of Berg (1093-1144) after the death of her husband, the Prince of Poland, Bolesław III Wrymouth. The stronghold in Tum, because of its neutrality and central location, has become an important political, administrative, and trade centre. Additionally, its role increased because of its role in the church, as the collegiate church was built there in 1140-1161. Important meetings of princes and church officials were held there in 1141, 1161, and 1180. In the 12$^{th}$ and 13$^{th}$ centuries, the stronghold was inhabited by Polish princes and their courts. The stronghold in Tum withstood many onslaughts from both the Lithuanians and the Tatars. It was abandoned in the late 13$^{th}$ century, probably after yet another attack of the Lithuanians (Kamińska 1953; Nadolski 1987). The presence of seeds of *Bunias orientalis* in archaeological deposits of this fortified settlement suggests that it was introduced there in the 12$^{th}$ and 13$^{th}$ century and grown for food, forage, and perhaps also as an ornamental (see Conert *et al.* 1986; Broda & Mowszowicz 2000; Łuczaj 2004; Birnbaum 2006). At present, *Bunias orientalis* persists at the site where it was cultivated in the past. The site is a specific habitat island of xerothermic and ruderal vegetation among meadows, and it is disseminated along the road leading to the village. It was not detected on the neighbouring meadows, which surround this site since the Middle Ages, when this area was severely deforested and turned into farmland (Dobrowolska 1961; Olaczek 1987).

***Camelina sativa*** – a Euro-Siberian species (Mirek 1981), in Central Europe regarded as an archaeophyte (Rothmaler *et al.* 2005) or neophyte (Pyšek *et al.* 2002). In Poland classified as one of man-made archaeophytes, so-called *archaeophyta anthropogena* (Mirek 1981; Zając 1988), as it derives from *Camelina microcarpa* (Lityńska-Zając & Wasylikowa 2005). Observed at the Flochberg castle in southern Germany (Schneider & Fleschutz 2001), and at the fortified settlement in Haćki in north-eastern Poland (see also Faliński & Kwiatkowska-Falińska 2005). Fruits of this species were found in archaeological deposits at very many Stone and Iron Age sites, including medieval ones from the area colonized by West Slavs (see Kroll 1995, 1996, 1997, 1998, 1999, 2000, 2001; Knörzer 1978). In northern Europe its cultivation dates back to the late Bronze Age and the early Hallstatt period. This species was used as a source of edible oil, mostly in the north, along the coasts of the Baltic and the North Sea (Lityńska-Zając & Wasylikowa 2005).

***Chaerophyllum bulbosum*** – a Euro-Siberian species (Zając & Zając 2009) whose range includes Central Europe (Hultén & Fries 1986). Its status in this region is unclear. Lohmeyer & Sukopp (1992) classify it as an archaeophyte in the western part of Central Europe, but elsewhere it is regarded as a native species (Slavík & Slavíková 1997; Mirek *et al.* 2001; Rothmaler *et al.* 2005). Widely distributed in Central Europe (Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001). In Poland found mostly in the Vistula valley, but it has many localities also in the regions of Wielkopolska, Pomerania, Silesia and the Lublin Province (Zając & Zając 2001). In many of its current localities in Poland it is probably a relic of cultivation (Nowiński 1977). In the Middle Ages it was grown and widely distributed thanks to monasteries (Nowiński 1977; Slavík & Slavíková 1997; Jäger *et al.* 2008). Till the late 18th century it was commonly used (Maurizio 1926), and even currently it is recommended as a good edible plant (Łuczaj 2004; Podgórska & Podgórski 2004). Reported as a relic of cultivation in the Czech Republic (Slavík & Slavíková 1997), also in other regions of Europe it is cultivated and naturalized as a garden escape (Meusel *et al.* 1978). Observed at the castles of the Harz Mountains (Brandes 1996b) and in 6 fortified settlements in the Chełmno region (Kamiński 2006a). During this study it was recorded at 5 West Slavic fortified settlements and one castle and 2 Teutonic castles.

***Lavatera thuringiaca*** – a Euro-Siberian species with a limit in Central Europe (Hultén & Fries 1986; Zając & Zając 2009). In western Germany regarded as an alien, probably an archaeophyte (Haeupler & Schönfelder 1989; see także Brandes 2000). In Poland and the Czech Republic it is assumed to be native (Slavík 1992; Mirek *et al.* 2001), but at least in some of its Polish localities, outside the continuous range of distribution, it is anthropogenic (Celka 2000b). This species is rare at archaeological sites in Germany, e.g. Sachsenburg castle in northern Thuringia (Barthel *et al.* 1997). In the present study, it was recorded at 20 archaeological sites: 17 in Poland and 3 in Ukraine. Populations of *Lavatera thuringiaca* at the 14 West Slavic sites are isolated, distant from the main distribution range, which covers south-eastern Poland. Very often they are composed of numerous individuals growing in xerothermic habitats, e.g. on sunny slopes (see section 6.4). Xerothermic grasslands with *L. thuringiaca* are characterized by a lower species diversity and a higher contribution of synanthropic species. This was observed e.g. at the fortified settlements along the river Vistula near Kałdus (Ceynowa-Giełdon & Kamiński 2004). This study confirms my earlier hypothesis (Celka 1999) about synanthropic origin of *L. thuringiaca* in central and northern Poland, and probably also in other regions. It must be emphasized that plants of this species are rare on roadsides and in roadside ditches outside the fortified settlements and castles.

My research conducted at several East Slavic castles and fortified settlements in Ukraine shows that also there *L. thuringiaca* is found at archaeological sites e.g. near the castles in Hubkiv, Korets, Khotyn, and Kamyanets-Podilsky (see also Kagalo *et al.* 2004), and along roads.

***Leonurus cardiaca*** – a species of Pontic-Pannonian origin (Zając 1988). Introduced as a medicinal plant, it has spread as a garden escape and has become naturalized in ruderal habitats throughout Central Europe (Hegi 1964a; Zarzycki 1967; Hultén & Fries 1986), where it is now frequent (Dostál 1989; Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001). It is commonly regarded in this region as an archaeophyte (Zając 1988; Pyšek *et al.* 2002; Rothmaler *et al.* 2005), which is supported by palaeobotanical data. *L. cardiaca* was found many times in archaeological deposits (Trzcińska-Tacik & Wieserowa 1976; Trzcińska-Tacik & Wasylikowa 1982; Polcyn 2003; Lityńska-Zając 2005b). Currently recorded in or near castles in Lower Austria (Hübl & Scharfetter 2008), western Germany (Lohmeyer 1975a; Hilgers 1995), and Estonia (Brandes 1996b). The presence of *L. cardiaca* at archaeological sites has also been documented in the present study. The species was observed at 13 West Slavic fortified settlements and castles, as well as at 2 Yotvingian settlements, a Teutonic castle, and 3 East Slavic sites.

***Lithospermum officinale*** – a Euro-Siberian-Mediterranean-Irano-Turanian species (Zając & Zając 2009). Its fruits species were found in archaeological deposits of human settlements from various periods and in burial sites (e.g. Zabłocki & Żurowski 1932; Jażdżewski 1938; Reyman 1948; Klichowska 1972; Hellwig 1997; Lityńska-Zając 1997, 2005a; 2005b; Trzcińska-Tacik & Lityńska-Zając 1999). A particularly interesting finding was a cataplasm (or poultice) made of heated birch-tar and herbs, from an early Bronze Age burial site in Szarbia. The fruits of *L. officinale* were embedded in the cataplasm and played a medical and/or magic role (Baczyńska 2005; Baczyńska & Lityńska-Zając 2005). Also Hultén & Fries (1986) and Slavík (2000a) note that some local populations of this species, within its range, are anthropogenic and result from its earlier cultivation. *L. officinale* is found at various archaeological sites. Rare at fortified sites in the Polish Western Carpathians (Suder & Towpasz 2010) and castles in

Lower Austria (Hübl & Scharfetter 2008). During the present study it was observed at 6 fortified settlements, but its abundance was always low. Associated with xerothermic grasslands, often located within habitat islands, lake islands, peninsulas, at river bends.

***Malva alcea*** – a species distributed in Central and South Europe, partly in West and North Europe (Hultén & Fries 1986). In Central Europe usually regarded as an archaeophyte (Lohmeyer & Sukopp 1992; Celka 1998; Rothmaler *et al*. 2005). In the Czech Republic, it is not listed as an alien (Pyšek *et al*. 2002). In the early Middle Ages it was often cultivated and naturalized (Dostál 1989; Slavík 1992). Reported from fortified settlements in Mecklenburg (Bauch 1934a, 1937a; Hollnagel 1953a, 1953b; Russow & Schulz 2001), Stolpen castle near Dresden (Otto & Krebs 1991), and castles in southern Germany (Vollrath 1958-1960; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001). It is the most frequent relic of cultivation in the area colonized by West Slavs. It was observed at 47 fortified settlements and castles (43% of the total number of West Slavic sites) and at 5 Yotvingian and Old Prussian settlements, a Teutonic castle (Kurzętnik), and an East Slavic castle (Hubkiv). The only Teutonic castle where *M. alcea* was recorded, is located in the area where medieval West Slavic settlements are found. During the wars between Poland and the Teutonic Order in the 15th century, the castle changed hands many times. Some of the Baltic settlements are close to the border with Polish land, while others (e.g. Szurpiły) were the scene of fierce fighting between Teutonic Knights and Yotvingians, and later also Lithuanians. *M. alcea* was found in archaeological deposits from the early Halstatt period in Biskupin (Klichowska 1972, as well as early medieval deposits in Gniezno (Klichowska 1972, the Lednica region (Tobolski & Polcyn 1993; Polcyn 2003), and Mikulčice (Opravil 1998).

***Marrubium vulgare*** – a species of Mediterranean origin, introduced also to North Africa, North and South America, Australia, and New Zealand (Hultén & Fries 1986). In Central Europe it was commonly cultivated as a medicinal plant. Found many times in archaeological deposits from the Bronze Age (Rösch 1996) and the Middle Ages (Trzcińska-Tacik & Wieserowa 1976; Trzcińska-Tacik & Wasylikowa 1982; Küster 1998; Rybníček *et al*. 1998; Rösch 1999). It has spread from the sites of its cultivation, and is now naturalized (Hegi 1964b; Hultén & Fries 1986). In this region it is now widespread in ruderal habitats (Dostál 1989; Haeupler & Schönfelder 1989; Benkert *et al*. 1996; Zając & Zając 2001), and regarded either as an archaeophyte (Hrouda 2000; Pyšek *et al*. 2002; Rothmaler *et al*. 2005) or as a kenophyte (Tokarska-Guzik 2005). During the present study, it was recorded only once, as a small population at the castle in Mirów.

***Nepeta cataria*** – a Mediterranean–Irano-Turanian species (Zając 1987b), introduced to Central Europe as a medicinal plant. It has spread quickly and is now naturalized (Hegi 1964c; Hultén & Fries 1986). Reported from archaeological deposits from the Bronze and Iron Ages, including medieval ones (e.g. Trzcińska-Tacik & Wieserowa 1976; Trzcińska-Tacik & Wasylikowa 1982; Hellwing 1997; Opravil 1998; Lityńska-Zając 1997, 2005b; Polcyn 2003). In this region commonly classified as an archaeophyte (Zając 1987b; Pyšek *et al*. 2002; Rothmaler *et al*. 2005). Recorded at the castles in Lower Austria (Hübl & Scharfetter 2008), in southern and western Germany (Kirschleger 1862; Vollrath 1958-1960; Lohmeyer 1975a, 1984; Hilgers 1995; Brandes 1996b; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), and at fortified settlements in Mecklenburg (Bauch 1934a). In this study, it was found at 4 West Slavic castles and 2 settlements, and at an East Slavic castle (Hubkiv in Ukraine). It grows in ruderal habitats near castle walls.

***Parietaria officinalis*** – a species of Mediterranean origin (Chrtek 1988). In Central Europe it is classified as introduced and rare (Schreiber 1981; Dostál 1989; Haeupler & Schönfelder 1989; Benkert *et al*. 1996; Zając & Zając 2001), regarded as an archaeophyte (Pyšek *et al*. 2002; Rothmaler *et al*. 2005). It persists at the sites where it was cultivated in the past, near castle walls, in thickets and gardens, also far away from its continuous range, e.g. in Kremenets in Ukraine, on the castle hill and near the former botanical garden where it was grown (Stecki & Zaleski 1928). Reported from castles in Lower Austria (Hübl & Scharfetter 2008), central Germany (Brandes 1992a, 1996b; Dehnen-Schmutz 2000), and near the monastery in Bielany in Kraków (Kornaś 1949-1950). At the studied West Slavic sites, found only near a wall of the castle in Międzyrzecz, where its population has been observed since 1994.

***Valerianella locusta*** – a Mediterranean-Central European species (Zając 1979), introduced to North America (Hultén & Fries 1986). In Central Europe quite frequent (Haeupler & Schönfelder 1989; Benkert *et al*. 1996; Zając & Zając 2001; Kirschner 2002). In Poland usually classified as an alien (Mirek *et al*. 2001; Zając & Zając 2001), in Germany most often as a probable archaeophyte (Rothmaler *et al*. 2005). Recorded in or near castles in southern and northern Germany (Otto & Krebs 1991; Brandes 1996b; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), Lower Austria (Hübl & Scharfetter 2008), and at the fortified settlement Wyszogród in Bydgoszcz (Korczyński 2010). Found at 3 Slavic settlements. Reported by Krause (1897) from an island of Teterower See, where its presence has not been confirmed recently. Found in early medieval deposits (e.g. Klichowska 1972; Trzcińska-Tacik & Wasylikowa 1982; Latałowa *et al*. 2003).

Relics of cultivation in the modern era

This group consists of 3 species used only in modern times, i.e. after the end of the 15th century: *Anthriscus cerefolium*, *Cymbalaria muralis*, and *Lycium barbarum*.

***Anthriscus cerefolium*** – a European-West Asiatic species (Slavík 1997) originating from the Eastern Mediterranean (Lohmeyer & Sukopp 1992). In Central Europe rare (Dostál 1989; Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001) and alien (Mirek *et al.* 2001). Rothmaler *et al.* (2005) classified it as an archaeophyte or neophyte. Observed at 9 castles in Lower Austria (Hübl & Scharfetter 2008) and castles in western Germany (Lohmeyer 1975a; Hilgers 1995). In this study, recorded only in an early medieval settlement in Mietlica, at the edge of a shrub community near a former manor park.

***Cymbalaria muralis*** – a species of Mediterranean origin, where it grows in rock crevices (Zając & Zając 1973). In Central Europe regarded as a kenophyte (Dostál 1989; Rothmaler *et al.* 2005; Tokarska-Guzik 2005). Its first records distant from the Mediterranean region date back to 1640 in the British Isles (Stace 1997) and 1644 in the Netherlands (Lohmeyer & Sukopp 1992). In Poland it was earliest found in the 1830s in Silesia, where soon after introduction into cultivation it has become naturalized in ruderal habitats (Zając & Zając 1973), and near Warsaw (Waga 1848). In our country it is now most frequent in Silesia and scattered in the western part of the country (Zając & Zając 2001). Observed very often on castle walls and their ruins, e.g. in Alsace (Kirschleger 1862), in various parts of Germany (Lohmeyer 1975a; Brandes 1987a, 1996b; Otto & Krebs 1991; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), Lower Austria (Hübl & Scharfetter 2008), and Estonia (Brandes 1996b). In the present study, recorded only at the castle in Wleń in Silesia and a Teutonic castle in Pokrzywno near Grudziądz in the Chełmno region. At the former site, it has colonized crevices in walls, while at the latter, it grows on bricks scattered near the wall.

***Lycium barbarum*** – a Eurasian species. The first information about it in Europe dates back to 1769 (Tokarska-Guzik 2005). In Poland reported by Waga (1847) as an ornamental. Widely distributed in Central Europe in ruderal habitats and in shrub communities (Dostál 1989; Lohmeyer & Sukopp 1992). Commonly classified as a kenophyte (Pyšek *et al.* 2002; Rothmaler *et al.* 2005; Tokarska-Guzik 2005). Observed at archaeological sites in Europe, e.g. Stolpen castle near Dresden (Otto & Krebs 1991), and castles in southern and northern Germany (Brandes 1996b; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001). Recorded also at 9 West Slavic archaeological sites, mostly castles and fortified settlements inhabited from late medieval to modern times; rarely early medieval sites, but only if adjacent to old manor parks or more recently planted shrubberies or wooded patches. *L. barbarum* grows also at a Teutonic castle in Radzyń Chełmiński (currently inhabited) and 2 sites in Ukraine (w Kiev and Korets), where it has become naturalized and forms its own plant communities (see also Święs 1997).

Relics of medieval-modern cultivation

Plants known and cultivated since the early Middle Ages and – often after a long interval – in several later historical periods. It includes 5 species: *Artemisia absinthium*, *Origanum vulgare*, *Pastinaca sativa*, *Saponaria officinalis*, *Vinca minor*, and *Viola odorata*.

***Artemisia absinthium*** – a Euro-Siberian species, found also in North Africa and North America (Hultén & Fries 1986). Its range of distribution is partly synanthropic because of former cultivation (Hultén & Fries 1986; Meusel & Jäger 1992). In Central Europe quite frequent (Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001; Grulich 2002). In Germany and the Czech Republic classified as an archaeophyte (Lohmeyer & Sukopp 1992; Pyšek *et al.* 2002; Rothmaler *et al.* 2005), in Poland also usually regarded as an alien (Jackowiak 1993; Chmiel 2006; Mirek *et al.* 2001; Zając & Zając 2001). Observed at the castles of southern and western Germany (Lohmeyer 1975b, 1984; Vollrath 1958-1960; Brandes 1996b; Dehnen-Schmutz 2000), Lower Austria (Hübl & Scharfetter 2008), Alsace (Kirschleger 1862), and at the fortified settlement Sabnie in Masovia (Ciosek & Piórek 2001). In the present study, recorded at 13 Slavic fortified settlements and 4 castles, and 2 Yotvingian settlements. Found in archaeological deposits e.g. from the La Těne period (Küster 1995), early Middle Ages (Greig 1996), and late Middle Ages (Rösch 1998).

***Origanum vulgare*** – a Euro-Siberian-Mediterranean-Irano-Turanian species (Zając & Zając 2009), widely distributed in Central Europe (Dostál 1989; Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001). Recorded at Slavic fortified settlements in Mecklenburg (Bauch 1934a, 1937a; Hollnagel 1953a, 1953b; Russow & Schulz 2001), the western part of Polish Carpathians (Suder & Towpasz 2010), castles in Lower Austria (Hübl & Scharfetter 2008), and in southern Germany (Janssen 1990; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001). During the present study, observed at 9 West Slavic fortified settlements and castles, often at isolated sites, e.g. on lake islands, hills, and near rivers. Recorded also at 2 Teutonic castles and a Ukrainian one, and at a Yotvingian settlement. Found in archaeological deposits at many sites from various periods, including the early Middle Ages (Trzcińska-Tacik & Wieserowa 1976; Lityńska-Zając 1997; Latałowa 1999a, 1999b; Latałowa *et al.* 2003; Polcyn 2003; see also Kroll 1997, 1998, 1999, 2000, 2001).

***Pastinaca sativa*** – a Euro-Siberian species, found also in North America (Hultén & Fries 1986). In Central Europe quite frequent (Haeupler & Schönfelder 1989; Benkert *et al.* 1996; Zając & Zając 2001). In the Czech Republic, *P. sativa* subsp. *sativa* and subsp. *urens* are classified as archaeophytes (Pyšek *et al.* 2002). In Germany its status is still unexplained (Lohmeyer & Sukopp 1992), sometimes regarded as an archaeophyte (Dehnen-Schmutz 2000). In Poland treated as a native species (Mirek *et al.* 2001), but its status raises some doubts (Zając & Zając 2001). Reported as a relic of cultivation from the Białowieża Forest (Faliński 1966). Observed at the castles of southern Germany (Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), Stolpen castle near Dresden (Otto & Krebs 1991), and castles of Lower Austria (Hübl & Scharfetter 2008). Recorded at West Slavic fortified settlements and 4 castles. Found in archaeological deposits dating back to from the Stone, Bronze, and Iron Age, including the early Middle Ages (e.g. Klichowska 1972; Kroll 1995, 1996, 1997, 1998, 1999, 2001; Latałowa 1999a; Lityńska-Zając 2005b). According to Polish archaeobotanical literature, probably cultivated since the Middle Ages (Latałowa & Badura 1996; Badura 1998). Also in ethnobotanical literature regarded as a species grown in Poland from the 12th to the 16th century, but later its cultivation was abandoned (Wierzbicka 2002; Podgórska & Podgórski 2004). European findings suggest that it was cultivated as early as in the Roman period (Zohary & Hopf 2000).

***Saponaria officinalis*** – a European-temperate-Mediterranean species (Zając & Zając 2009). Central Europe is crossed by its natural limit of distribution oriented latitudinally. North of this line, the species is only introduced and naturalized (Nowiński 1977; Meusel & Mühlenberg 1979; Hultén & Fries 1986). In the Czech Republic and in Germany regarded as an archaeophyte (Pyšek *et al.* 2002; Rothmaler *et al.* 2005). Reported from the castles of Lower Austria (Hübl & Scharfetter 2008), a fortified settlement in Sabnie in Masovia (Ciosek & Piórek 2001), and Wyszogród in Bydgoszcz (Korczyński 2010), as well as at the castles in Germany (Brandes 1996b; Schneider & Fleschutz 2001). In the present study recorded at 7 West Slavic fortified settlements and castles, as well as a Teutonic castle and 3 East Slavic sites (2 castles and a fortified settlement) in Ukraine. Distributed in grasslands, ruderal habitats, and rarely in shrub communities. Found in archaeological deposits from the Neolithic period (Lityńska-Zając *et al.* 2008), Roman period (Knörzer 1996; Stika 1996), and the Middle Ages (Trzcińska-Tacik & Wieserowa 1976; Trzcińska-Tacik & Wasylikowa 1982; Knörzer 1996; Polcyn 2003; Lityńska-Zając 2005).

***Vinca minor*** – a European-temperate-Mediterranean species (Zając & Zając 2009), with an unclear geographical-historical status (Haeupler & Schönfelder 1989). According to Meusel *et al.* (1978), Central Europe is crossed by a limit of its distribution, both natural and permanently naturalized in the past centuries. In eastern Germany regarded as an old ornamental plant, naturalized throughout the country: in the south as early as in the Middle Ages, while in the north in later periods (Benkert *et al.* 1996). In northern Germany its distribution is strongly associated with remnants of Roman settlements, so it has been classified as a relic of Roman cultivation (Prange 1996). According to Jäger *et al.* (2008) it is an archaeophyte in the temperate zone of Europe. In the Czech Republic only some of its populations located in the mountains are probably natural in oak-hornbeam forests and beech forests (Slavík 2000b). Often grown in gardens, parks, and cemeteries, where it spreads and becomes naturalized (Dostál 1989). A similar situation is observed in Poland (Bugała 1991), where it does not bring fruit in a large part of its range (Pawłowska 1971). Observed at archaeological sites in Europe, e.g. Stolpen castle near Dresden (Otto & Krebs 1991), at the castles in Lower Austria (Hübl & Scharfetter 2008), southern Germany (Vollrath 1958-1960; Janssen 1990; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), Alsace (Krause 1986), Ardennes (Duvigneaud 1991), and a fortified settlement in Chełm in Małopolska (Suder 2010). In this study, recorded at 2 sites: at a late medieval castle in Gościszów in Silesia and at an early medieval settlement in Wiatrowo Dolne in Pomerania, which is partly used as a cemetery. In both cases, the populations are very large.

***Viola odorata*** – a species originating from south-western Europe. In the north-eastern part of its range (including Central Europe), the species is only introduced and naturalized (Hultén & Fries 1986; Dostál 1989). In the Czech Republic and in Germany regarded as an archaeophyte (Pyšek *et al.* 2002; Rothmaler *et al.* 2005). Also in Poland treated as an alien (Mirek *et al.* 2001). In the north-western part of the country classified as a relic of cultivation and regarded as an archaeophyte (Latowski 1994). Very frequent at archaeological sites of Europe, e.g. castles in Alsace (Krause 1896), Ardennes (Duvigneaud 1991), Lower Austria (Hübl & Scharfetter 2008), many parts of Germany (Vollrath 1958-1960; Lohmeyer 1975b, 1984; Otto & Krebs 1991; Brandes 1996b; Dehnen-Schmutz 2000; Schneider & Fleschutz 2001), as well as at a fortified settlement in Chełm in Małopolska (Suder 2010). In the area colonized by West Slavs, recorded at 16 fortified settlements and castles, but also at 6 Teutonic castles and a Yotvingian settlement. Moderately abundant at nearly all sites. Found in archaeological deposits from the Roman period and early Middle Ages (Knörzer 1996).

### 6.5. Cultural and environmental value of West Slavic settlements and castles

Archaeological sites (fortified settlements, castles, etc.) are of great cultural value. Research within the humanities has documented their historical and archaeological value as well as their architecture. The studies are sources of knowledge about the people that inhabited those areas and their civilization. Archaeological earthworks, easily noticeable in the landscape, are the most interesting monuments of human activity, which has transformed the natural landscape into cultural one (anthropogenic) (Kobyliński 2000). There are over 10 000 archaeological sites in Central Europe: about 8 000 castles in Germany (Brandes 1996b), over 2300 fortified settlements in Poland (Antoniewicz & Wartołowska 1964), etc. Their presence, and often dominance in the landscape, is often an incentive to distinguish the archaeological landscape: the oldest cultural landscape, rich in human artefacts dating back to hundreds or even thousands of years ago. The archaeological landscape can play an important role in integration of the local community, forming a basis for development of the locality or region, contributing to creation of new jobs and development of tourist facilities (Kobyliński 2000; Rączkowski & Sroka 2002).

Changes in the natural environment have many aspects, so in research on archaeological sites it is important to cooperate with other specialists, both from the humanities and the sciences (Tobolski 1991; Wyrwa 2003; Makohonienko *et al.* 2007b). Interdisciplinary studies of archaeological sites in the area colonized by West Slavs were initiated in the early 20$^{th}$ century (Makohonienko *et al.* 2007c). Currently the role, importance, and possibilities of life sciences in the reconstruction of the natural environment, and prehistoric and medieval communities are very significant. This is reflected in creation of a new branch of research, termed environmental archaeology (Latałowa 2007). Research on prehistoric and medieval floras at archaeological sites are important because of transformations of the vegetation of Central Europe (e.g. Trzcińska-Tacik & Wasylikowa 1982; Sádlo & Matoušek 2008). The analysis of modern and fossil floristic data in settlement complexes has revealed a strong human impact, which gradually increased from the Middle Ages to the present day (Trzcińska-Tacik & Wieserowa 1976; Trzcińska-Tacik & Wasylikowa 1982; Trzcińska-Tacik & Lityńska-Zając 1999). Some of the species frequent in fossil materials (e.g. *Bromus secalinus*) are now declining, while others (e.g. the species closely associated with flax: *Cuscuta epilinum* or *Camelina alyssum*) have completely died out (Mirek 2001b; Mirek *et al.* 2002).

Floristic research conducted at archaeological sites has broadened our knowledge of their role in the ecosystem. The earthworks of earlier fortified settlements (ramparts, cone-shaped mounds, moats, etc.) are the habitats of many valuable plant species. Located in isolated places, often in the agricultural landscape, and surrounded with an aura of mystery, they were for centuries left alone. Only rarely they were used as pastures or for cultivation of crop plants, or as refuges in times of danger. In such favourable conditions, sometimes interesting plant communities have developed there, covering small patches but valuable in respect of species diversity and their phytosociological role. In the agricultural landscape, remnants of fortified settlements are often the only wooded sites, while moats or their fragments have become reservoirs of water. The diverse vegetation of fortified settlements creates favourable living conditions for other components of the natural environment: fungi and animals. Research on those groups of organisms at archaeological sites are not advanced yet, but information on the role of forest islands in the agricultural landscape is well-known (see Banaszak 2000, 2002; Symonides 2010). Their important components are often former fortified settlements. Also pioneering mycological investigations at archaeological sites have provided information about protected and rare species (e.g. Celka D. 2000).

Research on the current flora of archaeological sites supplies data on their role as (*i*) plant refuges for native species and archaeophytes; and (*ii*) sources of dispersal of alien species. Moreover, such studies broaden our knowledge of crop plants that are currently of no practical value (relics of cultivation). Finally, investigations of the current vegetation of archaeological sites provide additional reasons for protection of these valuable sites.

### 6.6. Conclusions

On the basis of this study and in light of the literature on this subject, the following conclusions can be drawn:

- the present vascular flora of archaeological sites is specific and differs remarkably from the flora of the surrounding habitats;
- an important feature distinguishing the flora of medieval settlements is the presence of relics of cultivation, which can play the role of plant indicators of archaeological sites;
- the specificity of the flora of castles is determined mostly by epilithic species, colonizing crevices in their walls;
- despite many features in common, floras of archaeological sites vary significantly, which results from differences in their geographical location, typology, and chronology of their origin;
- historical sites occupied in the past by different tribes, still differ in their vascular flora.

Results of this study lead also to a more general conclusion. It seems that because of such a unique combination of elements of the native flora and alien species that accompanied Slavic settlers over 1000 years ago, the best-preserved archaeological sites should be protected as our both cultural and natural heritage. From the biological standpoint, it is particularly important to preserve the habitats of plant relics of cultivation, which require more detailed research on their population ecology and genetics.

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# Appendices

**Appendix 1.** List of West Slavic archaeological sites included in this study

| Site (province, country) | Geographical location (GPS) | Number in Fig. 3 | Site type | Chronology; size class | Dominant habitats |
|---|---|---|---|---|---|
| Błonie (Mazowieckie, Poland) | N52º12`29.9`` E20º38`21.5`` | 70 | Concave settlement | 8th-13th c.; III | Dry grassland |
| Bobrowo (Kujawsko-pomorskie, Poland) | N53º17`49.7`` E19º17`11.7`` | 55 | Concave settlement | 9th-12th c.; II | Dry grassland |
| Bolkowice (Dolnośląskie, Poland) | N50º59`21.6`` E16º12`19.9`` | 94 | Concave settlement | 10th-12th c.; I | Deciduous forest |
| Bonikowo (Wielkopolskie, Poland) | N52º07`30.4`` E16º36`06.1`` | 37 | Concave settlement | 7th-10th c.; III | Dry grassland, meadow |
| Chełmiec (Dolnośląskie, Poland) | N51º03`32.3`` E16º05`55.5`` | 92 | Concave settlement | 11th-12th c.; II | Deciduous forest |
| Chlebnia (Mazowieckie, Poland) | N52º07`15.9`` E20º36`18.6`` | 71 | Concave and cone-shaped settlement | 11th-13th c.; III | Dry grassland, meadow |
| Cieciorki (Podlaskie, Poland) | N53º01`22.5`` E22º14`14.8`` | 61 | Concave settlement | EM, 13th c.?; II | Dry grassland |
| Czaple Szlacheckie (Mazowieckie, Poland) | N52º22`11.7`` E22º32`57.8`` | 75 | Cone-shaped settlement | 13th-14th c.; I | Dry grassland |
| Czudec (Podkarpackie, Poland) | N49º56`13.8`` E21º50`21.8`` | 108 | Fortified settlement?, castle | 13th-17th c.; II | Deciduous forest |
| Czuprynowo (Podlaskie, Poland) | N53º28`09.0`` E23º37`10.1`` | 66 | Fortified settlement? cone-shaped? | EM; I | Dry grassland, ruderal habitats |
| Dalków 1 (Dolnośląskie, Poland) | N51º39`18.1`` E15º52`52.7`` | 77 | Concave settlement | EM; I | Deciduous forest |
| Dalków 2 (Dolnośląskie, Poland) | N51º39`15.1`` E15º52`40.3`` | 78 | Concave settlement | EM; II | Deciduous forest |
| Dormowo (Wielkopolskie, Poland) | N52º31`15.4`` E15º52`04.8`` | 24 | Cone-shaped settlement | LM?; I | Dry grassland |
| Drohiczyn (Podlaskie, Poland) | N52º23`39.4`` E22º39`29.4`` | 73 | Cone-shaped settlement | 9th-12th c.; II | Dry grassland, ruderal habitats |
| Dziedzice (Mazowieckie, Poland) | N52º41`19.2`` E19º51`56.5`` | 68 | Concave settlement | 11th c. II | Dry grassland |
| Dzierznica (Wielkopolskie, Poland) | N52º19`42.5`` E17º24`23.9`` | 40 | Fortified settlement, castle? | LM; II | Ruderal habitats, groups of trees |
| Feldberg (Mecklenburg-Vorpommern, Germany) | N53º21`18.7`` E13º27`07.3`` | 4 | Concave settlement | 6th-9th c.; III | Beech forest |
| Gołczewo (Pomorskie, Poland) | N54º12`09.1`` E17º37`55.3`` | 10 | Concave settlement | 9th c.; II | Beech forest |
| Gostyń (Dolnośląskie, Poland) | N51º38`54.3`` E15º52`57.6`` | 79 | Concave settlement | 7th-8th c.; I | Deciduous forest |
| Gościszów (Dolnośląskie, Poland) | N51º09`40.8`` E15º27`15.0`` | 83 | Castle | 13th-19th c.; I | Castle ruins, ruderal habitats |
| Grąbczyn (Zachodniopomorskie, Poland) | N53º51`50.5`` E16º38`20.6`` | 16 | Concave settlement | 9th-11th c.; III | Dry grassland, deciduous forest |
| Grodzisk (Mazowieckie, Poland) | N52º09`45.4`` E21º52`24.7`` | 76 | Concave settlement | 11th c.; III | Dry grassland, shrubland, field |
| Grodziszczany (Podlaskie, Poland) | N53º37`38.2`` E23º24`42.7`` | 65 | Concave settlement | 10th-13th c.; I | Dry grassland, ruderal habitats |
| Grodziszcze (Dolnośląskie, Poland) | N51º33`27.1`` E16º12`48.5`` | 82 | Concave settlement | 9th-12th c.; II | Shrubland |
| Gross Raden (Mecklenburg-Vorpommern, Germany) | N53º44`07.7`` E11º52`36.7`` | 1 | Concave settlement | 8th c., III | Dry grassland, meadow, ruderal habitats |
| Haćki (Podlaskie, Poland) | N52º49`58.9`` E23º10`54.3`` | 67 | Concave settlement | La Tène period -EM; II | Dry grassland |
| Izdebno (Kujawsko-pomorskie, Poland) | N52º44`57.2`` E17º37`52.3`` | 30 | Concave settlement, cone-shaped | Lus., 10th-14th c.; III | Meadow, groups of trees |
| Jaguszewice (Kujawsko-pomorskie, Poland) | N53º22`36.4`` E19º08`55.0`` | 53 | Concave settlement | 10th-12th c.; II | Dry grassland, shrubland |

| Site (province, country) | Geographical location (GPS) | Number in Fig. 3 | Site type | Chronology; size class | Dominant habitats |
|---|---|---|---|---|---|
| Jamno (Pomorskie, Poland) | N54º12`12.0`` E17º37`47.9`` | 11 | Concave settlement | $8^{th}$-$9^{th}$ c.; I | Arable field |
| Janowo) (Wielkopolskie, Poland) | N52º22`06.4`` E18º04`54.9`` | 42 | Concave and cone-shaped settlement | Lus., $13^{th}$-$14^{th}$ c.; III | Dry grassland, groups of trees |
| Jarantów (Wielkopolskie, Poland) | N51º56`39.1`` E18º03`59.6`` | 49 | Concave settlement | $10^{th}$-$11^{th}$ c.; II | Pine forest |
| Jeżewo (Wielkopolskie, Poland) | N51º57`14.7`` E17º10`29.5`` | 48 | Cone-shaped settlement | $11^{th}$-$14^{th}$ c.; I | Deciduous forest |
| Kałdus (Kujawsko-pomorskie, Poland) | N53º02`40.3`` E18º22`57.2`` | 52 | Concave settlement | $10^{th}$-$13^{th}$ c.; LM; III | Dry grassland, shrubland, ruderal habitats |
| Kczewo (Pomorskie, Poland) | N54º20`56.6`` E16º51`45.5`` | 7 | Concave settlement | $7^{th}$-$9^{th}$ c.; II | Deciduous forest |
| Kłonice (Dolnośląskie, Poland) | N50º59`44.8`` E16º07`55.8`` | 93 | Cone-shaped settlement? | Medieval, I | Forest, ruderal habitats |
| Kociałkowa Górka (Wielkopolskie, Poland) | N52º26`36.3`` E17º17`45.6`` | 39 | Concave settlement | $7^{th}$-$11^{th}$ c.; II | Deciduous forest |
| Koło (Wielkopolskie, Poland) | N52º11`51.9`` E18º36`28.8`` | 43 | Castle | $14^{th}$-$18^{th}$ c., III | Castle ruins, ruderal habitats |
| Kórnik (Wielkopolskie, Poland) | N52º13`37.2`` E17º06`04.8`` | 38 | Concave settlement (beside cone-shaped) | $10^{th}$-$14^{th}$ c.; III | Dry grassland, field, meadow, ruderal habitats |
| Krobia (Wielkopolskie, Poland) | N51º46`31.2`` E16º59`11.4`` | 46 | Castle | $14^{th}$/$15^{th}$-$18^{th}$ c.; II | Partly built-up, ruderal habitats, groups of trees |
| Królikowo (Kujawsko-pomorskie, Poland) | N52º58`37.3`` E17º38`40.5`` | 29 | Concave settlement | $7^{th}$-$10^{th}$ c.; I | Forest |
| Kruszwica (Kujawsko-pomorskie, Poland) | N52º40`23.7`` E18º19`36.3`` | 34 | Concave settlement, castle | $9^{th}$-$17^{th}$ c.; III | Buildings, ruderal habitats |
| Krzymosze (Mazowieckie, Poland) | N52º10`32.4`` E22º28`28.1`` | 74 | Concave settlement | $13^{th}$-mid $14^{th}$ c.; III | Forest |
| Laschendorf (Mecklenburg-Vorpommern, Germany) | N53º29`02.2`` E12º26`54.0`` | 3 | Concave settlement | $11^{th}$-$13^{th}$ c.; II | Deciduous forest |
| Ląd (Wielkopolskie, Poland) | N52º11`22.4`` E17º54`11.9`` | 41 | Concave settlement | $7^{th}$-$13^{th}$ c.; III | Dry grassland, group of trees |
| Lembarg (Kujawsko-pomorskie, Poland) | N53º20`36.9`` E19º12`40.5`` | 54 | Concave settlement | $11^{th}$-$12^{th}$ c.; II | Dry grassland, shrubland |
| Marczów (Dolnośląskie, Poland) | N51º03`18.5`` E15º39`26.6`` | 84 | Concave settlement | EM, $13^{th}$? c.; II | Deciduous forest |
| Mietlica (Kujawsko-pomorskie, Poland) | N52º32`28.4`` E18º22`52.6`` | 35 | Concave settlement | $10^{th}$-$13^{th}$ c.; II | Dry grassland, field, groups of trees |
| Międzyrzecz (Lubuskie, Poland) | N52º26`42.3`` E15º34`21.3`` | 19 | Concave settlement, castle | $9^{th}$-$17^{th}$ c.; II | castle walls, ruderal habitats, moat |
| Mirów (Śląskie, Poland) | N50º36`50.4`` E19º28`08.2`` | 103 | Castle | $14^{th}$-$17^{th}$ c.; II | Ruins, ruderal habitats, dry grassland |
| Myślibórz (Dolnośląskie, Poland) | N51º01`11.8`` E16º06`51.9`` | 90 | Concave settlement | $14^{th}$-$15^{th}$ c.; II | Deciduous forest |
| Myślibórz I (Dolnośląskie, Poland) | N51º01`18.3`` E16º07`09.6`` | 91 | Castle | $13^{th}$-$15^{th}$ c.; I | Deciduous forest |
| Myślibórz II (Dolnośląskie, Poland) | N51º01`12.7`` E16º05`59.8`` | 89 | Concave settlement | Medieval; II | Deciduous forest |
| Myślibórz III (Dolnośląskie, Poland) | N51º01`08.1`` E16º05`20.4`` | 88 | Concave settlement | EM; II | Deciduous forest |
| Napole (Kujawsko-pomorskie, Poland) | N 53º08`46.5`` E 18º57`03.7`` | 56 | Concave settlement | $10^{th}$-$14^{th}$ c.; II | Dry grassland |
| Niepart (Wielkopolskie, Poland) | N51º42`34.6`` E17º00`25.1`` | 47 | Concave settlement | $10^{th}$-$11^{th}$ c.; II | Dry grassland, groups of trees |
| Niesulice (Lubuskie, Poland) | N52º13`38.5`` N15º24`17.8`` | 22 | Concave settlement | $7^{th}$-$8^{th}$, $11^{th}$-$15^{th}$ c.; III | Beech forest |
| Niewęgłosz (Lubelskie, Poland) | N51º42`47.6`` E22º40`20.4`` | 107 | Concave settlement | $10^{th}$-$12^{th}$ c.; II | Dry grassland |

| Site (province, country) | Geographical location (GPS) | Number in Fig. 3 | Site type | Chronology; size class | Dominant habitats |
|---|---|---|---|---|---|
| Obiszów 1 (Dolnośląskie, Poland) | N51º34`14.0`` E16º06`39.4`` | 81 | Concave settlement | EM; II | Deciduous forest, dry grassland |
| Obrzycko (Wielkopolskie, Poland) | N52º42`34.3`` E16º31`07.3`` | 25 | Cone-shaped settlement | 13th-? c.; I | Dry grassland |
| Ociąż (Wielkopolskie, Poland) | N51º43`02.4`` E17º56`33.2`` | 51 | Concave settlement | 10th-11th c.; III | Dry grassland, forest |
| Odrzykoń (Podkarpackie, Poland) | N49º44`32.9`` E21º47`10.6`` | 109 | Fortified settlement, castle | 14th-18th c.; II | Ruins, ruderal habitats, shrubland |
| Olsztyn (Śląskie, Poland) | N50º44`53.8`` E19º16`22.4`` | 101 | Castle | 13th-17th c.; III | Ruins, dry grassland, ruderal habitats |
| Ostrężnik (Śląskie, Poland) | N50º40`09.1`` E19º23`28.2`` | 102 | Castle | 14th-? c.; II | Ruins, deciduous forest |
| Ostroróg (Wielkopolskie, Poland) | N52º37`27.3`` E16º27`03.0`` | 26 | Concave settlement, castle | 9th-10th, 14th-16th c.; I | Dry grassland, ruderal habitats |
| Ostrowiec (Zachodniopomorskie, Poland) | N54º16`52.7`` E16º40`55.4`` | 13 | Concave settlement | 8th-10th c.; III | Beech forest |
| Ostrowo near Gniewkowo (Kujawsko-pomorskie, Poland) | N52º51`30.4`` E18º22`18.3`` | 33 | Concave settlement | 7th-10th c.; I | Dry grassland |
| Piersko (Wielkopolskie, Poland) | N52º30`30.4`` E16º29`25.7`` | 27 | Cone-shaped settlement on island | 13th-15th c.; III | Forest, meadow, emergent vegetation |
| Podzamcze (Ogrodzieniec) (Śląskie, Poland) | N50º27`10.1`` E19º33`12.4`` | 104 | Fortified settlement, castle | 14th-19th c.; III | Ruins, dry grassland, ruderal habitats, shrubland |
| Pokutice (Ústecký, Czech Republic) | N50º22`00.4`` E13º14`42.5`` | 96 | Concave settlement | Medieval; III | Forest, dry grassland, shrubland, pond |
| Połęcko (Lubuskie, Poland) | N52º03`17.2`` N14º53`35.4`` | 17 | Cone-shaped settlement | LM; I | Shrubland, dry grassland |
| Przedmoście (Dolnośląskie, Poland) | N51º38`12.9`` E16º11`13.7`` | 80 | Concave settlement | 8th-12th c.; III | Field, dry grassland |
| Przytok (Lubuskie, Poland) | N51º57`33.6`` N15º37`35.2`` | 44 | Concave settlement | Medieval, I | Dry grassland, ruderal habitats |
| Pszczew 1 (Lubuskie, Poland) | N52º28`58.7`` E15º46`36.2`` | 20 | Cone-shaped settlement | 14th-15th c.; I | Shrubland, ruderal habitats |
| Radacz (Zachodniopomorskie, Poland) | N53º43`10.9`` E16º32`53.4`` | 14 | Concave settlement | 7th-11th c.; II | Dry grassland, forest |
| Radłówka (Dolnośląskie, Poland) | N51º07`19.6`` E15º32`46.0`` | 85 | Castle | 16th-18th c.; I | Ruins, ruderal habitats |
| Radyně (Plzeňský, Czech Republic) | N49º40`51.7`` N13º27`53.6`` | 100 | Castle | 14th-16th c.; II | Ruins, ruderal habitats, shrubland |
| Rubín (Ústecký, Czech Republic) | N50º15`15.5`` E13º26`19.0`` | 97 | Concave settlement | Medieval; III | Dry grassland, shrubland, forest |
| Rząsiny (Dolnośląskie, Poland) | N51º05`02.9`` E15º27`33.3`` | 86 | Castle | 13th-16th c.; II | Groups of trees |
| Sambory (Podlaskie, Poland) | N53º13`10.8`` E22º25`36.2`` | 59 | Concave settlement | 11th-14th? c.; I | Dry grassland |
| Sampława (Warmińsko-mazurskie, Poland) | N53º30`07.0`` E19º40`28.0`` | 57 | Cone-shaped settlement | 14th-15th c.; I | Dry grassland, shrubland |
| Santok (Lubuskie, Poland) | N52º44`01.8`` N15º24`02.6`` | 18 | Concave settlement, cone-shaped | 7th-11th, 13th-14th c.; III | Ruderal habitats, shrubland |
| Siedmica (Dolnośląskie, Poland) | N50º59`55.9`` E16º05`51.2`` | 95 | Concave settlement | Medieval, II | Forest |
| Skąpe (Lubuskie, Poland) | N52º10`08.3`` N15º27`50.2`` | 23 | Concave settlement | 9th-10th c.; II | Meadow, dry grassland |
| Sławsko (Zachodniopomorskie, Poland) | N54º23`13.9`` E16º42`50.6`` | 6 | Concave settlement | 11th-14th c.; III | Meadow |
| Smuszewo 1 (Wielkopolskie, Poland) | N52º53`21.2`` E17º24`05.0`` | 28 | Concave settlement | 9th-11th c.; I | Dry grassland |
| Stara Łomża (Podlaskie, Poland) | N53º09`15.3`` E22º07`16.4`` | 58 | Concave settlement | 11th-13th c.; III | Dry grassland |

| Site (province, country) | Geographical location (GPS) | Number in Fig. 3 | Site type | Chronology; size class | Dominant habitats |
|---|---|---|---|---|---|
| Stara Warka (Mazowieckie, Poland) | N51º47`55.5`` E21º14`23.5`` | 72 | Concave settlement | 11th-12th c.; I | Dry grassland |
| Stary Kraków (Zachodniopomorskie, Poland) | N54º26`16.6`` E16º35`42.1`` | 5 | Fortified settlement with transverse ridge? | EM-LM; III | Beech forest |
| Starý Plzenec (Plzeňský, Czech Republic) | N49º42`13.7`` E13º28`28.5`` | 99 | Concave settlement | 8th-13th c., III | Dry grassland, forest, ruderal habitats |
| Stęszew (Wielkopolskie, Poland) | N52º16`36.0`` E16º42`08.8`` | 36 | Castle | 14th-17th c.; III | Dry grassland, railway tracks |
| Stradów (Świętokrzyskie, Poland) | N50º22`26.7`` E20º28`46.4`` | 105 | Concave settlement | 9th-11th c.; III | Dry grassland, meadow |
| Sycewice (Pomorskie, Poland) | N54º24`46.6`` E16º52`44.5`` | 8 | Concave settlement | 9th-10th c.; II | Beech forest |
| Szarlej Zagople (Kujawsko-pomorskie, Poland) | N52º42`57.3`` E18º18`28.2`` | 32 | Cone-shaped settlement | 14th-15th c.; I | Dry grassland, groups of trees |
| Teterow (Mecklenburg-Vorpommern, Germany) | N53º47`22.6`` E12º35`52.3`` | 2 | Concave settlement | 9th-12th c.; III | Forest, dry grassland, meadow, ruderal habitats |
| Topola Wielka (Wielkopolskie, Poland) | N51º35`25.2`` E17º44`37.0`` | 50 | Concave settlement | 10th-11th c.; II | Meadow, dry grassland |
| Trzciel (Lubuskie, Poland) | N52º22`20.6`` N15º52`25.2`` | 21 | Cone-shaped settlement | 13th-17th c.; II | Forest |
| Tum (Łódzkie, Poland) | N52º03`22.5`` E19º13`57.9`` | 69 | Concave settlement | 8th-13th c.; III | Dry grassland |
| Tykocin (Podlaskie, Poland) | N53º11`34.1`` E22º46`34.4`` | 63 | Concave settlement | 11th-14th c.; II | Ruderal habitat |
| Tykocin (Podlaskie, Poland) | N53º12`46.0`` E22º46`16.1`` | 62 | Castle | 14th-18th c.; II | Ruins, ruderal habitats |
| Vladař (Karlovy Vary Czech Republic) | N50º04`42.1`` E13º12`50.0`` | 98 | Concave settlement | La Tène period, Bronze Age, Roman period, Medieval; III | Dry grassland, forest, shrubland, pond with *Sphagnum* mat |
| Wenecja (Kujawsko-pomorskie, Poland) | N52º47`51.2`` E17º44`58.9`` | 31 | Castle | 14th-15th c. to modern; II | Ruins, ruderal habitats |
| Wiatrowo (Pomorskie, Poland) | N54º33`25.1`` E17º17`09.1`` | 9 | Concave settlement | 8th-9th c.; II | Deciduous forest |
| Wierzchowo (Zachodniopomorskie, Poland) | N53º52`05.1`` E16º36`43.0`` | 15 | Cone-shaped settlement | 8th-11th c., LM, II | Deciduous forest, dry grassland |
| Wiślica (Świętokrzyskie, Poland) | N50º20`41.7`` E20º40`41.1`` | 106 | Concave settlement | 10th-13th c.; III | Dry grassland, meadow |
| Wizna (Podlaskie, Poland) | N53º11`16.2`` E22º22`53.3`` | 60 | Concave settlement | 11th-13th c.; III | Pasture, ruderal habitat |
| Wleń (Dolnośląskie, Poland) | N51º01`03.4`` E15º39`45.4`` | 87 | Concave settlement, castle | 10th-13th c., to 18th c.; II | Castle ruins, ruderal habitats |
| Wojnowice (Wielkopolskie, Poland) | N51º56`48.3`` E16º43`39.7`` | 45 | Concave settlement | LM?; I | Groups of trees dry grassland |
| Wrześnica (Zachodniopomorskie, Poland) | N54º24`50.2`` E16º44`26.1`` | 12 | Concave settlement | 9th-11th c.; III | Dry grassland, shrubland |
| Zamczysk (Podlaskie, Poland) | N53º21`15.1`` E23º10`32.6`` | 64 | Concave settlement | EM?; I | Dry grassland |

Explanations: EM – early medieval (600-1250 AD), LM – late medieval (1250-1500 AD), Lus. – Lusatian culture (1300-400 BC), Mig. – Migration Period (300-700 AD); I – small (≤ 0.25 ha), II – medium-sized (0.26-1.00 ha), III – large (> 1.00 ha)

**Appendix 2.** List of Baltic, Teutonic, and East Slavic archaeological sites included in this study

| Site (province, country) | Geographical location (GPS) | User | Site type | Chronology; size class | Dominant habitats |
|---|---|---|---|---|---|
| Boże (Warmińsko-mazurskie, Poland) | N53º57`21.9`` E21º22`06.3`` | B | Concave settlement | 10th-12th c.; I | Dry grassland, field |
| Grodzisko (Warmińsko-mazurskie, Poland) | N54º11`44.2`` E22º01`01.4`` | B | Concave settlement | Mig.-EM; III | Dry grassland |
| Gubkiv (Rivne, Ukraine) | N50º49`34.1`` E27º02`42.2`` | ES | Fortified settlement, castle | 10th-13th, 15th-17th c.; II | Ruins, dry grassland, ruderal habitats, shrubland |
| Jegliniec (Podlaskie, Poland) | N54º18`31.0`` E23º08`12.5`` | B | Concave settlement | 10th-13th c.; II | Deciduous forest, dry grassland |
| Kiev (Kiev City Municipality, Ukraine) | N50º27`35.9`` E30º30`48.9`` | ES | Concave settlement | EM, II | Dry grassland, shrubland, ruderal habitats |
| Kolniszki (Warmińsko-mazurskie, Poland) | N54º16`18.9`` E22º22`51.5`` | B | Cone-shaped settlement | EM; I | Shrubland |
| Konikowo (Warmińsko-mazurskie, Poland) | N54º16`51.3`` E22º17`50.3`` | B | Concave settlement | EM (to 11th c.); I | Deciduous forest |
| Korets (Rivne, Ukraine) | N50º37`00.7`` E27º09`28.1`` | ES | Castle | 16th-19th c., II | Ruins, ruderal habitats |
| Kowalewo Pomorskie (Kujawsko-pomorskie, Poland) | N53º09`22.7`` E18º53`52.8`` | TC | Teutonic castle | 13th-18th c.; II | Ruins, ruderal habitats |
| Kurzętnik (Warmińsko-mazurskie, Poland) | N53º23`47.6`` E19º34`37.6`` | TC | Teutonic castle | 13th-18th c.; II | Ruins, ruderal habitats, forest |
| Mieruniszki (Podlaskie, Poland) | N54º08`53.1`` E22º34`02.4`` | B | Cone-shaped settlement | EM 13th? c.; II | Dry grassland |
| Nielbark (Warmińsko-mazurskie, Poland) | N53º22`00.6`` E19º34`34.5`` | B | Concave settlement | EM (to 13th c.); I | Dry grassland |
| Papowo Biskupie (Kujawsko-pomorskie, Poland) | N53º15`06.5`` E18º33`51.3`` | TC | Teutonic castle | 13th-18th c.; I | Ruins, ruderal habitats |
| Pokrzywno (Kujawsko-pomorskie, Poland) | N53º26`10.2`` E18º51`01.9`` | TC | Teutonic castle | 13th-18th c.; III | Ruins, ruderal habitats, forest |
| Radzyń Chełmiński (Kujawsko-pomorskie, Poland) | N53º23`16.7`` E18º56`07.1`` | TC | Teutonic castle | 13th-18th c.; II | Ruins, ruderal habitats |
| Rajgród (Podlaskie, Poland) | N53º44`00.2`` E22º41`10.1`` | B | Concave settlement | Mig., 10th-14th, 16th-17th c.; III | Shrubland, ruderal habitats |
| Remieńkiń (Podlaskie, Poland) | N54º07`11.1`` E23º08`44.2`` | B? | Fortified settlement with transverse ridge? | Bronze Age; I | Dry grassland |
| Szurpiły (Podlaskie, Poland) | N54º14`02.1`` E22º53`02.6`` | B | Concave settlement | 2nd c. BC -13th c.; III | Dry grassland, deciduous forest |
| Wąbrzeźno (Kujawsko-pomorskie, Poland) | N53º17`00.5`` E18º56`18.8`` | TC | Teutonic castle | 14th-17th c.; II | Ruins, ruderal habitats, forest |
| Wyszembork (Warmińsko-mazurskie, Poland) | N53º55`39.1`` E21º19`44.1`` | B | Cone-shaped settlement? | EM; I | Shrubland, dry grassland |
| Zyndaki (Warmińsko-mazurskie, Poland) | N53º54`50.1`` E21º10`12.4`` | B | Cone-shaped settlement? | EM; I | Dry grassland |

Explanations: B – Baltic tribes (Yotvingians, Old Prussians), ES – East Slavs, TC – Teutonic knights; EM – early medieval (600-1250 AD); Mig. – Migration Period (300-700 AD); I – small (≤ 0.25 ha), II – medium-sized (0.26-1.00 ha), III – large (> 1.00 ha)

**Appendix 3.** Alphabetic list of species found at West Slavic archaeological sites. Each species name is followed by abbreviations of geographical-historical group (see Fig. 14), Raunkiaer life-form (see Fig. 16), socio-ecological group (see section 4.3.4), number of sites, frequency class (see Table 1), mean abundance (see section 4.2), and rarity coefficient (see section 4.3.6). * – species of old deciduous forests (see section 4.3.7)

*Abies alba* Mill. – Sn, Ph, G9, 2, RRR, 1.0, 0.98; *Acer campestre* L. – Ap, Ph, G12, 10, R, 1.6, 0.91; *Acer negundo* L. – Kn, Ph, G10, 7, R, 1.1, 0.94; *Acer platanoides* L. – Ap, Ph, G12, 47, FF, 1.3, 0.57; *Acer pseudoplatanus* L. – Ap, Ph, G12, 40, FF, 1.3, 0.63; *Achillea millefolium* L. s. str. – Ap, H, G5, 76, C, 2.0, 0.30; *Achillea pannonica* Scheele – Sn, H, G6, 9, R, 1.4, 0.92; *Achillea ptarmica* L. – Sn, H, G5, 2, RRR, 1.5, 0.98; *Achillea salicifolia* Besser – Sn, H, G10, 1, RRR, 1.0, 0.99; *Acinos arvensis* (Lam.) Dandy – Ap, H, G6, 14, R, 1.9, 0.87; *Acorus calamus* L. – Kn, Hy, G4, 7, R, 1.3, 0.94; *Actaea spicata* L.* – Sn, H, G12, 5, RR, 1.0, 0.95; *Adonis aestivalis* L. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Adoxa moschatellina* L.* – Sn, G, G12, 16, F, 2.0, 0.85; *Aegopodium podagraria* L.* Ap, G, G11, 46, FF, 1.8, 0.58; *Aesculus hippocastanum* L. – Kn, Ph, G16, 11, R, 1.1, 0.90; *Aethusa cynapium* L. – Ap, Th, G14, 9, R, 1.3, 0.92; *Agrimonia eupatoria* L. – Ap, H, G7, 32, FF, 1.4, 0.71; *Agrostemma githago* L. – Ar, Th, G13, 3, RR, 1.0, 0.97; *Agrostis canina* L. s. str. – Sn, H, G2, 1, RRR, 2.0, 0.99; *Agrostis capillaris* L. – Ap, H, G6, 51, FF, 2.2, 0.53; *Agrostis gigantea* Roth – Ap, H, G5, 34, FF, 1.3, 0.69; *Agrostis stolonifera* L. – Ap, H, G5, 8, R, 1.8, 0.93; *Agrostis vinealis* Schreb. – Sn, H, G6, 2, RRR, 1.5, 0.98; *Ajuga genevensis* L. – Sn, H, G6, 9, R, 1.3, 0.92; *Ajuga reptans* L.* – Sn, H, G12, 11, R, 1.3, 0.90; *Alchemilla* cfr *monticola* Opiz – Sn, H, G5, 7, R, 1.0, 0.94; *Alisma plantago-aquatica* L. – Ap, Hy, G4, 10, R, 1.2, 0.91; *Alliaria petiolata* (M. Bieb.) Cavara & Grande – Ap, H, G12, 30, F, 1.7, 0.72; *Allium angulosum* L. – Sn, G, G5, 1, RRR, 1.0, 0.99; *Allium montanum* F. W. Schmidt – Sn, G, G6, 1, RRR, 3.0, 0.99; *Allium oleraceum* L. – Ap, G, G6, 25, F, 1.2, 0.77; *Allium scorodoprasum* L. – Ar, G, G12, 7, R, 2.1, 0.94; *Allium ursinum* L.* – Sn, G, G11, 2, RRR, 1.5, 0.98; *Allium vineale* L. – Ap, G, G6, 10, R, 1.0, 0.91; *Alnus glutinosa* (L.) Gaertn. – Ap, Ph, G11, 28, F, 1.3, 0.74; *Alnus incana* (L.) Moench – Sn, Ph, G12, 1, RRR, 1.0, 0.99; *Alopecurus geniculatus* L. – Ap, H, G5, 9, R, 2.1, 0.92; *Alopecurus pratensis* L. – Ap, H, G5, 32, FF, 2.0, 0.71; *Alyssum alyssoides* (L.) L. – Ap, Th, G6, 2, RRR, 1.5, 0.98; *Alyssum montanum* L. – Ap, Ch, G6, 2, RRR, 1.5, 0.98; *Amaranthus chlorostachys* Willd. – Kn, Th, G13, 1, RRR, 1.0, 0.99; *Amaranthus retroflexus* L. – Kn, Th, G13, 6, RR, 1.0, 0.94; *Anagallis arvensis* L. – Ar, Th, G13, 3, RR, 1.0, 0.97; *Anchusa arvensis* (L.) M. Bieb. – Ar, Th, G13, 4, RR, 1.0, 0.96; *Anchusa officinalis* L. – Ar, H, G14, 27, F, 1.4, 0.75; *Androsace septentrionalis* L. – Sn, Th, G6, 1, RRR, 1.0, 0.99; *Anemone nemorosa* L.* – Sn, G, G12, 20, F, 1.7, 0.82; *Anemone ranunculoides* L.* – Sn, G, G12, 8, R, 1.3, 0.93; *Anemone sylvestris* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Angelica archangelica* L. – Ap, H, G5, 1, RRR, 1.0, 0.99; *Angelica sylvestris* L. – Sn, H, G12, 12, R, 1.2, 0.89; *Anthemis arvensis* L. – Ar, Th, G13, 4, RR, 1.0, 0.96; *Anthemis tinctoria* L. – Ar, H, G6, 2, RRR, 1.5, 0.98; *Anthericum ramosum* L. – Sn, G, G7, 3, RR, 1.3, 0.97; *Anthoxanthum odoratum* L. s. str. – Ap, H, G5, 14, R, 2.2, 0.87; *Anthriscus cerefolium* (L.) Hoffm. – Ar, Th, G14, 1, RRR, 1.0, 0.99; *Anthriscus sylvestris* (L.) Hoffm. – Ap, H, G12, 63, C, 1.3, 0.42; *Anthyllis vulneraria* L. – Sn, H, G6, 7, R, 1.5, 0.94; *Apera spica-venti* (L.) P. Beauv. – Ar, Th, G13, 13, R, 1.0, 0.88; *Aphanes arvensis* L. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Arabidopsis thaliana* (L.) Heynh. – Ap, Th, G13, 3, RR, 1.3, 0.97; *Arabis glabra* (L.) Bernh. – Sn, H, G6, 24, F, 1.3, 0.78; *Arabis hirsuta* (L.) Scop. – Sn, H, G6, 2, RRR, 1.0, 0.98; *Arctium lappa* L. – Ap, H, G14, 6, RR, 1.0, 0.94; *Arctium minus* (Hill) Bernh. – Ap, H, G14, 7, R, 1.0, 0.94; *Arctium tomentosum* Mill. – Ap, H, G14, 31, FF, 1.1, 0.72; *Arenaria serpyllifolia* L. – Ap, Th, G6, 24, F, 1.9, 0.78; *Armeria maritima* (Mill.) Willd. subsp. *elongata* (Hoffm.) Bonnier – Ap, H, G6, 17, F, 1.4, 0.84; *Armoracia rusticana* P. Gaertn., B. Mey. & Scherb. – Ar, G, G14, 14, R, 1.1, 0.87; *Arnoseris minima* (L.) Schweigg. & Körte – Ap, Th, G13, 1, RRR, 1.0, 0.99; *Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl – Ap, H, G5, 54, FF, 2.0, 0.50; *Artemisia absinthium* L. – Ar, Ch, G14, 17, F, 1.1, 0.84; *Artemisia campestris* L. subsp. *campestris* – Ap, Ch, G6, 29, F, 1.6, 0.73; *Artemisia vulgaris* L. – Ap, H, G14, 65, C, 1.5, 0.40; *Asarum europaeum* L.* – Sn, H, G11, 8, R, 1.8, 0.93; *Asparagus officinalis* L. – Ap, G, G6, 11, R, 1.1, 0.90; *Asperugo procumbens* L. – Ar, Th, G14, 1, RRR, 1.0, 0.99; *Asperula cynanchica* L. – Sn, H, G6, 1, RRR, 2.0, 0.99; *Asperula tinctoria* L. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Asplenium ruta-muraria* L. – Ap, H, G15, 10, R, 2.1, 0.91; *Asplenium trichomanes* L. – Ap, H, G15, 7, R, 1.3, 0.94; *Astragalus cicer* L. – Ap, H, G7, 13, R, 1.6, 0.88; *Astragalus glycyphyllos* L. – Ap, H, G7, 30, F, 1.4, 0.72; *Athyrium filix-femina* (L.) Roth* – Sn, H, G9, 2, RRR, 1.0, 0.98; *Atriplex hortensis* L. – Ef, Th, G14, 1, RRR, 1.0, 0.99; *Atriplex nitens* Schkuhr – Ar, Th, G14, 3, RR, 1.3, 0.97; *Atriplex patula* L. – Ap, Th, G14, 17, F, 1.2, 0.84; *Atriplex prostrata* Boucher ex DC. subsp. *prostrata* – Ap, Th, G3, 3, RR, 1.0, 0.97; *Avena fatua* L. – Ar, Th, G13, 5, RR, 1.1, 0.95; *Avena sativa* L. – Ef, Th, G16, 2, RRR, 1.0, 0.98; *Avenula pratensis* (L.) Dumort. – Sn, H, G6, 2, RRR, 2.0, 0.98; *Avenula pubescens* (Huds.) Dumort. – Ap, H, G5, 16, F, 1.6, 0.85; *Ballota nigra* L. – Ar, Ch, G14, 44, FF, 1.4, 0.60; *Barbarea stricta* Andrz. – Sn, H, G10, 2, RRR, 1.0, 0.98; *Barbarea vulgaris* R. Br. – Sn, H, G10, 1, RRR, 1.0, 0.99; *Batrachium trichophyllum* (Chaix) Bosch – Sn, Hy, G1, 1, RRR, 2.0, 0.99; *Bellis perennis* L. – Ap, H, G5, 12, R, 1.8, 0.89; *Berberis vulgaris* L. – Sn, Ph, G7, 5, RR, 1.0, 0.95; *Berteroa incana* (L.) DC. – Ar, H, G14, 19, F, 1.4, 0.83; *Betonica officinalis* L. – Sn, H, G6, 6, RR, 1.0, 0.94; *Betula pendula* Roth – Ap, Ph, G9, 41, FF, 1.1, 0.62; *Betula pubescens* Ehrh. subsp. *pubescens* – Sn, Ph, G11, 4, RR, 1.0, 0.96; *Bidens cernua* L. – Sn, Th, G3, 3, RR, 1.0, 0.97; *Bidens frondosa* L. – Kn, Th, G3, 5, RR, 1.1, 0.95; *Bidens tripartita* L. – Ap, Th, G3, 8, R, 1.1, 0.93; *Bolboschoenus maritimus* (L.) Palla – Sn, G, G4, 1, RRR, 2.0, 0.99; *Bothriochloa ischaemum* (L.) Keng. – Sn, H, G6, 1, RRR, 2.0, 0.99; *Botrychium multifidum* (S. G. Gmel.) Rupr. – Sn, G, G12, 1, RRR, -, 0.99; *Brachypodium pinnatum* (L.) P. Beauv. – Sn, H, G6, 5, RR, 1.2, 0.95; *Brachypodium sylvaticum* (Huds.) P. Beauv.* – Sn, H, G12, 12, R, 1.4, 0.89; *Brassica napus* L. subsp. *napus* – Ef, Th, G16, 2, RRR, 1.0, 0.98; *Briza media* L. – Sn, H, G5, 16, F, 1.6, 0.85; *Bromus benekenii* (Lange) Trimen* – Sn, H, G12, 3, RR, 1.0, 0.97; *Bromus carinatus* Hook. & Arn. – Kn, Th, G14, 3, RR, 1.0, 0.97; *Bromus hordeaceus* L. – Ap, Th, G14, 13, R, 1.9, 0.88; *Bromus inermis* Leyss. – Ap, H, G6, 40, FF, 2.3, 0.63; *Bromus secalinus* L. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Bromus sterilis* L. – Ar, Th, G14, 11, R, 1.8, 0.90; *Bromus tectorum* L. – Ar, Th, G14, 13, R, 1.6, 0.88; *Bryonia alba* L. – Kn, H, G14, 5, RR, 1.0, 0.95; *Bunias orientalis* L. – Ar, H, G14, 2, RRR, 2.3, 0.98; *Butomus umbellatus* L. – Sn, Hy, G4, 2, RRR, 1.3, 0.98; *Calamagrostis arundinacea* (L.) Roth – Sn, H, G9, 9, R, 1.8, 0.92; *Calamagrostis epigejos* (L.) Roth – Ap, G, G8, 47, FF, 2.1, 0.57; *Calamagrostis villosa* (Chaix) J. F. Gmel. – Sn, H, G9, 1, RRR, 2.0, 0.99; *Calla palustris* L. – Sn, Hy, G4, 1, RRR, 2.0, 0.99; *Callitriche cophocarpa* Sendtn. – Sn, Hy, G1, 1, RRR, 1.0, 0.99; *Calluna vulgaris* (L.) Hull – Sn, Ch, G9, 2, RRR, 1.0, 0.98; *Caltha palustris* L. subsp. *palustris* – Sn, H, G5, 12, R, 1.1, 0.89; *Calystegia sepium* (L.) R. Br. – Ap, G, G10, 14, R, 1.2, 0.87; *Camelina microcarpa* Andrz. subsp. *sylvestris* (Wallr.) Hiitonen – Ar, Th, G6, 9, R, 1.1, 0.92; *Camelina sativa* (L.) Crantz – Ar, Th, G14, 1, RRR, 1.0, 0.99; *Campanula bononiensis* L. – Sn, H, G6, 3, RR, 1.0, 0.97; *Campanula glomerata* L. – Sn, H, G6, 14, R, 1.4, 0.87; *Campanula latifolia* L.* – Ap, H, G12, 3, RR, 1.8, 0.97; *Campanula patula* L. s. str. – Sn, H, G5, 13, R, 1.4, 0.88; *Campanula persicifolia* L. – Sn, H, G12, 19, F, 1.3, 0.83; *Campanula rapunculoides* L. – Ap, H, G7, 28, F, 1.6, 0.74; *Campanula rotundifolia* L. – Sn, H, G8, 19, F, 1.5, 0.83; *Campanula trachelium* L.* – Sn, H, G12, 17, F, 1.1, 0.84; *Cannabis ruderalis* Janisch. – Kn, Th, G14, 2, RRR, 1.0, 0.98; *Cannabis sativa* L. – Kn, Th, G16, 3, RR, 1.4, 0.97; *Capsella bursa-pastoris* (L.) Medik. – Ar, H, G14, 30, F, 1.5, 0.72; *Caragana arborescens* Lam. – Ef, Ph, G16, 2, RRR, 1.5, 0.98; *Cardamine amara* L. subsp. *amara* – Sn, H, G1, 3, RR, 2.0, 0.97; *Cardamine impatiens* L. – Sn, H, G12, 1, RRR, 1.0, 0.99; *Cardamine pratensis* L. s. str. – Sn, H, G5, 3, RR, 1.6, 0.97; *Cardaminopsis arenosa* (L.) Hayek – Ap, H, G5, 11, R, 1.4, 0.90; *Cardaria draba* (L.) Desv. – Kn, G, G14, 2, RRR, 1.0, 0.98; *Carduus acanthoides* L. – Ar, H, G14, 38, FF, 1.3, 0.65; *Carduus crispus* L. – Ap, H, G10, 15, F, 1.1, 0.86; *Carduus nutans* L. – Ar, H, G14, 1, RRR, 2.0, 0.99; *Carex acutiformis* Ehrh. – Sn, G, G4, 19, F, 1.8, 0.83; *Carex caryophyllea* Latourr. – Sn, G, G6, 7, R, 1.6, 0.94; *Carex cuprina* (I. Sándor ex Heuff.) Nendtv. ex A. Kern. – Sn, H, G4, 1, RRR, 1.5, 0.99; *Carex digitata* L.* – Sn, H, G12, 5, RR, 1.2, 0.95; *Carex disticha* Huds. – Sn, G, G4, 2, RRR, 2.0, 0.98; *Carex flacca* Schreb. – Sn, G, G5, 2, RRR, 2.0, 0.98; *Carex gracilis* Curtis – Sn, G, G4, 6, RR, 1.7, 0.94; *Carex hirta* L. – Ap, G, G14, 35, FF, 2.2, 0.68; *Carex humilis* Leyss. – Sn, H, G6, 1, RRR, 2.0, 0.99; *Carex nigra* Reichard – Sn, G, G2, 2, RRR, 2.0, 0.98; *Carex ovalis* Gooden. – Ap, H, G12, 4, RR, 1.5, 0.96; *Carex pairae* F. W. Schultz – Sn, H, G8, 9, R, 1.6, 0.92; *Carex pallescens* L. – Sn, H, G12, 1, RRR, 1.0, 0.99; *Carex paniculata* L. – Sn, H, G4, 2, RRR, 1.0, 0.98; *Carex praecox* Schreb. – Sn, G, G6, 6, RR, 2.0, 0.94; *Carex pseudocyperus* L. – Sn, H, G4, 3, RR, 1.3, 0.97; *Carex remota* L.* – Sn, H, G12, 1, RRR, 2.0, 0.99; *Carex riparia* Curtis – Sn, H, G4, 1, RRR, 3.0, 0.99; *Carex spicata* Huds. – Ap, H, G8, 13, R, 1.5, 0.88; *Carex supina* Wahlenb. Sn, G, G6, 2, RRR, 1.5, 0.98; *Carex sylvatica* Huds.* – Sn, H, G12, 7, R, 1.4, 0.94; *Carex vesicaria* L. – Sn, H, G4, 2, RRR, 1.5, 0.98; *Carex vulpina* L. – Ap, G, G4, 6, RR, 1.2, 0.94; *Carlina acaulis* L. – Sn, H, G6, 2, RRR, 1.0, 0.98; *Carlina vulgaris* L. – Sn, H, G6, 3, RR, 1.3, 0.97; *Carpinus betulus* L. – Sn, Ph, G12, 28, F, 1.4, 0.74; *Carum carvi* L. – Ap, H, G5, 4, RR, 1.3, 0.96; *Centaurea cyanus* L. – Ar, Th, G13, 12, R, 1.1, 0.89; *Centaurea jacea* L. – Ap, H, G5, 20, F, 1.4, 0.82; *Centaurea scabiosa* L. – Ap, H, G6, 34, FF, 1.6, 0.69; *Centaurea stoebe* L. – Ap, H, G6, 26, F, 1.5, 0.76; *Centaurium erythraea* Rafn. subsp. *erythraea* – Sn, Th, G8, 1, RRR, 1.0, 0.99; *Cephalanthera longifolia* (L.) Fritsch* – Sn, G, G12, 1, RRR, 1.0, 0.99; *Cerastium arvense* L. s. str. – Ap, Ch, G6, 18, F, 1.8, 0.83; *Cerastium holosteoides* Fr. emend. Hyl. – Ap, Ch, G5, 34, FF, 1.9, 0.69; *Cerastium semidecandrum* L. – Ap, H, G6, 10, R, 2.1, 0.91; *Cerasus avium* (L.) Moench – Ap, Ph, G12, 18, F, 1.1, 0.83; *Cerasus fruticosa* Pall. – Sn, Ph, G7, 1, RRR, 2.0, 0.99; *Cerasus vulgaris* Mill. subsp. *vulgaris* – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Ceratophyllum demersum* L. s. str. – Sn, Hy, G1, 4, RR, 1.6, 0.96; *Cerinthe minor* L. – Ap, H, G14, 1, RRR, 1.0, 0.99; *Chaenorhinum minus* (L.) Lange – Ap, Th, G13, 4, RR, 1.4, 0.96; *Chaerophyllum aromaticum* L. – Sn, H, G12, 7, R, 1.0, 0.94; *Chaerophyllum aureum* L. – Ap, H, G14, 1, RRR, 1.0, 0.99; *Chaerophyllum bulbosum* L. – Ar, Th, G12, 6, RR, 1.7, 0.94; *Chaerophyllum temulum* L. – Ap, Th, G12, 36, FF, 1.4, 0.67; *Chamaecytisus ruthenicus* (Fisch. ex Woł.) Klásk. – Sn, Ch, G6, 1, RRR, 1.0, 0.99; *Chamaenerion angustifolium* (L.) Scop. – Ap, H, G8, 16, F, 1.3, 0.85; *Chamomilla recutita* (L.) Rauschert – Ar, Th, G13, 3, RR, 1.7, 0.97; *Chamomilla suaveolens* (Pursh) Rydb. – Kn, Th, G14, 14, R, 1.9, 0.87; *Chelidonium majus* L. – Ap, H, G12, 48, FF, 1.4, 0.56; *Chenopodium album* L. – Ap, Th, G14, 41, FF, 1.2, 0.62; *Chenopodium bonus-henricus* L. – Ar, Ch, G14, 3, RR, 1.0, 0.97; *Chenopodium hybridum* L. – Ar, Th, G14, 17, F, 1.1, 0.84; *Chenopodium polyspermum* L. – Ap, Th, G3, 7, R, 1.0, 0.94; *Chenopodium rubrum* L. – Ap, Th, G3, 1, RRR, 1.0, 0.99; *Chimaphila umbellata* (L.) W. P. C. Barton – Sn, Ch, G9, 1, RRR, 1.0, 0.99; *Chondrilla juncea* L. – Ap, H, G6, 3, RR, 2.0, 0.97; *Chrysantheum segetum* L. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Chrysosplenium alternifolium* L.* – Sn, H, G11, 1, RRR, 1.0, 0.99; *Cichorium intybus* L. subsp. *intybus* – Ar, H, G14, 16, F, 1.1, 0.85; *Cicuta virosa* L. – Sn, H, G4, 2, RRR, 1.0, 0.98; *Circaea lutetiana* L.* – Sn, G, G12, 10, R, 1.1, 0.91; *Cirsium acaule* Scop. – Sn, H, G6, 4, RR, 1.0, 0.96; *Cirsium arvense* (L.) Scop. – Ap, G, G14, 69, C, 1.4, 0.37; *Cirsium canum* (L.) All. – Sn, H, G5, 1, RRR, 1.0, 0.99; *Cirsium eriophorum* (L.) Scop. – Sn, H, G6, 3, RR, 1.0, 0.97; *Cirsium oleraceum* (L.) Scop. – Sn, H, G5, 14, R, 1.1, 0.87; *Cirsium palustre* (L.) Scop. – Sn, H, G5, 8, R, 1.1, 0.93; *Cirsium rivulare* (Jacq.) All. – Sn, H, G5, 1, RRR, 1.0, 0.99; *Cirsium vulgare* (Savi) Ten. – Ap, H, G14, 31, FF, 1.2, 0.72; *Clematis vitalba* L. – Kn, Ph, G16, 1, RRR, 1.0, 0.99; *Clinopodium vulgare* L. – Sn, H, G6, 19, F, 1.6, 0.83; *Cnidium dubium* (Schkuhr) Thell – Sn, H, G5, 2, RRR, 1.0, 0.98; *Colutea arborescens* L. – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Comarum palustre* L. – Sn, Ch, G2, 3, RR, 1.0, 0.97; *Conium maculatum* L. – Ar, Th, G14, 3, RR, 2.0, 0.97; *Consolida regalis* Gray – Ar, Th, G13, 16, F, 1.0, 0.85; *Convallaria majalis* L.* – Sn, G, G9, 20, F, 2.0, 0.82; *Convolvulus arvensis* L. – Ap, G, G14, 54, FF, 1.5, 0.50; *Conyza canadensis* (L.) Cronquist – Kn, Th, G14, 43, FF, 1.3, 0.61; *Cornus sanguinea* L. – Sn, Ph, G7, 30, F, 1.2, 0.72; *Coronilla varia* L. – Ap, H, G6, 40, FF, 1.5, 0.63; *Corydalis cava* Schweigg. & Körte* – Sn, G, G12, 6, RR, 1.3, 0.94; *Corydalis intermedia* (L.) Mérat* – Sn, G, G12, 4, RR, 1.2, 0.96; *Corydalis solida* (L.) Clairv.* – Sn, G, G12, 2, RRR, 1.0, 0.98; *Corylus avellana* L. – Sn, Ph, G12, 46, FF, 1.2, 0.58; *Corynephorus canescens* (L.) P. Beauv. – Ap, H, G6, 1, RRR, 1.0, 0.99; *Cotoneaster intergerrimus* Medik. – Sn, Ph, G7, 1, RRR, 1.0, 0.99; *Crataegus laevigata* (Poir.) DC. – Sn, Ph, G7, 8, R, 1.1, 0.93; *Crataegus ×macrocarpa* Hegetschw. – Sn, Ph, G7, 4, RR, 1.0, 0.96; *Crataegus monogyna* Jacq. – Ap, Ph, G7, 61, C, 1.1, 0.44; *Crataegus rhipidophylla* Gand. var. *rhipidophylla* – Sn, Ph, G7, 3, RR, 1.0, 0.97; *Crepis biennis* L. – Ap, H, G5, 4, RR, 1.0, 0.96; *Crepis capillaris* (L.) Wallr. – Ap, H, G5, 2, RRR, 1.0, 0.98; *Cruciata glabra* (L.) Ehrend. – Sn, H, G12, 1, RRR, 1.0, 0.99; *Cucubalus baccifer* L. – Sn, H, G10, 1, RRR, 1.0, 0.99; *Cuscuta epithymum* (L). L. s. str. – Sn, Th, G5, 3, RR, 2.0, 0.97; *Cuscuta europaea* L. subsp. *europaea* – Sn, Th, G10, 5, RR, 2.0, 0.95; *Cymbalaria muralis* P. Gaertn., B. Mey. & Scherb. – Kn, Ch, G15, 1, RRR, 1.0, 0.99; *Cynoglossum officinale* L. – Ap, H, G14, 16, F, 1.3, 0.85; *Cynosurus cristatus* L. – Ap, H, G5, 3, RR, 1.7, 0.97; *Cystopteris fragilis* (L.) Bernh. – Ap, H, G15, 6, RR, 1.3, 0.94; *Dactylis glomerata* L. subsp. *glomerata* – Ap, H, G5, 83, C, 1.8, 0.24; *Dactylis polygama* Horv.* – Sn, H, G12, 8, R, 1.4, 0.93; *Danthonia decumbens* DC. – Sn, H, G8, 2, RRR, 1.7, 0.98; *Daphne mezereum* L.* – Sn, Ph, G11, 4, RR, 1.0, 0.96; *Datura stramonium* L. – Kn, Th, G14, 1, RRR, 1.0, 0.99; *Daucus carota* L. – Ap, H, G5, 19, F, 1.4, 0.83; *Dentaria enneaphyllos* L.* – Sn, G, G12, 1, RRR, 1.0, 0.99; *Deschampsia caespitosa* (L.) P. Beauv. – Ap, H, G5, 40, FF, 1.8, 0.63; *Deschampsia flexuosa* (L.) Trin. – Sn, H, G9, 20, F, 1.9, 0.82; *Descurainia sophia* (L.) Webb ex Prantl – Ar, Th, G14, 15, F, 1.1, 0.86; *Dianthus carthusianorum* L. – Sn, Ch, G6, 14, R, 1.7, 0.87; *Dianthus deltoides* L. – Sn, Ch, G6, 11, R, 1.5, 0.90; *Dianthus superbus* Rchb. – Sn, H, G5, 2, RRR, 1.4, 0.98; *Digitalis grandiflora* Mill. – Sn, H, G12, 4, RR, 1.0, 0.96; *Digitaria ischaemum* (Schreb.) H. L. Mühl. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Diphasiastrum complanatum* (L.) Holub – Sn, Ch, G9, 1, RRR, -, 0.99; *Diplotaxis muralis* (L.) DC. – Kn, Th, G14, 1, RRR, 1.0, 0.99; *Diplotaxis tenuifolia* (L.) DC. – Kn, Ch, G14, 1, RRR, 1.0, 0.99; *Dipsacus sylvestris* Huds. – Ef, H, G16, 1, RRR, 1.0, 0.99; *Draba nemorosa* L. – Sn, Th, G6, 2, RRR, 1.5, 0.98; *Dryopteris carthusiana* (Vill.) H. P. Fuchs* – Sn, H, G12, 18, F, 1.3, 0.83; *Dryopteris dilatata* (Hoffm.) A. Gray* – Sn, H, G12, 2, RRR, 1.5, 0.98; *Dryopteris filix-mas* (L.) Schott* – Sn, H, G12, 37, FF, 1.5, 0.66; *Echinochloa crus-galli* (L.) P. Beauv. – Ar, Th, G13, 7, R, 1.4, 0.94; *Echinocystis lobata* (F. Michx.) Torr. & A. Gray – Kn, Th, G10, 2, RRR, 1.0, 0.98; *Echinops sphaerocephalus* L. – Kn, H, G14, 4, RR, 1.0, 0.96; *Echium vulgare* L. – Ap, H, G14, 26, F, 1.2, 0.76; *Eleocharis palustris* (L.) Roem. & Schult. subsp. *palustris* – Sn, Hy, G4, 6, RR, 1.8, 0.94; *Eleocharis uniglumis* (Link) Schult. – Sn, Hy, G2, 1, RRR, 1.0, 0.99; *Elodea canadensis* Michx. – Kn, Hy, G1, 3, RR, 1.0, 0.97; *Elymus caninus* (L.) L. * – Sn, H, G11, 8, R, 1.5, 0.93; *Elymus hispidus* (Opiz) Melderis subsp. *hispidus* – Sn, G, G6, 2, RRR, 2.5, 0.98; *Elymus repens* (L.) Gould – Ap, G, G14, 53, FF, 1.9, 0.51; *Epilobium ciliatum* Raf. – Kn, H, G4, 7, R, 1.0, 0.94; *Epilobium hirsutum* L. – Ap, H, G5, 22, F, 1.3, 0.80; *Epilobium montanum* L.* – Sn, H, G12, 5, RR, 1.0, 0.95; *Epilobium palustre* L. – Sn, H, G2, 3, RR, 1.0, 0.97; *Epilobium parviflorum* Schreb. – Ap, H, G4, 3, RR, 1.0, 0.97; *Epilobium roseum* Schreb. – Sn, H, G4, 3, RR, 1.3, 0.97; *Epipactis helleborine* (L.) Crantz s. str.* – Sn, G, G12, 1, RRR, 1.0, 0.99; *Equisetum arvense* L. – Ap, G, G13, 47, FF, 1.3, 0.57; *Equisetum fluviatile* L. – Sn, Hy, G4, 2, RRR, 1.5, 0.98; *Equisetum hyemale* L.* – Sn, Ch, G12, 1, RRR, 1.0, 0.99; *Equisetum palustre* L. – Sn, G, G5, 10, R, 1.2, 0.91; *Equisetum pratense*

Ehrh. – Sn, G, G12, 4, RR, 1.5, 0.96; *Equisetum sylvaticum* L.* – Sn, G, G12, 3, RR, 1.3, 0.97; *Eragrostis minor* Host. – Kn, Th, G14, 1, RRR, 1.0, 0.99; *Erigeron acris* L. – Ap, H, G6, 8, R, 1.1, 0.93; *Erigeron annuus* (L.) Pers. – Kn, H, G14, 3, RR, 1.0, 0.97; *Erodium cicutarium* (L.) L'Hér. – Ap, Th, G6, 9, R, 1.0, 0.92; *Erophila verna* (L.) Chevall. – Ap, Th, G6, 8, R, 1.3, 0.93; *Eryngium campestre* L. – Sn, H, G6, 2, RRR, 2.0, 0.98; *Eryngium planum* L. – Ap, H, G6, 3, RR, 1.7, 0.97; *Erysimum cheiranthoides* L. – Ap, Th, G14, 6, RR, 1.0, 0.94; *Erysimum crepidifolium* Rchb. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Erysimum odoratum* Ehrh. – Sn, H, G6, 2, RRR, 1.0, 0.98; *Euonymus europaea* L. – Ap, Ph, G12, 42, FF, 1.1, 0.61; *Euonymus verrucosa* Scop. – Sn, Ph, G12, 2, RRR, 1.0, 0.98; *Eupatorium cannabinum* L. – Ap, H, G5, 9, R, 1.4, 0.92; *Euphorbia cyparissias* L. – Ap, G, G6, 31, FF, 1.7, 0.72; *Euphorbia esula* L. – Ap, H, G6, 6, RR, 1.9, 0.94; *Euphorbia helioscopia* L. – Ar, Th, G13, 5, RR, 1.1, 0.95; *Euphorbia peplus* L. – Ar, Th, G13, 4, RR, 1.0, 0.96; *Euphrasia rostkoviana* Hayne – Sn, Th, G5, 3, RR, 1.0, 0.97; *Euphrasia stricta* D. Wolff ex J. F. Lehm. – Sn, Th, G6, 6, RR, 1.7, 0.94; *Fagus silvatica* L. subsp. *sylvatica* – Sn, Ph, G12, 26, F, 1.8, 0.76; *Falcaria vulgaris* Bernh. – Ap, H, G6, 9, R, 1.5, 0.92; *Fallopia convolvulus* (L.) Á. Löve – Ar, Th, G13, 20, F, 1.2, 0.82; *Fallopia dumetorum* (L.) Holub – Sn, Th, G10, 27, F, 1.2, 0.75; *Festuca arundinacea* Schreb. – Ap, H, G5, 4, RR, 1.8, 0.96; *Festuca gigantea* (L.) Vill.* – Sn, H, G12, 15, F, 1.4, 0.86; *Festuca ovina* L. s. str. – Sn, H, G9, 11, R, 1.3, 0.90; *Festuca pratensis* Huds. – Ap, H, G5, 27, F, 1.8, 0.75; *Festuca pseudovina* Hack. ex Wiesb. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Festuca rubra* L. s. str. – Ap, H, G5, 32, FF, 1.9, 0.71; *Festuca trachyphylla* (Hack.) Krajina – Sn, H, G6, 15, F, 2.0, 0.86; *Festuca valesiaca* Schleich. ex Gaudin – Sn, H, G6, 1, RRR, 3.0, 0.99; *Ficaria verna* Huds.* – Sn, G, G11, 14, R, 1.9, 0.87; *Filago arvensis* L. – Ap, Th, G13, 1, RRR, 1.0, 0.99; *Filipendula ulmaria* (L.) Maxim. – Sn, H, G5, 17, F, 1.4, 0.84; *Filipendula vulgaris* Lam. – Sn, H, G6, 14, R, 1.6, 0.87; *Fragaria ×ananassa* Duchesne – Ef, H, G16, 1, RRR, 1.0, 0.99; *Fragaria vesca* L. – Ap, H, G8, 26, F, 1.5, 0.76; *Fragaria viridis* Duchesne – Sn, H, G7, 39, FF, 2.5, 0.64; *Frangula alnus* Mill. – Sn, Ph, G11, 12, R, 1.0, 0.89; *Fraxinus excelsior* L. – Ap, Ph, G11, 52, FF, 1.1, 0.52; *Fumaria officinalis* L. subsp. *officinalis* – Ar, Th, G13, 6, RR, 1.0, 0.94; *Gagea arvensis* (Pers.) Dumort. – Ar, G, G12, 1, RRR, 1.0, 0.99; *Gagea lutea* (L.) Ker. Gawl.* – Sn, G, G12, 8, R, 1.3, 0.93; *Gagea minima* (L.) Ker. Gawl.* – Ap, G, G12, 2, RRR, 1.3, 0.98; *Gagea pratensis* (Pers.) Dumort. – Ap, G, G13, 8, R, 1.4, 0.93; *Galanthus nivalis* L.* – Sn, G, G12, 2, RRR, 1.0, 0.98; *Galeobdolon luteum* Huds. subsp. *luteum** – Sn, Ch, G12, 22, F, 1.7, 0.80; *Galeopsis bifida* Boenn. – Ap, Th, G8, 7, R, 1.2, 0.94; *Galeopsis ladanum* L. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Galeopsis pubescens* Besser – Ap, Th, G12, 21, F, 1.1, 0.81; *Galeopsis speciosa* Mill. – Sn, Th, G8, 5, RR, 1.2, 0.95; *Galeopsis tetrahit* L. – Ap, Th, G8, 32, FF, 1.1, 0.71; *Galinsoga ciliata* (Raf.) S. F. Blake – Kn, Th, G13, 1, RRR, 1.0, 0.99; *Galinsoga parviflora* Cava. – Kn, Th, G13, 8, R, 1.3, 0.93; *Galium aparine* L. – Ap, Th, G12, 59, FF, 1.5, 0.46; *Galium boreale* L. – Sn, H, G5, 13, R, 1.4, 0.88; *Galium cracoviense* Ehrend. – Sn, H, G6, 1, RRR, 2.0, 0.99; *Galium glaucum* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Galium mollugo* L. s. str. – Ap, H, G5, 70, C, 1.8, 0.36; *Galium odoratum* (L.) Scop.* – Sn, H, G12, 23, F, 2.3, 0.79; *Galium palustre* L. – Sn, H, G4, 15, F, 1.5, 0.86; *Galium rotundifolium* L.* – Sn, Ch, G9, 3, RR, 3.0, 0.97; *Galium sylvaticum* L.* – Sn, G, G12, 10, R, 1.3, 0.91; *Galium uliginosum* L. – Sn, H, G5, 6, RR, 1.6, 0.94; *Galium verum* L. s. str. – Ap, H, G6, 49, FF, 1.9, 0.55; *Genista germanica* L. – Sn, Ch, G8, 1, RRR, 1.0, 0.99; *Genista tinctoria* L. – Sn, Ch, G9, 2, RRR, 1.0, 0.98; *Gentiana cruciata* L. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Geranium dissectum* L. – Ar, Th, G14, 1, RRR, 1.0, 0.99; *Geranium molle* L. – Ar, Th, G14, 5, RR, 1.2, 0.95; *Geranium palustre* L. – Sn, H, G5, 10, R, 1.1, 0.91; *Geranium pratense* L. – Ap, H, G5, 24, F, 1.4, 0.78; *Geranium pusillum* Burm. f. ex L. – Ar, Th, G13, 18, F, 1.3, 0.83; *Geranium pyrenaicum* Burm. f. – Kn, H, G14, 1, RRR, 2.0, 0.99; *Geranium robertianum* L. – Ap, H, G12, 44, FF, 1.6, 0.60; *Geranium sanguineum* L. – Sn, H, G7, 2, RRR, 1.5, 0.98; *Geranium sylvaticum* L. – Sn, H, G12, 1, RRR, 1.0, 0.99; *Geum rivale* L. – Sn, H, G5, 2, RRR, 2.0, 0.98; *Geum urbanum* L.* – Ap, H, G12, 68, C, 1.3, 0.38; *Glechoma hederacea* L. – Ap, G, G12, 51, FF, 1.8, 0.53; *Glyceria fluitans* (L.) R. Br. – Sn, Hy, G4, 3, RR, 2.0, 0.97; *Glyceria maxima* (Hartm.) Holmb. – Sn, Hy, G4, 8, R, 1.8, 0.93; *Glyceria notata* Chevall. – Ap, Hy, G4, 4, RR, 2.0, 0.96; *Gnaphalium sylvaticum* L. – Sn, H, G8, 4, RR, 1.0, 0.96; *Gnaphalium uliginosum* L. – Ap, Th, G3, 4, RR, 1.0, 0.96; *Gymnocarpium dryopteris* (L.) Newman* – Sn, G, G12, 1, RRR, 1.0, 0.99; *Gypsophila fastigiata* L. – Sn, Ch, G6, 1, RRR, 2.0, 0.99; *Hedera helix* L.* – Ap, Ph, G12, 13, R, 1.1, 0.88; *Helianthemum nummularium* (L.) Mill. subsp. *obscurum* (Čelak.) Holub – Sn, Ch, G6, 7, R, 1.9, 0.94; *Helianthus annuus* L. – Ef, Th, G16, 2, RRR, 1.0, 0.98; *Helichrysum arenarium* (L.) Moench – Ap, H, G6, 11, R, 1.5, 0.90; *Hemerocallis fulva* L. – Ef, G, G16, 1, RRR, 1.0, 0.99; *Hepatica nobilis* Schreb.* – Sn, H, G12, 7, R, 1.1, 0.94; *Heracleum sibiricum* L. – Ap, H, G5, 27, F, 1.2, 0.75; *Heracleum sphondylium* L. s. str. – Ap, H, G5, 18, F, 1.0, 0.83; *Herniaria glabra* L. – Ap, H, G6, 3, RR, 1.3, 0.97; *Hesperis matronalis* L. subsp. *matronalis* – Kn, H, G16, 1, RRR, 1.0, 0.99; *Hieracium caespitosum* Dumort. – Ap, H, G5, 2, RRR, 1.0, 0.98; *Hieracium echioides* Lumn. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Hieracium lachenalii* C. C. Gmel. – Sn, H, G9, 5, RR, 1.0, 0.95; *Hieracium laevigatum* Willd. – Sn, H, G9, 5, RR, 1.0, 0.95; *Hieracium murorum* L.* – Sn, H, G9, 17, F, 1.2, 0.84; *Hieracium pilosella* L. – Ap, H, G6, 23, F, 2.0, 0.79; *Hieracium sabaudum* L.* – Sn, H, G9, 11, R, 1.0, 0.90; *Hieracium umbellatum* L. – Sn, H, G9, 7, R, 1.7, 0.94; *Holcus lanatus* L. – Ap, H, G5, 26, F, 1.8, 0.76; *Holcus mollis* L. – Ap, G, G9, 5, RR, 1.6, 0.95; *Holosteum umbellatum* L. – Ap, Th, G6, 5, RR, 1.8, 0.95; *Hordeum murinum* L. – Ar, Th, G14, 6, RR, 1.8, 0.94; *Humulus lupulus* L. – Ap, H, G10, 20, F, 1.4, 0.82; *Hydrocharis morsus-ranae* L. – Sn, Hy, G1, 4, RR, 1.0, 0.96; *Hydrocotyle vulgaris* L. – Sn, H, G2, 1, RRR, 2.5, 0.99; *Hyoscyamus niger* L. – Ar, H, G14, 5, RR, 1.0, 0.95; *Hypericum maculatum* Crantz – Sn, H, G5, 6, RR, 1.0, 0.94; *Hypericum perforatum* L. – Ap, H, G6, 74, C, 1.5, 0.32; *Hypochoeris radicata* L. – Ap, H, G6, 8, R, 1.1, 0.93; *Iberis umbellata* L. – Ef, Th, G16, 1, RRR, 1.0, 0.99; *Impatiens glandulifera* Royle – Kn, Th, G14, 2, RRR, 1.0, 0.98; *Impatiens noli-tangere* L.* – Sn, Th, G12, 5, RR, 1.2, 0.95; *Impatiens parviflora* DC. – Kn, Th, G12, 21, F, 1.3, 0.81; *Inula britannica* L. – Ap, H, G5, 6, RR, 1.3, 0.94; *Inula conyza* DC. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Inula salicina* L. – Sn, H, G5, 2, RRR, 1.0, 0.98; *Iris pseudacorus* L. – Sn, G, G4, 16, F, 1.2, 0.85; *Isopyrum thalictroides* L.* – Sn, G, G12, 2, RRR, 1.7, 0.98; *Jasione montana* L. – Ap, H, G6, 4, RR, 1.3, 0.96; *Jovibarba sobolifera* (Sims) Opiz – Sn, Ch, G6, 4, RR, 1.5, 0.96; *Juglans regia* L. – Ef, Ph, G16, 9, R, 1.0, 0.92; *Juncus articulatus* L. emend. K. Richt. – Ap, H, G5, 9, R, 1.4, 0.92; *Juncus bufonius* L. – Ap, Th, G3, 4, RR, 2.0, 0.96; *Juncus compressus* Jacq. – Ap, G, G5, 2, RRR, 1.5, 0.98; *Juncus effusus* L. – Ap, H, G5, 15, F, 1.6, 0.86; *Juncus inflexus* L. – Ap, H, G5, 6, RR, 1.4, 0.94; *Juncus tenuis* Willd. – Kn, H, G14, 1, RRR, 1.0, 0.99; *Juniperus communis* L. subsp. *communis* – Sn, Ph, G9, 5, RR, 1.0, 0.95; *Knautia arvensis* (L.) J. M. Coult. – Ap, H, G5, 39, FF, 1.4, 0.64; *Koeleria glauca* (Spreng.) DC. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Koeleria macrantha* (Ledeb.) Schult. – Sn, H, G6, 4, RR, 2.0, 0.96; *Lactuca serriola* L. – Ar, H, G14, 34, FF, 1.1, 0.69; *Lamium album* L. – Ar, H, G14, 19, F, 1.3, 0.83; *Lamium amplexicaule* L. – Ar, Th, G13, 4, RR, 1.2, 0.96; *Lamium maculatum* L. – Sn, H, G12, 21, F, 1.4, 0.81; *Lamium purpureum* L. – Ar, Th, G14, 12, R, 1.2, 0.89; *Lappula squarrosa* (Retz.) Dumort. – Ap, Th, G14, 1, RRR, 1.0, 0.99; *Lapsana communis* L. s. str. – Ap, H, G12, 26, F, 1.2, 0.76; *Larix decidua* Mill. – Ef, Ph, G16, 9, R, 1.0, 0.92; *Lathraea squamaria* L. subsp. *squamaria** – Sn, G, G12, 3, RR, 1.0, 0.97; *Lathyrus montanus* Bernh.* – Sn, G, G12, 1, RRR, 1.5, 0.99; *Lathyrus niger* (L.) Bernh.* – Sn, G, G12, 3, RR, 1.0, 0.97; *Lathyrus pratensis* L. – Ap, H, G5, 27, F, 1.5, 0.75; *Lathyrus sylvestris* L. – Ap, H, G7, 3, RR, 1.0, 0.97; *Lathyrus tuberosus* L. – Ar, H, G13, 3, RR, 1.7, 0.97; *Lathyrus vernus* (L.) Bernh.* – Sn, G, G12, 10, R, 1.1, 0.91; *Lavatera thuringiaca* L. – Ar, H, G6, 17, F, 1.6, 0.84; *Lemna minor* L. – Ap, Hy, G1, 15, F, 2.3, 0.86; *Lemna trisulca* L. – Sn, Hy, G1, 3, RR, 1.3, 0.97; *Leontodon autumnalis* L. – Ap, H, G5, 29, F, 1.5, 0.73; *Leontodon hispidus* L. – Ap, H, G5, 10, R, 1.2, 0.91; *Leonurus cardiaca* L. – Ar, H, G14, 13, R, 1.3, 0.88;

*Lepidium campestre* (L.) R. Br. – Ar, Th, G14, 1, RRR, 1.0, 0.99; *Lepidium ruderale* L. – Ar, H, G14, 2, RRR, 1.0, 0.98; *Leucanthemum vulgare* Lam. s. str. – Sn, H, G5, 11, R, 1.6, 0.90; *Libanotis pyrenaica* (L.) Bourg. – Sn, H, G6, 6, RR, 1.9, 0.94; *Ligustrum vulgare* L. – Kn, Ph, G16, 7, R, 1.3, 0.94; *Lilium martagon* L.* – Sn, G, G12, 5, RR, 1.0, 0.95; *Linaria vulgaris* Mill. – Ap, G, G14, 41, FF, 1.3, 0.62; *Linum catharticum* L. – Sn, Th, G5, 3, RR, 2.0, 0.97; *Lithospermum arvense* L. – Ar, Th, G13, 10, R, 1.0, 0.91; *Lithospermum officinale* L. – Sn, H, G6, 5, RR, 1.2, 0.95; *Lolium perenne* L. – Ap, H, G5, 46, FF, 2.1, 0.58; *Lonicera tatarica* L. – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Lonicera xylosteum* L. – Sn, Ph, G12, 4, RR, 1.0, 0.96; *Lotus corniculatus* L. – Ap, H, G5, 29, F, 1.5, 0.73; *Lotus uliginosus* Schkuhr – Sn, H, G5, 9, R, 1.4, 0.92; *Lupinus polyphyllus* Lindl. – Kn, H, G16, 3, RR, 1.0, 0.97; *Luzula campestris* (L.) DC. – Sn, H, G5, 8, R, 1.3, 0.93; *Luzula luzuloides* (Lam.) Dandy & Wilmott* – Sn, H, G12, 8, R, 1.4, 0.93; *Luzula multiflora* (Retz.) Lej. – Sn, H, G8, 4, RR, 1.3, 0.96; *Luzula pilosa* (L.) Willd.* – Sn, H, G9, 5, RR, 1.8, 0.95; *Lychnis flos-cuculi* L. – Sn, H, G5, 10, R, 1.6, 0.91; *Lycium barbarum* L. – Kn, Ph, G14, 9, R, 1.4, 0.92; *Lycopersicon esculentum* Mill. – Ef, Th, G16, 1, RRR, 1.0, 0.99; *Lycopodium annotinum* L.* – Sn, Ch, G9, 1, RRR, -, 0.99; *Lycopodium clavatum* L. – Sn, Ch, G9, 1, RRR, -, 0.99; *Lycopus europaeus* L. – Ap, H, G11, 20, F, 1.4, 0.82; *Lysimachia nummularia* L. – Ap, Ch, G4, 15, F, 1.3, 0.86; *Lysimachia vulgaris* L. – Sn, H, G5, 20, F, 1.3, 0.82; *Lythrum salicaria* L. – Ap, H, G5, 19, F, 1.3, 0.83; *Maianthemum bifolium* (L.) F. W. Schmidt* – Sn, Ch, G9, 13, R, 2.2, 0.88; *Malus domestica* Borkh. – Ef, Ph, G16, 7, R, 1.0, 0.94; *Malus sylvestris* Mill. – Ap, Ph, G12, 15, F, 1.0, 0.86; *Malva alcea* L. – Ar, H, G14, 47, FF, 1.4, 0.57; *Malva neglecta* Wallr. – Ar, H, G14, 9, R, 1.1, 0.92; *Malva sylvestris* L. – Ar, H, G14, 6, RR, 1.2, 0.94; *Marrubium vulgare* L. – Ar, Ch, G14, 1, RRR, 1.0, 0.99; *Matricaria maritima* L. subsp. *inodora* (L.) Dostál – Ar, H, G13, 19, F, 1.1, 0.83; *Medicago falcata* L. – Ap, H, G6, 45, FF, 1.7, 0.59; *Medicago lupulina* L. – Ap, H, G14, 38, FF, 1.6, 0.65; *Medicago minima* (L.) L. – Sn, Th, G6, 1, RRR, 2.0, 0.99; *Medicago sativa* L. s. str. – Kn, H, G5, 9, R, 1.1, 0.92; *Medicago ×varia* Martyn – Kn, H, G14, 5, RR, 1.0, 0.95; *Melampyrum arvense* L. – Sn, Th, G6, 3, RR, 1.3, 0.97; *Melampyrum nemorosum* L.* – Sn, Th, G12, 6, RR, 1.3, 0.94; *Melampyrum pratense* L.* – Sn, Th, G9, 2, RRR, 1.5, 0.98; *Melandrium album* (Mill.) Garcke – Ap, Th, G14, 55, FF, 1.1, 0.50; *Melandrium noctiflorum* (L.) Fr. – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Melandrium rubrum* (Weigel) Garcke – Sn, H, G12, 5, RR, 1.0, 0.95; *Melica nutans* L.* – Sn, G, G12, 15, F, 1.6, 0.86; *Melica picta* K. Koch – Sn, H, G12, 1, RRR, 2.0, 0.99; *Melica transsilvanica* Schur – Sn, H, G6, 1, RRR, 2.0, 0.99; *Melica uniflora* Retz.* – Sn, G, G12, 3, RR, 2.3, 0.97; *Melilotus alba* Medik. – Ap, Th, G14, 21, F, 1.1, 0.81; *Melilotus officinalis* (L.) Pall. – Ap, Th, G14, 11, R, 1.4, 0.90; *Melittis melissophyllum* L.* – Sn, H, G12, 1, RRR, 1.0, 0.99; *Mentha aquatica* L. – Sn, H, G4, 7, R, 1.9, 0.94; *Mentha arvensis* L. – Ap, G, G3, 4, RR, 1.3, 0.96; *Mentha longifolia* (L.) L. – Ap, H, G14, 2, RRR, 1.0, 0.98; *Mentha spicata* L. emend. L. – Ef, H, G16, 2, RRR, 1.0, 0.98; *Mentha ×verticillata* L. – Sn, H, G5, 2, RRR, 1.0, 0.98; *Mercurialis perennis* L.* – Sn, G, G11, 8, R, 1.8, 0.93; *Milium effusum* L.* – Sn, H, G12, 16, F, 1.8, 0.85; *Moehringia trinervia* (L.) Clairv.* – Sn, H, G12, 40, FF, 1.9, 0.63; *Molinia caerulea* (L.) Moench s. str. – Sn, H, G5, 2, RRR, 1.3, 0.98; *Monotropa hypophegea* Wallr. – Sn, G, G12, 1, RRR, 1.0, 0.99; *Mycelis muralis* (L.) Dumort.* – Sn, H, G9, 24, F, 1.2, 0.78; *Myosotis arvensis* (L.) Hill – Ar, Th, G13, 20, F, 1.4, 0.82; *Myosotis caespitosa* Schultz – Sn, H, G11, 1, RRR, 1.0, 0.99; *Myosotis palustris* (L.) L. emend. Rchb. subsp. *palustris* – Sn, H, G4, 13, R, 1.4, 0.88; *Myosotis ramosissima* Rochel – Sn, Th, G6, 4, RR, 1.3, 0.96; *Myosotis sparsiflora* Pohl – Sn, Th, G11, 3, RR, 1.3, 0.97; *Myosotis stricta* Link ex Roem. & Schult. – Ap, Th, G6, 7, R, 1.4, 0.94; *Myosotis sylvatica* Ehrh. ex Hoffm. – Ef, H, G12, 1, RRR, 1.0, 0.99; *Myosoton aquaticum* (L.) Moench – Ap, G, G11, 14, R, 1.3, 0.87; *Nardus stricta* L. – Sn, H, G8, 1, RRR, 2.0, 0.99; *Nepeta cataria* L. – Ar, Ch, G14, 6, RR, 1.3, 0.94; *Neslia paniculata* (L.) Desv. – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Nonea pulla* (L.) DC. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Nuphar lutea* (L.) Sibth. & Sm. – Sn, Hy, G1, 1, RRR, 1.0, 0.99; *Nymphaea alba* L. – Sn, Hy, G1, 1, RRR, 1.0, 0.99; *Odontites serotina* (Lam.) Rchb. s. str. – Sn, Th, G5, 2, RRR, 1.0, 0.98; *Odontites verna* (Bellardi) Dumort. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Oenanthe aquatica* (L.) Poir. – Ap, H, G4, 4, RR, 1.0, 0.96; *Oenothera biennis* L. – Ap, H, G14, 10, R, 1.0, 0.91; *Ononis arvensis* L. – Sn, H, G6, 5, RR, 1.0, 0.95; *Ononis spinosa* L. – Sn, H, G6, 5, RR, 1.2, 0.95; *Onopordum acanthium* L. – Ar, H, G14, 16, F, 1.3, 0.85; *Ophioglossum vulgatum* L. – Sn, G, G5, 1, RRR, 3.0, 0.99; *Origanum vulgare* L. – Ap, Ch, G7, 9, R, 1.3, 0.92; *Orobanche bartlingii* Griesb. – Sn, G, G6, 1, RRR, 2.0, 0.99; *Orobanche caryophyllacea* Sm. – Sn, G, G6, 1, RRR, 1.0, 0.99; *Oxalis acetosella* L.* – Sn, G, G12, 20, F, 2.1, 0.82; *Oxalis fontana* Bunge – Kn, G, G13, 2, RRR, 1.0, 0.98; *Padus avium* Mill. – Sn, Ph, G11, 24, F, 1.2, 0.78; *Padus serotina* (Ehrh.) Borkh. – Kn, Ph, G9, 5, RR, 1.2, 0.95; *Papaver argemone* L. – Ar, Th, G13, 1, RRR, 1.0, 0.99; *Papaver dubium* L. – Ar, Th, G13, 7, R, 1.1, 0.94; *Papaver rhoeas* L. – Ar, Th, G13, 14, R, 1.1, 0.87; *Papaver somniferum* L. – Ef, Th, G16, 1, RRR, 1.0, 0.99; *Parietaria officinalis* L. – Ar, H, G14, 1, RRR, 1.5, 0.99; *Paris quadrifolia* L.* – Sn, G, G11, 2, RRR, 1.0, 0.98; *Parnassia palustris* L. – Sn, H, G5, 1, RRR, 1.5, 0.99; *Parthenocissus inserta* (A. Kern.) Fritsch – Kn, H, G16, 2, RRR, 1.5, 0.98; *Pastinaca sativa* L. s. str. – Ar, H, G5, 15, F, 1.1, 0.86; *Petasites hybridus* (L.) P. Gaertn., B. Mey. & Scherb. – Ap, G, G5, 1, RRR, 1.0, 0.99; *Petrorhagia prolifera* (L.) P. W. Ball & Heywood – Ap, Th, G6, 1, RRR, 1.0, 0.99; *Petroselinum crispum* (Mill.) A. W. Hill. – Ef, H, G16, 1, RRR, 1.0, 0.99; *Peucedanum cervaria* (L.) Lapeyr. – Sn, H, G7, 4, RR, 1.6, 0.96; *Peucedanum oreoselinum* (L.) Moench – Sn, H, G7, 9, R, 2.0, 0.92; *Peucedanum palustre* (L.) Moench – Sn, H, G11, 3, RR, 1.0, 0.97; *Phalaris arundinacea* L. – Ap, G, G4, 26, F, 1.8, 0.76; *Philadelphus coronarius* L. – Ef, Ph, G16, 3, RR, 1.3, 0.97; *Phleum phleoides* (L.) H. Karst. – Sn, H, G6, 25, F, 1.9, 0.77; *Phleum pratense* L. – Ap, H, G5, 35, FF, 1.7, 0.68; *Phragmites australis* (Cav.) Trin. ex Steud. – Ap, G, G4, 30, F, 1.9, 0.72; *Physocarpus opulifolius* (L.) Maxim. – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Phyteuma spicatum* L.* – Sn, H, G12, 2, RRR, 1.0, 0.98; *Picea abies* (L.) H. Karst. – Sn, Ph, G9, 9, R, 1.1, 0.92; *Picris hieracioides* L. – Ap, H, G14, 6, RR, 1.3, 0.94; *Pimpinella major* (L.) Huds. – Sn, H, G5, 2, RRR, 1.0, 0.98; *Pimpinella saxifraga* L. – Ap, H, G14, 52, FF, 1.4, 0.52; *Pinus sylvestris* L. – Ap, Ph, G9, 30, F, 1.3, 0.72; *Plantago intermedia* Gilib. – Ap, H, G3, 1, RRR, 1.0, 0.99; *Plantago lanceolata* L. – Ap, H, G5, 49, FF, 1.5, 0.55; *Plantago major* L. s. str. – Ap, H, G5, 56, FF, 1.8, 0.49; *Plantago media* L. – Ap, H, G5, 32, FF, 1.6, 0.71; *Poa angustifolia* L. – Sn, H, G6, 16, F, 1.9, 0.85; *Poa annua* L. – Ap, H, G5, 40, FF, 2.1, 0.63; *Poa compressa* L. subsp. *compressa* – Ap, H, G6, 20, F, 1.8, 0.82; *Poa nemoralis* L. subsp. *nemoralis** – Ap, H, G12, 46, FF, 2.2, 0.58; *Poa palustris* L. – Sn, H, G4, 16, F, 1.7, 0.85; *Poa pratensis* L. s. str. – Ap, H, G5, 68, C, 2.0, 0.38; *Poa trivialis* L. – Ap, H, G5, 33, FF, 1.6, 0.70; *Polygala amarella* Crantz – Sn, H, G5, 2, RRR, 1.0, 0.98; *Polygala comosa* Schkuhr – Sn, H, G5, 2, RRR, 1.0, 0.98; *Polygala vulgaris* L. s. str. – Sn, H, G5, 2, RRR, 1.0, 0.98; *Polygonatum multiflorum* (L.) All.* – Sn, G, G12, 21, F, 1.1, 0.81; *Polygonatum odoratum* (Mill.) Druce* – Sn, G, G9, 12, R, 1.4, 0.89; *Polygonum amphibium* L. – Ap, Hy, G5, 21, F, 1.5, 0.81; *Polygonum aviculare* L. – Ap, Th, G14, 42, FF, 1.9, 0.61; *Polygonum bistorta* L. – Sn, G, G5, 5, RR, 1.3, 0.95; *Polygonum hydropiper* L. – Ap, Th, G3, 10, R, 1.1, 0.91; *Polygonum lapathifolium* L. subsp. *lapathifolium* – Ap, Th, G3, 4, RR, 1.0, 0.96; *Polygonum lapathifolium* L. subsp. *pallidum* (With.) Fr. – Ar, Th, G13, 8, R, 1.4, 0.93; *Polygonum persicaria* L. – Ap, Th, G13, 14, R, 1.2, 0.87; *Polypodium vulgare* L. – Sn, H, G9, 9, R, 1.4, 0.92; *Populus alba* L. – Ap, Ph, G10, 6, RR, 1.0, 0.94; *Populus nigra* L. – Ap, Ph, G10, 7, R, 1.1, 0.94; *Populus tremula* L. – Ap, Ph, G9, 17, F, 1.2, 0.84; *Potentilla anserina* L. – Ap, H, G5, 29, F, 1.6, 0.73; *Potentilla arenaria* Borkh. – Sn, H, G6, 10, R, 1.8, 0.91; *Potentilla argentea* L. s. str. – Ap, H, G6, 32, FF, 1.6, 0.71; *Potentilla collina* Wibel s.str. – Sn, H, G6, 3, RR, 1.0, 0.97; *Potentilla erecta* (L.) Raeusch. – Sn, H, G5, 10, R, 1.3, 0.91; *Potentilla heptaphylla* L. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Potentilla neumanniana* Rchb. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Potentilla recta* L. – Ap, H, G14, 1, RRR, 1.0, 0.99; *Potentilla reptans* L. – Ap, H, G14, 29, F, 1.7, 0.73; *Prenanthes* *purpurea* L.* – Sn, H, G12, 2, RRR, 1.0, 0.98; *Primula elatior* (L.) Hill.* – Sn, H, G12, 5, RR, 1.0, 0.95; *Primula veris* L.* – Sn, H, G7, 29, F, 1.4, 0.73; *Prunella vulgaris* L. – Sn, H, G5, 15, F, 1.4, 0.86; *Prunus domestica* L. subsp. *domestica* – Ef, Ph, G16, 6, RR, 1.0, 0.94; *Prunus domestica* L. subsp. *insititia* (L.) Bonnier & Layens – Ef, Ph, G16, 13, R, 1.2, 0.88; *Prunus spinosa* L. – Ap, Ph, G7, 29, F, 2.1, 0.73; *Pteridium aquilinum* (L.) Kuhn* – Sn, G, G9, 9, R, 1.6, 0.92; *Puccinellia distans* (Jacq.) Parl. – Ap, H, G14, 1, RRR, 1.0, 0.99; *Pulmonaria obscura* Dumort.* – Sn, H, G12, 11, R, 1.3, 0.90; *Pulsatilla pratensis* (L.) Mill. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Pyrus pyraster* (L.) Burgsd. – Ap, Ph, G7, 40, FF, 1.0, 0.63; *Quercus petraea* (Matt.) Liebl. – Sn, Ph, G9, 26, F, 1.2, 0.76; *Quercus robur* L. – Sn, Ph, G12, 59, FF, 1.3, 0.46; *Quercus rubra* L. – Kn, Ph, G9, 4, RR, 1.0, 0.96; *Ranunculus acris* L. s. str. – Ap, H, G5, 42, FF, 1.3, 0.61; *Ranunculus auricomus* L. s. l.* – Sn, H, G12, 4, RR, 1.3, 0.96; *Ranunculus bulbosus* L. – Sn, G, G6, 11, R, 1.1, 0.90; *Ranunculus flammula* L. – Sn, H, G2, 2, RRR, 1.0, 0.98; *Ranunculus lanuginosus* L.* – Sn, H, G12, 7, R, 1.0, 0.94; *Ranunculus polyanthemos* L. – Sn, H, G6, 1, RRR, 1.0, 0.99; *Ranunculus repens* L. – Ap, H, G5, 35, FF, 1.5, 0.68; *Ranunculus sceleratus* L. – Ap, Th, G3, 6, RR, 1.5, 0.94; *Raphanus raphanistrum* L. – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Reseda lutea* L. – Ap, H, G14, 4, RR, 1.0, 0.96; *Reynoutria japonica* Houtt. – Kn, G, G16, 2, RRR, 1.0, 0.98; *Rhamnus cathartica* L. – Sn, Ph, G7, 16, F, 1.1, 0.85; *Rhinanthus minor* L. – Sn, Th, G5, 1, RRR, 1.0, 0.99; *Rhinanthus serotinus* (Schönh.) Oborný – Sn, Th, G5, 8, R, 1.2, 0.93; *Ribes alpinum* L. – Ap, Ph, G12, 4, RR, 1.0, 0.96; *Ribes nigrum* L.* – Sn, Ph, G11, 4, RR, 1.0, 0.96; *Ribes spicatum* E. Robson* – Sn, Ph, G12, 13, R, 1.1, 0.88; *Ribes uva-crispa* L. subsp. *uva-crispa** – Ap, Ph, G12, 17, F, 1.1, 0.84; *Robinia pseudoacacia* L. – Kn, Ph, G12, 17, F, 1.2, 0.84; *Rorippa amphibia* (L.) Besser – Ap, H, G4, 5, RR, 2.2, 0.95; *Rorippa austriaca* (Crantz) Besser – Ap, H, G5, 1, RRR, 1.0, 0.99; *Rorippa palustris* (L.) Besser – Ap, Th, G3, 3, RR, 1.0, 0.97; *Rorippa sylvestris* (L.) Besser – Ap, G, G14, 1, RRR, 1.0, 0.99; *Rosa canina* L. – Ap, Ph, G7, 53, FF, 1.1, 0.51; *Rosa dumalis* Bechst. emend. Boulenger – Ap, Ph, G7, 4, RR, 1.0, 0.96; *Rosa inodora* Fr. – Ap, Ph, G7, 1, RRR, 1.0, 0.99; *Rosa rubiginosa* L. – Sn, Ph, G7, 1, RRR, 1.0, 0.99; *Rosa rugosa* Thunb. – Kn, Ph, G16, 1, RRR, 1.0, 0.99; *Rubus caesius* L. – Ap, Ph, G12, 60, FF, 1.4, 0.45; *Rubus grabowskii* Weihe ex Günther & All. – Sn, Ph, G9, 1, RRR, 1.0, 0.99; *Rubus gracilis* J. Presl & C. Presl – Sn, Ph, G9, 3, RR, 1.3, 0.97; *Rubus idaeus* L. – Ap, Ph, G8, 24, F, 1.1, 0.78; *Rubus plicatus* Weihe & Nees – Sn, Ph, G9, 4, RR, 1.3, 0.96; *Rudbeckia laciniata* L. – Ef, H, G16, 1, RRR, 1.0, 0.99; *Rumex acetosa* L. – Ap, H, G5, 53, FF, 1.5, 0.51; *Rumex acetosella* L. – Ap, G, G6, 16, F, 1.5, 0.85; *Rumex conglomeratus* Murray – Ap, H, G14, 1, RRR, 1.0, 0.99; *Rumex crispus* L. – Ap, H, G14, 44, FF, 1.1, 0.60; *Rumex hydrolapathum* Huds. – Ap, H, G4, 9, R, 1.1, 0.92; *Rumex maritimus* L. – Ap, Th, G3, 3, RR, 1.0, 0.97; *Rumex obtusifolius* L. – Ap, H, G14, 17, F, 1.2, 0.84; *Rumex palustris* Sm. – Sn, Th, G3, 1, RRR, 1.0, 0.99; *Sagina procumbens* L. – Ap, Ch, G3, 3, RR, 1.0, 0.97; *Sagittaria sagittifolia* L. – Sn, Hy, G4, 1, RRR, 1.0, 0.99; *Salix alba* L. – Ap, Ph, G10, 13, R, 1.0, 0.88; *Salix aurita* L. – Sn, Ph, G11, 6, RR, 1.0, 0.94; *Salix caprea* L. – Sn, Ph, G8, 11, R, 1.1, 0.90; *Salix cinerea* L. – Ap, Ph, G11, 22, F, 1.1, 0.80; *Salix ×dasyclados* Wimm. – Sn, Ph, G10, 1, RRR, 1.0, 0.99; *Salix fragilis* L. – Ap, Ph, G10, 15, F, 1.2, 0.86; *Salix pentandra* L. – Sn, Ph, G11, 1, RRR, 1.0, 0.99; *Salix purpurea* L. – Sn, Ph, G10, 3, RR, 1.2, 0.97; *Salix repens* L. subsp. *rosmarinifolia* (L.) Hartm. – Sn, Ch, G2, 3, RR, 1.7, 0.97; *Salix ×rubens* Schrank – Ap, Ph, G10, 1, RRR, 1.0, 0.99; *Salix triandra* L. – Sn, Ph, G10, 1, RRR, 1.0, 0.99; *Salix viminalis* L. – Sn, Ph, G10, 6, RR, 1.2, 0.94; *Salsola kali* L. subsp. *ruthenica* (Iljin) Soó – Kn, Th, G14, 2, RRR, 2.0, 0.98; *Salvia glutinosa* L. – Sn, H, G12, 1, RRR, 1.0, 0.99; *Salvia nemorosa* L. – Ap, H, G6, 1, RRR, 2.0, 0.99; *Salvia pratensis* L. – Sn, H, G6, 19, F, 1.6, 0.83; *Salvia verticillata* L. – Ap, H, G6, 5, RR, 1.0, 0.95; *Sambucus nigra* L. – Ap, Ph, G12, 82, C, 1.3, 0.25; *Sambucus racemosa* L. – Ap, Ph, G8, 4, RR, 1.0, 0.96; *Sanguisorba minor* Scop. s. str. – Sn, H, G6, 4, RR, 1.3, 0.96; *Sanguisorba officinalis* L. – Sn, H, G5, 3, RR, 1.5, 0.97; *Sanicula europaea* L.* – Sn, H, G12, 5, RR, 1.0, 0.95; *Saponaria officinalis* L. – Ar, H, G14, 7, R, 1.2, 0.94; *Sarothamnus scoparius* (L.) W. D. J. Koch – Sn, Ph, G8, 1, RRR, 1.3, 0.99; *Saxifraga granulata* L. – Sn, H, G6, 5, RR, 1.3, 0.95; *Saxifraga paniculata* Mill. – Sn, Ch, G6, 1, RRR, 1.0, 0.99; *Saxifraga tridactylites* L. – Ap, Th, G6, 6, RR, 1.0, 0.94; *Scabiosa columbaria* L. s. str. – Sn, H, G6, 2, RRR, 1.5, 0.98; *Scabiosa ochroleuca* L. – Sn, H, G6, 12, R, 1.7, 0.89; *Schoenoplectus lacustris* (L.) Palla – Sn, G, G4, 4, RR, 1.3, 0.96; *Schoenoplectus tabernaemontani* (C. C. Gmel.) Palla – Sn, G, G4, 1, RRR, 2.0, 0.99; *Scilla sibirica* Haw. – Ef, G, G16, 1, RRR, 1.0, 0.99; *Scirpus sylvaticus* L. – Ap, G, G5, 7, R, 1.3, 0.94; *Scleranthus annuus* L. – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Scleranthus perennis* L. – Sn, Ch, G6, 2, RRR, 1.0, 0.98; *Scorzonera humilis* L. – Sn, H, G9, 1, RRR, 1.0, 0.99; *Scrophularia nodosa* L.* – Sn, H, G12, 36, FF, 1.1, 0.67; *Scrophularia umbrosa* Dumort. – Sn, H, G4, 2, RRR, 1.0, 0.98; *Scutellaria galericulata* L. – Sn, H, G4, 7, R, 1.1, 0.94; *Scutellaria hastifolia* L. – Sn, H, G5, 1, RRR, 1.0, 0.99; *Secale cereale* L. – Ef, Th, G16, 3, RR, 1.0, 0.97; *Sedum acre* L. – Ap, Ch, G6, 15, F, 2.3, 0.86; *Sedum maximum* (L.) Hoffm. – Ap, G, G6, 17, F, 1.4, 0.84; *Sedum sexangulare* L. – Ap, Ch, G6, 10, R, 1.8, 0.91; *Sedum spurium* M. Bieb. – Ef, Ch, G16, 1, RRR, 1.0, 0.99; *Selinum carvifolia* (L.) L. – Sn, H, G5, 5, RR, 1.3, 0.95; *Senecio jacobaea* L. – Ap, H, G6, 28, F, 1.5, 0.74; *Senecio nemorensis* L. – Sn, H, G8, 2, RRR, 1.0, 0.98; *Senecio ovatus* (P. Gaertn., B. Mey. & Scherb.) Willd. – Sn, H, G12, 2, RRR, 2.0, 0.98; *Senecio sylvaticus* L. – Sn, Th, G8, 1, RRR, 1.0, 0.99; *Senecio vernalis* Waldst. & Kit. – Kn, H, G14, 9, R, 1.1, 0.92; *Senecio viscosus* L. – Ap, Th, G14, 2, RRR, 1.0, 0.98; *Senecio vulgaris* L. – Ar, H, G13, 9, R, 1.1, 0.92; *Serratula tinctoria* L. – Sn, G, G5, 1, RRR, 2.0, 0.99; *Seseli annuum* L. – Sn, H, G6, 5, RR, 1.4, 0.95; *Seseli hippomarathrum* L. – Sn, H, G6, 1, RRR, 2.0, 0.99; *Setaria pumila* (Poir.) Roem. & Schult. – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Setaria viridis* (L.) P. Beauv. – Ar, Th, G13, 9, R, 1.1, 0.92; *Silene nutans* L. subsp. *nutans* – Sn, H, G6, 8, R, 1.1, 0.93; *Silene otites* (L.) Wibel – Sn, H, G6, 5, RR, 1.2, 0.95; *Silene vulgaris* (Moench) Garcke – Ap, Ch, G14, 20, F, 1.3, 0.82; *Sinapis arvensis* L. – Ar, Th, G13, 6, RR, 1.0, 0.94; *Sisymbrium altissiumum* L. – Kn, H, G14, 1, RRR, 1.0, 0.99; *Sisymbrium loeselii* L. – Kn, H, G14, 7, R, 1.0, 0.94; *Sisymbrium officinale* (L.) Scop. – Ar, Th, G14, 15, F, 1.2, 0.86; *Sium latifolium* L. Sn, H, – G4, 7, R, 1.0, 0.94; *Solanum dulcamara* L. – Ap, Ph, G11, 22, F, 1.2, 0.80; *Solanum nigrum* L. emend. Mill. – Ar, Th, G14, 3, RR, 1.0, 0.97; *Solanum tuberosum* L. – Ef, G, G16, 3, RR, 1.0, 0.97; *Solidago canadensis* L. – Kn, G, G14, 7, R, 1.3, 0.94; *Solidago gigantea* Aiton – Kn, G, G14, 3, RR, 1.0, 0.97; *Solidago virgaurea* L. s. str.* – Sn, H, G9, 20, F, 1.1, 0.82; *Sonchus arvensis* L. subsp. *arvensis* – Ap, G, G14, 22, F, 1.1, 0.80; *Sonchus asper* (L.) Hill – Ar, Th, G13, 9, R, 1.0, 0.92; *Sonchus oleraceus* L. – Ar, H, G13, 7, R, 1.0, 0.94; *Sorbus aucuparia* L. emend. Hedl. subsp. *aucuparia* – Ap, Ph, G9, 37, FF, 1.1, 0.66; *Sorbus intermedia* (Ehrh.) Pers. – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Sorbus torminalis* (L.) Crantz – Sn, Ph, G12, 1, RRR, 1.0, 0.99; *Sparganium erectum* L. emend. Rchb. s. str. – Sn, Hy, G4, 5, RR, 1.2, 0.95; *Spergula arvensis* L. subsp. *arvensis* – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Spiraea salicifolia* L. – Ef, Ph, G16, 4, RR, 1.0, 0.96; *Spirodela polyrhiza* (L.) Schleid. – Sn, Hy, G1, 3, RR, 1.0, 0.97; *Stachys annua* (L.) L. – Ar, Th, G13, 2, RRR, 1.0, 0.98; *Stachys germanica* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Stachys palustris* L. – Sn, G, G5, 8, R, 1.3, 0.93; *Stachys recta* L. – Sn, H, G6, 9, R, 1.5, 0.92; *Stachys sylvatica* L.* – Sn, H, G12, 23, F, 1.5, 0.79; *Stellaria graminea* L. – Ap, H, G5, 25, F, 1.5, 0.77; *Stellaria holostea* L.* – Sn, Ch, G12, 15, F, 1.9, 0.86; *Stellaria media* (L.) Vill. – Ap, Th, G13, 39, FF, 1.8, 0.64; *Stellaria nemorum* L.* – Sn, H, G12, 1, RRR, 2.0, 0.99; *Stellaria palustris* Retz. – Sn, H, G5, 3, RR, 1.5, 0.97; *Stipa capillata* L. – Sn, H, G6, 2, RRR, 2.5, 0.98; *Succisa pratensis* Moench – Sn, H, G5, 3, RR, 1.6, 0.97; *Symphoricarpos albus* (L.) S. F. Blake – Kn, Ph, G16, 10, R, 1.3, 0.91; *Symphytum officinale* L. – Sn, G, G5, 16, F, 1.3, 0.85; *Syringa vulgaris* L. – Ef, Ph, G16, 12, R, 1.9, 0.89; *Tanacetum vulgare* L. – Ap, H, G14, 23, F, 1.2, 0.79; *Taraxacum laevigatum* (Willd.) DC. – Sn, H, G5, 1, RRR, 1.0, 0.99; *Taraxacum officinale* F. H. Wigg. – Ap, H, G5, 72, C, 1.6, 0.34; *Taxus baccata* L. – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Teesdalea nudicaulis* (L.) R. Br. – Ap, H, G13, 1, RRR, 1.0, 0.99; *Thalictrum aquilegiifolium*

L. – Sn, H, G11, 1, RRR, 1.0, 0.99; *Thalictrum flavum* L. – Sn, H, G5, 4, RR, 1.0, 0.96; *Thalictrum lucidum* L. – Sn, H, G5, 2, RRR, 1.0, 0.98; *Thalictrum minus* L. subsp. *minus* – Sn, H, G6, 23, F, 1.6, 0.79; *Thelypteris palustris* Schott – Sn, G, G11, 2, RRR, 2.0, 0.98; *Thesium linophyllon* L. – Sn, G, G6, 1, RRR, 2.0, 0.99; *Thladiantha dubia* Bunge – Ef, H, G16, 1, RRR, 1.0, 0.99; *Thlaspi arvense* L. – Ar, Th, G13, 6, RR, 1.0, 0.94; *Thuja occidentalis* L. – Ef, Ph, G16, 1, RRR, 1.0, 0.99; *Thymus kosteleckyanus* Opiz – Sn, Ch, G6, 3, RR, 2.8, 0.97; *Thymus praecox* Opiz – Sn, Ch, G6, 1, RRR, 2.0, 0.99; *Thymus pulegioides* L. – Ap, Ch, G6, 27, F, 2.5, 0.75; *Thymus serpyllum* L. emend. Fr. – Ap, Ch, G6, 2, RRR, 1.5, 0.98; *Tilia cordata* Mill. – Ap, Ph, G12, 21, F, 1.1, 0.81; *Tilia platyphyllos* Scop. – Ap, Ph, G12, 15, F, 1.1, 0.86; *Torilis japonica* (Houtt.) DC. – Ap, H, G12, 36, FF, 1.2, 0.67; *Tragopogon dubius* Scop. – Ap, H, G14, 3, RR, 1.0, 0.97; *Tragopogon orientalis* L. – Ap, H, G6, 7, R, 1.0, 0.94; *Tragopogon pratensis* L. s. str. – Ap, H, G5, 24, F, 1.2, 0.78; *Trientalis europaea* L.* – Sn, G, G9, 1, RRR, 2.0, 0.99; *Trifolium alpestre* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Trifolium arvense* L. – Ap, Th, G6, 22, F, 1.4, 0.80; *Trifolium aureum* Pollich – Sn, H, G6, 1, RRR, 1.0, 0.99; *Trifolium campestre* Schreb. – Ap, Th, G6, 10, R, 1.5, 0.91; *Trifolium dubium* Sibth. – Ap, Th, G5, 10, R, 1.5, 0.91; *Trifolium fragiferum* L. subsp. *fragiferum* – Ap, H, G5, 1, RRR, 1.0, 0.99; *Trifolium hybridum* L. subsp. *hybridum* – Ap, H, G5, 2, RRR, 1.0, 0.98; *Trifolium medium* L. – Ap, H, G7, 15, F, 1.8, 0.86; *Trifolium montanum* L. – Sn, H, G7, 4, RR, 1.4, 0.96; *Trifolium pratense* L. – Ap, H, G5, 39, FF, 1.4, 0.64; *Trifolium repens* L. subsp. *repens* – Ap, Ch, G14, 41, FF, 2.1, 0.62; *Trifolium rubens* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Triglochin maritimum* L. – Sn, H, G5, 1, RRR, 1.0, 0.99; *Triglochin palustre* L. – Sn, H, G5, 1, RRR, 1.0, 0.99; *Trisetum flavescens* (L.) P. Beauv. – Sn, H, G5, 3, RR, 1.3, 0.97; *Triticum aestivum* L. – Ef, Th, G16, 3, RR, 1.0, 0.97; *Tussilago farfara* L. – Ap, G, G14, 16, F, 1.4, 0.85; *Typha angustifolia* L. – Ap, H, G4, 1, RRR, 1.0, 0.99; *Typha latifolia* L. – Ap, H, G4, 10, R, 1.5, 0.91; *Ulmus glabra* Huds. – Ap, Ph, G11, 22, F, 1.2, 0.80; *Ulmus laevis* Pall. – Ap, Ph, G11, 14, R, 1.3, 0.87; *Ulmus minor* Mill. emend. Richens – Sn, Ph, G11, 7, R, 1.5, 0.94; *Urtica dioica* L. subsp. *dioica* – Ap, H, G12, 98, C, 1.8, 0.10; *Urtica urens* L. – Ar, Th, G14, 6, RR, 1.1, 0.94; *Utricularia australis* R. Br. – Sn, Hy, G1, 1, RRR, 1.0, 0.99; *Vaccinium myrtillus* L.* – Sn, Ch, G9, 11, R, 1.5, 0.90; *Vaccinium vitis-idaea* L.* – Sn, Ch, G9, 2, RRR, 1.0, 0.98; *Valeriana officinalis* L. – Sn, H, G5, 13, R, 1.1, 0.88; *Valerianella locusta* Laterr. emend. Betcke – Ar, Th, G6, 3, RR, 1.7, 0.97; *Verbascum densiflorum* Bertol. – Ap, H, G6, 22, F, 1.3, 0.80; *Verbascum lychnitis* L. – Ap, H, G6, 21, F, 1.1, 0.81; *Verbascum nigrum* L. – Ap, H, G6, 21, F, 1.3, 0.81; *Verbascum phlomoides* L. – Ap, H, G6, 9, R, 1.1, 0.92; *Veronica anagallis-aquatica* L. – Ap, H, G4, 4, RR, 1.0, 0.96; *Veronica arvensis* L. – Ar, Th, G13, 7, R, 1.0, 0.94; *Veronica beccabunga* L. – Sn, Hy, G4, 3, RR, 1.3, 0.97; *Veronica catenata* Pennell – Sn, Hy, G4, 2, RRR, 1.0, 0.98; *Veronica chamaedrys* L. s. str. – Ap, Ch, G5, 63, C, 1.7, 0.42; *Veronica hederifolia* L. – Ap, Th, G12, 26, F, 1.5, 0.76; *Veronica longifolia* L. – Sn, H, G5, 3, RR, 1.0, 0.97; *Veronica montana* L.* – Sn, Ch, G12, 1, RRR, 1.0, 0.99; *Veronica officinalis* L. – Sn, Ch, G9, 10, R, 1.6, 0.91; *Veronica persica* Poir. – Kn, Th, G13, 8, R, 1.0, 0.93; *Veronica prostrata* L. – Sn, Ch, G6, 1, RRR, 1.0, 0.99; *Veronica scutellata* L. – Sn, H, G2, 3, RR, 1.0, 0.97; *Veronica spicata* L. subsp. *spicata* – Sn, H, G6, 12, R, 1.8, 0.89; *Veronica teucrium* L. – Sn, Ch, G6, 23, F, 1.8, 0.79; *Veronica triphyllos* L. – Ar, Th, G13, 3, RR, 1.0, 0.97; *Veronica verna* L. – Ap, Th, G6, 1, RRR, 1.0, 0.99; *Viburnum opulus* L. – Sn, Ph, G7, 9, R, 1.2, 0.92; *Vicia angustifolia* L. – Ar, Th, G13, 11, R, 1.0, 0.90; *Vicia cassubica* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Vicia cracca* L. – Ap, H, G5, 47, FF, 1.5, 0.57; *Vicia dumetorum* L. – Sn, H, G7, 7, R, 1.2, 0.94; *Vicia grandiflora* Scop. – Kn, Th, G13, 1, RRR, 1.0, 0.99; *Vicia hirsuta* (L.) Gray – Ar, Th, G13, 16, F, 1.0, 0.85; *Vicia pisiformis* L. – Sn, H, G7, 1, RRR, 1.0, 0.99; *Vicia sepium* L. – Ap, H, G12, 15, F, 1.2, 0.86; *Vicia sylvatica* L. – Sn, H, G7, 5, RR, 1.0, 0.95; *Vicia tenuifolia* Roth – Sn, G, G6, 2, RRR, 2.2, 0.98; *Vicia tetrasperma* (L.) Schreb. – Ar, Th, G13, 10, R, 1.0, 0.91; *Vicia villosa* Roth – Ar, Th, G13, 7, R, 1.1, 0.94; *Vinca minor* L.* – Ef, Ch, G16, 2, RRR, 2.5, 0.98; *Vincetoxicum hirundinaria* Medik. – Sn, H, G7, 8, R, 1.6, 0.93; *Viola arvensis* Murray – Ar, Th, G13, 22, F, 1.3, 0.80; *Viola canina* L. s. str. – Sn, H, G8, 6, RR, 1.2, 0.94; *Viola hirta* L. – Sn, H, G6, 5, RR, 1.6, 0.95; *Viola mirabilis* L.* – Sn, H, G12, 4, RR, 1.2, 0.96; *Viola odorata* L. – Ar, H, G12, 16, F, 1.6, 0.85; *Viola reichenbachiana* Jord. ex Boreau* – Sn, H, G12, 29, F, 1.2, 0.73; *Viola riviniana* Rchb.* – Sn, H, G12, 7, R, 1.4, 0.94; *Viola rupestris* F. W. Schmidt – Sn, H, G6, 1, RRR, 1.0, 0.99; *Viola tricolor* L. s. str. – Ap, Th, G6, 5, RR, 1.2, 0.95; *Viscaria vulgaris* Röhl – Sn, Ch, G6, 9, R, 1.3, 0.92; *Viscum album* L. subsp. *album* – Ap, Ch, G12, 6, RR, 1.1, 0.94; *Xanthium albinum* (Widder) H. Scholz – Kn, Th, G3, 1, RRR, 1.0, 0.99.

**Appendix 4.** Species richness, floristic value, and floristic dissimilarity index of West Slavic sites

| Site no. (Fig. 3) | Site name | No. of species | Floristic value | Floristic dissimilarity |
|---|---|---|---|---|
| 1 | Gross Raden | 131 | 95.1 | 0.73 |
| 2 | Teterow | 156 | 113.7 | 0.73 |
| 3 | Laschendorf | 44 | 31.1 | 0.71 |
| 4 | Feldberg | 48 | 34.0 | 0.71 |
| 5 | Stary Kraków | 35 | 24.6 | 0.70 |
| 6 | Sławsko | 93 | 76.0 | 0.82 |
| 7 | Kczewo | 48 | 34.1 | 0.71 |
| 8 | Sycewice | 48 | 32.8 | 0.68 |
| 9 | Wiatrowo Dolne | 72 | 53.3 | 0.74 |
| 10 | Gołczewo | 52 | 40.7 | 0.78 |
| 11 | Jamno | 63 | 51.6 | 0.82 |
| 12 | Wrześnica | 163 | 123.6 | 0.76 |
| 13 | Ostrowiec | 33 | 22.3 | 0.68 |
| 14 | Radacz | 83 | 55.6 | 0.67 |
| 15 | Wierzchowo | 98 | 68.4 | 0.70 |
| 16 | Grąbczyn | 85 | 57.7 | 0.68 |
| 17 | Połęcko | 70 | 43.1 | 0.62 |
| 18 | Santok | 73 | 50.1 | 0.69 |
| 19 | Międzyrzecz | 144 | 109.5 | 0.76 |
| 20 | Pszczew 1 | 79 | 52.8 | 0.67 |
| 21 | Trzciel | 88 | 61.7 | 0.70 |
| 22 | Niesulice | 63 | 48.0 | 0.76 |
| 23 | Skąpe | 71 | 48.1 | 0.68 |
| 24 | Dormowo | 85 | 62.1 | 0.73 |
| 25 | Obrzycko | 128 | 93.2 | 0.73 |
| 26 | Ostroróg | 75 | 47.3 | 0.63 |
| 27 | Piersko | 78 | 54.4 | 0.70 |
| 28 | Smuszewo 1 | 100 | 70.0 | 0.70 |
| 29 | Królikowo | 61 | 42.9 | 0.70 |
| 30 | Izdebno | 124 | 87.4 | 0.70 |
| 31 | Wenecja | 76 | 51.8 | 0.68 |
| 32 | Szarlej | 83 | 57.5 | 0.69 |
| 33 | Ostrowo | 44 | 27.1 | 0.62 |
| 34 | Kruszwica 2-5 | 83 | 58.7 | 0.71 |
| 35 | Mietlica | 81 | 60.0 | 0.74 |
| 36 | Stęszew | 171 | 126.0 | 0.74 |
| 37 | Bonikowo | 170 | 135.9 | 0.80 |
| 38 | Kórnik | 186 | 144.2 | 0.78 |
| 39 | Kociałkowa Górka | 73 | 53.7 | 0.74 |
| 40 | Dzierznica | 55 | 36.5 | 0.66 |
| 41 | Ląd | 93 | 67.3 | 0.72 |
| 42 | Janowo | 137 | 100.3 | 0.73 |
| 43 | Koło | 77 | 54.8 | 0.71 |
| 44 | Przytok | 51 | 34.0 | 0.67 |
| 45 | Wojnowice | 64 | 41.9 | 0.65 |
| 46 | Krobia | 99 | 71.7 | 0.72 |
| 47 | Niepart | 113 | 83.3 | 0.74 |
| 48 | Jeżewo | 55 | 38.9 | 0.71 |
| 49 | Jarantów | 106 | 80.0 | 0.76 |
| 50 | Topola Wielka | 78 | 53.4 | 0.68 |
| 51 | Ociąż | 57 | 40.9 | 0.72 |
| 52 | Kałdus | 198 | 150.1 | 0.76 |
| 53 | Jaguszewice | 119 | 83.2 | 0.70 |
| 54 | Lembarg | 123 | 84.3 | 0.69 |
| 55 | Bobrowo | 142 | 105.7 | 0.74 |
| 56 | Napole Ostrowite | 179 | 132.8 | 0.74 |
| 57 | Sampława | 79 | 49.7 | 0.63 |
| 58 | Stara Łomża | 81 | 57.7 | 0.71 |
| 59 | Sambory Ruś | 51 | 37.1 | 0.73 |
| 60 | Wizna | 63 | 41.2 | 0.65 |
| 61 | Cieciorki | 71 | 48.9 | 0.69 |
| 62 | Tykocin | 65 | 48.1 | 0.74 |
| 63 | Tykocin zamek | 77 | 54.5 | 0.71 |
| 64 | Zamczysk | 50 | 33.7 | 0.67 |
| 65 | Grodziszczany | 58 | 37.3 | 0.64 |
| 66 | Czuprynowo | 45 | 28.5 | 0.63 |
| 67 | Haćki | 106 | 75.1 | 0.71 |

| Site no. (Fig. 3) | Site name | No. of species | Floristic value | Floristic dissimilarity |
|---|---|---|---|---|
| 68 | Dziedzice | 96 | 64.9 | 0.68 |
| 69 | Tum | 102 | 70.2 | 0.69 |
| 70 | Błonie | 89 | 62.0 | 0.70 |
| 71 | Chlebnia | 109 | 78.8 | 0.72 |
| 72 | Stara Warka | 89 | 64.5 | 0.72 |
| 73 | Drohiczyn | 86 | 58.6 | 0.68 |
| 74 | Krzymosze | 85 | 57.7 | 0.68 |
| 75 | Czaple Szlacheckie | 68 | 47.9 | 0.70 |
| 76 | Grodzisk | 77 | 53.0 | 0.69 |
| 77 | Dalków 1 | 39 | 26.1 | 0.67 |
| 78 | Dalków 2 | 42 | 30.4 | 0.72 |
| 79 | Gostyń | 51 | 36.0 | 0.71 |
| 80 | Przedmoście | 80 | 62.7 | 0.78 |
| 81 | Obiszów 1 | 72 | 51.4 | 0.71 |
| 82 | Grodziszcze | 95 | 68.6 | 0.72 |
| 83 | Gościszów | 81 | 56.1 | 0.69 |
| 84 | Marczów | 67 | 49.5 | 0.74 |
| 85 | Radłówka | 90 | 64.6 | 0.72 |
| 86 | Rząsiny | 63 | 41.4 | 0.66 |
| 87 | Wleń | 171 | 130.8 | 0.76 |
| 88 | Myślibórz III | 42 | 33.0 | 0.78 |
| 89 | Myślibórz II | 42 | 32.2 | 0.77 |
| 90 | Myślibórz | 74 | 57.7 | 0.78 |
| 91 | Myślibórz I zamek | 62 | 47.9 | 0.77 |
| 92 | Chełmiec | 48 | 36.4 | 0.76 |
| 93 | Kłonice-Radogost | 77 | 56.4 | 0.73 |
| 94 | Bolkowice | 58 | 43.4 | 0.75 |
| 95 | Siedmica | 38 | 30.2 | 0.79 |
| 96 | Pokutice | 70 | 50.2 | 0.72 |
| 97 | Rubin | 101 | 80.7 | 0.80 |
| 98 | Vladar | 94 | 70.8 | 0.75 |
| 99 | Stary Plzen | 105 | 70.3 | 0.67 |
| 100 | Radyne | 57 | 38.4 | 0.67 |
| 101 | Olsztyn | 268 | 213.6 | 0.80 |
| 102 | Ostrężnik | 95 | 75.4 | 0.79 |
| 103 | Mirów | 225 | 173.9 | 0.77 |
| 104 | Podzamcze | 252 | 197.8 | 0.78 |
| 105 | Stradów | 234 | 180.6 | 0.77 |
| 106 | Wiślica | 130 | 96.7 | 0.74 |
| 107 | Niewęgłosz | 94 | 71.5 | 0.76 |
| 108 | Czudec | 105 | 78.0 | 0.74 |
| 109 | Odrzykoń | 107 | 73.8 | 0.69 |

**Appendix 5.** Indices of anthropogenic changes in the flora of West Slavic sites

| Site no. | $WS_t$ | $WS_p$ | $WAp_t$ | $WAp_p$ | *Wap* | $WAn_t$ | $WAn_p$ | $WAr_t$ | $WAr_p$ | $WKn_t$ | $WKn_p$ | *WM* | *WF* | *WN* | $WT_a$ | $WT_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 81.7 | 81.7 | 67.2 | 67.2 | 78.6 | 14.5 | 14.5 | 12.2 | 12.2 | 2.3 | 2.3 | 15.8 | 0.0 | 18.3 | 100.0 | 100.0 |
| 2 | 76.3 | 75.8 | 60.3 | 61.4 | 71.8 | 16.0 | 14.4 | 7.7 | 7.8 | 6.4 | 6.5 | 45.5 | 1.9 | 23.7 | 88.0 | 98.1 |
| 3 | 43.2 | 43.2 | 40.9 | 40.9 | 41.9 | 2.3 | 2.3 | 2.3 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 | 56.8 | 100.0 | 100.0 |
| 4 | 43.8 | 43.8 | 41.7 | 41.7 | 42.6 | 2.1 | 2.1 | 0.0 | 0.0 | 2.1 | 2.1 | 100.0 | 0.0 | 56.3 | 100.0 | 100.0 |
| 5 | 45.7 | 44.1 | 42.9 | 44.1 | 44.1 | 2.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.9 | 54.3 | 0.0 | 97.1 |
| 6 | 66.7 | 66.7 | 65.6 | 65.6 | 66.3 | 1.1 | 1.1 | 1.1 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 100.0 | 100.0 |
| 7 | 37.5 | 37.5 | 33.3 | 33.3 | 34.8 | 4.2 | 4.2 | 4.2 | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 62.5 | 100.0 | 100.0 |
| 8 | 45.8 | 45.8 | 45.8 | 45.8 | 45.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 54.2 | 0.0 | 100.0 |
| 9 | 54.2 | 52.2 | 48.6 | 50.7 | 51.5 | 5.6 | 1.4 | 0.0 | 0.0 | 1.4 | 1.4 | 100.0 | 4.2 | 45.8 | 25.0 | 95.8 |
| 10 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 75.0 | 0.0 | 100.0 |
| 11 | 98.4 | 98.4 | 39.7 | 39.7 | 96.2 | 58.7 | 58.7 | 57.1 | 57.1 | 1.6 | 1.6 | 2.7 | 0.0 | 1.6 | 100.0 | 100.0 |
| 12 | 63.8 | 63.8 | 58.9 | 58.9 | 61.9 | 4.9 | 4.9 | 3.1 | 3.1 | 1.8 | 1.8 | 37.5 | 0.0 | 36.2 | 100.0 | 100.0 |
| 13 | 36.4 | 36.4 | 36.4 | 36.4 | 36.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 63.6 | 0.0 | 100.0 |
| 14 | 72.3 | 71.6 | 69.9 | 71.6 | 71.6 | 2.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 27.7 | 0.0 | 97.6 |
| 15 | 67.3 | 67.3 | 65.3 | 65.3 | 66.7 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 50.0 | 0.0 | 32.7 | 100.0 | 100.0 |
| 16 | 69.4 | 69.4 | 67.1 | 67.1 | 68.7 | 2.4 | 2.4 | 1.2 | 1.2 | 1.2 | 1.2 | 50.0 | 0.0 | 30.6 | 100.0 | 100.0 |
| 17 | 92.9 | 92.8 | 80.0 | 81.2 | 91.8 | 12.9 | 11.6 | 10.0 | 10.1 | 1.4 | 1.4 | 12.5 | 1.4 | 7.1 | 88.9 | 98.6 |
| 18 | 97.3 | 97.3 | 68.5 | 68.5 | 96.2 | 28.8 | 28.8 | 21.9 | 21.9 | 6.8 | 6.8 | 23.8 | 0.0 | 2.7 | 100.0 | 100.0 |
| 19 | 87.5 | 87.4 | 63.2 | 63.6 | 83.5 | 24.3 | 23.8 | 14.6 | 14.7 | 9.0 | 9.1 | 38.2 | 0.7 | 12.5 | 97.1 | 99.3 |
| 20 | 93.7 | 93.5 | 72.2 | 74.0 | 91.9 | 21.5 | 19.5 | 12.7 | 13.0 | 6.3 | 6.5 | 33.3 | 2.5 | 6.3 | 88.2 | 97.5 |
| 21 | 71.6 | 71.3 | 65.9 | 66.7 | 69.9 | 5.7 | 4.6 | 4.5 | 4.6 | 0.0 | 0.0 | 0.0 | 1.1 | 28.4 | 80.0 | 98.9 |
| 22 | 38.1 | 38.1 | 36.5 | 36.5 | 37.1 | 1.6 | 1.6 | 1.6 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 61.9 | 100.0 | 100.0 |
| 23 | 88.7 | 88.7 | 81.7 | 81.7 | 87.9 | 7.0 | 7.0 | 7.0 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.3 | 100.0 | 100.0 |
| 24 | 68.2 | 68.2 | 55.3 | 55.3 | 63.5 | 12.9 | 12.9 | 11.8 | 11.8 | 1.2 | 1.2 | 9.1 | 0.0 | 31.8 | 100.0 | 100.0 |
| 25 | 89.1 | 89.1 | 65.6 | 65.6 | 85.7 | 23.4 | 23.4 | 16.4 | 16.4 | 7.0 | 7.0 | 30.0 | 0.0 | 10.9 | 100.0 | 100.0 |
| 26 | 94.7 | 94.5 | 70.7 | 72.6 | 93.0 | 24.0 | 21.9 | 14.7 | 15.1 | 6.7 | 6.8 | 31.3 | 2.7 | 5.3 | 88.9 | 97.3 |
| 27 | 80.8 | 80.8 | 66.7 | 66.7 | 77.6 | 14.1 | 14.1 | 12.8 | 12.8 | 1.3 | 1.3 | 9.1 | 0.0 | 19.2 | 100.0 | 100.0 |
| 28 | 79.0 | 79.0 | 67.0 | 67.0 | 76.1 | 12.0 | 12.0 | 11.0 | 11.0 | 1.0 | 1.0 | 8.3 | 0.0 | 21.0 | 100.0 | 100.0 |
| 29 | 72.1 | 71.2 | 59.0 | 61.0 | 67.9 | 13.1 | 10.2 | 6.6 | 6.8 | 3.3 | 3.4 | 33.3 | 3.3 | 27.9 | 75.0 | 96.7 |
| 30 | 84.7 | 84.7 | 74.2 | 74.2 | 82.9 | 10.5 | 10.5 | 9.7 | 9.7 | 0.8 | 0.8 | 7.7 | 0.0 | 15.3 | 100.0 | 100.0 |
| 31 | 96.1 | 96.0 | 63.2 | 64.0 | 94.1 | 32.9 | 32.0 | 26.3 | 26.7 | 5.3 | 5.3 | 16.7 | 1.3 | 3.9 | 96.0 | 98.7 |
| 32 | 86.7 | 86.7 | 66.3 | 66.3 | 83.3 | 20.5 | 20.5 | 19.3 | 19.3 | 1.2 | 1.2 | 5.9 | 0.0 | 13.3 | 100.0 | 100.0 |
| 33 | 90.9 | 90.9 | 84.1 | 84.1 | 90.2 | 6.8 | 6.8 | 6.8 | 6.8 | 0.0 | 0.0 | 0.0 | 0.0 | 9.1 | 100.0 | 100.0 |
| 34 | 98.8 | 98.8 | 61.4 | 61.4 | 98.1 | 37.3 | 37.3 | 24.1 | 24.1 | 13.3 | 13.3 | 35.5 | 0.0 | 1.2 | 100.0 | 100.0 |
| 35 | 77.8 | 77.2 | 55.6 | 57.0 | 71.4 | 22.2 | 20.3 | 16.0 | 16.5 | 3.7 | 3.8 | 18.8 | 2.5 | 22.2 | 88.9 | 97.5 |
| 36 | 86.0 | 85.5 | 65.5 | 67.5 | 82.4 | 20.5 | 18.1 | 13.5 | 13.9 | 4.1 | 4.2 | 23.3 | 2.9 | 14.0 | 85.7 | 97.1 |
| 37 | 63.5 | 63.5 | 57.6 | 57.6 | 61.3 | 5.9 | 5.9 | 4.7 | 4.7 | 1.2 | 1.2 | 20.0 | 0.0 | 36.5 | 100.0 | 100.0 |
| 38 | 87.1 | 86.7 | 52.7 | 54.4 | 80.3 | 34.4 | 32.2 | 23.1 | 23.9 | 8.1 | 8.3 | 25.9 | 3.2 | 12.9 | 90.6 | 96.8 |
| 39 | 42.5 | 42.5 | 41.1 | 41.1 | 41.7 | 1.4 | 1.4 | 0.0 | 0.0 | 1.4 | 1.4 | 100.0 | 0.0 | 57.5 | 100.0 | 100.0 |
| 40 | 85.5 | 85.5 | 60.0 | 60.0 | 80.5 | 25.5 | 25.5 | 21.8 | 21.8 | 3.6 | 3.6 | 14.3 | 0.0 | 14.5 | 100.0 | 100.0 |
| 41 | 68.8 | 68.5 | 55.9 | 56.5 | 64.2 | 12.9 | 12.0 | 9.7 | 9.8 | 2.2 | 2.2 | 18.2 | 1.1 | 31.2 | 91.7 | 98.9 |
| 42 | 67.2 | 67.2 | 62.8 | 62.8 | 65.6 | 4.4 | 4.4 | 2.9 | 2.9 | 1.5 | 1.5 | 33.3 | 0.0 | 32.8 | 100.0 | 100.0 |
| 43 | 96.1 | 96.1 | 70.1 | 70.1 | 94.7 | 26.0 | 26.0 | 20.8 | 20.8 | 5.2 | 5.2 | 20.0 | 0.0 | 3.9 | 100.0 | 100.0 |
| 44 | 78.4 | 78.4 | 74.5 | 74.5 | 77.6 | 3.9 | 3.9 | 3.9 | 3.9 | 0.0 | 0.0 | 0.0 | 0.0 | 21.6 | 100.0 | 100.0 |
| 45 | 82.8 | 82.5 | 65.6 | 66.7 | 79.2 | 17.2 | 15.9 | 14.1 | 14.3 | 1.6 | 1.6 | 10.0 | 1.6 | 17.2 | 90.9 | 98.4 |
| 46 | 93.9 | 93.8 | 69.7 | 71.1 | 92.0 | 24.2 | 22.7 | 14.1 | 14.4 | 8.1 | 8.2 | 36.4 | 2.0 | 6.1 | 91.7 | 98.0 |
| 47 | 77.0 | 77.0 | 65.5 | 65.5 | 74.0 | 11.5 | 11.5 | 9.7 | 9.7 | 1.8 | 1.8 | 15.4 | 0.0 | 23.0 | 100.0 | 100.0 |
| 48 | 61.8 | 61.8 | 58.2 | 58.2 | 60.4 | 3.6 | 3.6 | 1.8 | 1.8 | 1.8 | 1.8 | 50.0 | 0.0 | 38.2 | 100.0 | 100.0 |
| 49 | 64.2 | 63.8 | 58.5 | 59.0 | 62.0 | 5.7 | 4.8 | 3.8 | 3.8 | 0.9 | 1.0 | 20.0 | 0.9 | 35.8 | 83.3 | 99.1 |
| 50 | 76.9 | 76.9 | 75.6 | 75.6 | 76.6 | 1.3 | 1.3 | 0.0 | 0.0 | 1.3 | 1.3 | 100.0 | 0.0 | 23.1 | 100.0 | 100.0 |
| 51 | 50.9 | 50.9 | 49.1 | 49.1 | 50.0 | 1.8 | 1.8 | 1.8 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 49.1 | 100.0 | 100.0 |
| 52 | 70.2 | 69.9 | 51.5 | 52.0 | 63.4 | 18.7 | 17.9 | 14.1 | 14.3 | 3.5 | 3.6 | 20.0 | 1.0 | 29.8 | 94.6 | 99.0 |
| 53 | 83.2 | 82.9 | 69.7 | 70.9 | 80.6 | 13.4 | 12.0 | 10.1 | 10.3 | 1.7 | 1.7 | 14.3 | 1.7 | 16.8 | 87.5 | 98.3 |
| 54 | 82.1 | 81.7 | 69.9 | 71.7 | 79.6 | 12.2 | 10.0 | 8.1 | 8.3 | 1.6 | 1.7 | 16.7 | 2.4 | 17.9 | 80.0 | 97.6 |
| 55 | 76.8 | 76.4 | 61.3 | 62.1 | 72.5 | 15.5 | 14.3 | 12.0 | 12.1 | 2.1 | 2.1 | 15.0 | 1.4 | 23.2 | 90.9 | 98.6 |
| 56 | 78.8 | 78.5 | 61.5 | 62.1 | 74.3 | 17.3 | 16.4 | 12.3 | 12.4 | 3.9 | 4.0 | 24.1 | 1.1 | 21.2 | 93.5 | 98.9 |
| 57 | 87.3 | 87.2 | 74.7 | 75.6 | 85.5 | 12.7 | 11.5 | 8.9 | 9.0 | 2.5 | 2.6 | 22.2 | 1.3 | 12.7 | 90.0 | 98.7 |
| 58 | 74.1 | 74.1 | 66.7 | 66.7 | 72.0 | 7.4 | 7.4 | 6.2 | 6.2 | 1.2 | 1.2 | 16.7 | 0.0 | 25.9 | 100.0 | 100.0 |
| 59 | 68.6 | 68.6 | 58.8 | 58.8 | 65.2 | 9.8 | 9.8 | 7.8 | 7.8 | 2.0 | 2.0 | 20.0 | 0.0 | 31.4 | 100.0 | 100.0 |
| 60 | 96.8 | 96.8 | 74.6 | 74.6 | 95.9 | 22.2 | 22.2 | 17.5 | 17.5 | 4.8 | 4.8 | 21.4 | 0.0 | 3.2 | 100.0 | 100.0 |
| 61 | 78.9 | 78.9 | 76.1 | 76.1 | 78.3 | 2.8 | 2.8 | 2.8 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 21.1 | 100.0 | 100.0 |
| 62 | 95.4 | 95.4 | 70.8 | 70.8 | 93.9 | 24.6 | 24.6 | 20.0 | 20.0 | 4.6 | 4.6 | 18.8 | 0.0 | 4.6 | 100.0 | 100.0 |
| 63 | 93.5 | 93.5 | 72.7 | 72.7 | 91.8 | 20.8 | 20.8 | 16.9 | 16.9 | 3.9 | 3.9 | 18.8 | 0.0 | 6.5 | 100.0 | 100.0 |
| 64 | 80.0 | 79.6 | 74.0 | 75.5 | 78.7 | 6.0 | 4.1 | 2.0 | 2.0 | 2.0 | 2.0 | 50.0 | 2.0 | 20.0 | 66.7 | 98.0 |
| 65 | 79.3 | 78.9 | 72.4 | 73.7 | 77.8 | 6.9 | 5.3 | 5.2 | 5.3 | 0.0 | 0.0 | 0.0 | 1.7 | 20.7 | 75.0 | 98.3 |
| 66 | 84.4 | 84.4 | 75.6 | 75.6 | 82.9 | 8.9 | 8.9 | 8.9 | 8.9 | 0.0 | 0.0 | 0.0 | 0.0 | 15.6 | 100.0 | 100.0 |
| 67 | 74.5 | 74.5 | 65.1 | 65.1 | 71.9 | 9.4 | 9.4 | 8.5 | 8.5 | 0.9 | 0.9 | 10.0 | 0.0 | 25.5 | 100.0 | 100.0 |
| 68 | 81.3 | 80.6 | 72.9 | 75.3 | 79.5 | 8.3 | 5.4 | 5.2 | 5.4 | 0.0 | 0.0 | 0.0 | 3.1 | 18.8 | 62.5 | 96.9 |
| 69 | 89.2 | 89.0 | 64.7 | 66.0 | 85.7 | 24.5 | 23.0 | 19.6 | 20.0 | 2.9 | 3.0 | 13.0 | 2.0 | 10.8 | 92.0 | 98.0 |
| 70 | 88.8 | 88.8 | 75.3 | 75.3 | 87.0 | 13.5 | 13.5 | 11.2 | 11.2 | 2.2 | 2.2 | 16.7 | 0.0 | 11.2 | 100.0 | 100.0 |
| 71 | 82.6 | 82.4 | 74.3 | 75.0 | 81.0 | 8.3 | 7.4 | 4.6 | 4.6 | 2.8 | 2.8 | 37.5 | 0.9 | 17.4 | 88.9 | 99.1 |
| 72 | 73.0 | 72.7 | 61.8 | 62.5 | 69.6 | 11.2 | 10.2 | 7.9 | 8.0 | 2.2 | 2.3 | 22.2 | 1.1 | 27.0 | 90.0 | 98.9 |
| 73 | 94.2 | 94.0 | 64.0 | 65.5 | 91.7 | 30.2 | 28.6 | 25.6 | 26.2 | 2.3 | 2.4 | 8.3 | 2.3 | 5.8 | 92.3 | 97.7 |
| 74 | 74.1 | 74.1 | 69.4 | 69.4 | 72.8 | 4.7 | 4.7 | 3.5 | 3.5 | 1.2 | 1.2 | 25.0 | 0.0 | 25.9 | 100.0 | 100.0 |
| 75 | 88.2 | 88.2 | 75.0 | 75.0 | 86.4 | 13.2 | 13.2 | 13.2 | 13.2 | 0.0 | 0.0 | 0.0 | 0.0 | 11.8 | 100.0 | 100.0 |

| Site no. | $WS_t$ | $WS_p$ | $WAp_t$ | $WAp_p$ | $Wap$ | $WAn_t$ | $WAn_p$ | $WAr_t$ | $WAr_p$ | $WKn_t$ | $WKn_p$ | $WM$ | $WF$ | $WN$ | $WT_a$ | $WT_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 76 | 93.5 | 93.5 | 72.7 | 72.7 | 91.8 | 20.8 | 20.8 | 18.2 | 18.2 | 2.6 | 2.6 | 12.5 | 0.0 | 6.5 | 100.0 | 100.0 |
| 77 | 84.2 | 83.8 | 73.7 | 75.7 | 82.4 | 10.5 | 8.1 | 7.9 | 8.1 | 0.0 | 0.0 | 0.0 | 2.6 | 15.8 | 75.0 | 97.4 |
| 78 | 45.2 | 45.2 | 42.9 | 42.9 | 43.9 | 2.4 | 2.4 | 0.0 | 0.0 | 2.4 | 2.4 | 100.0 | 0.0 | 54.8 | 100.0 | 100.0 |
| 79 | 72.5 | 72.5 | 56.9 | 56.9 | 67.4 | 15.7 | 15.7 | 9.8 | 9.8 | 5.9 | 5.9 | 37.5 | 0.0 | 27.5 | 100.0 | 100.0 |
| 80 | 87.5 | 87.5 | 66.3 | 66.3 | 84.1 | 21.3 | 21.3 | 16.3 | 16.3 | 5.0 | 5.0 | 23.5 | 0.0 | 12.5 | 100.0 | 100.0 |
| 81 | 59.7 | 58.6 | 52.8 | 54.3 | 56.7 | 6.9 | 4.3 | 1.4 | 1.4 | 2.8 | 2.9 | 66.7 | 2.8 | 40.3 | 60.0 | 97.2 |
| 82 | 64.2 | 64.2 | 56.8 | 56.8 | 61.4 | 7.4 | 7.4 | 6.3 | 6.3 | 1.1 | 1.1 | 14.3 | 0.0 | 35.8 | 100.0 | 100.0 |
| 83 | 81.5 | 80.5 | 67.9 | 71.4 | 78.6 | 13.6 | 9.1 | 2.5 | 2.6 | 6.2 | 6.5 | 71.4 | 4.9 | 18.5 | 63.6 | 95.1 |
| 84 | 55.2 | 53.8 | 46.3 | 47.7 | 50.8 | 9.0 | 6.2 | 3.0 | 3.1 | 3.0 | 3.1 | 50.0 | 3.0 | 44.8 | 66.7 | 97.0 |
| 85 | 66.7 | 66.3 | 60.0 | 60.7 | 64.3 | 6.7 | 5.6 | 3.3 | 3.4 | 2.2 | 2.2 | 40.0 | 1.1 | 33.3 | 83.3 | 98.9 |
| 86 | 82.5 | 82.5 | 77.8 | 77.8 | 81.7 | 4.8 | 4.8 | 3.2 | 3.2 | 1.6 | 1.6 | 33.3 | 0.0 | 17.5 | 100.0 | 100.0 |
| 87 | 71.9 | 70.9 | 55.0 | 57.0 | 66.2 | 17.0 | 13.9 | 8.2 | 8.5 | 5.3 | 5.5 | 39.1 | 3.5 | 28.1 | 79.3 | 96.5 |
| 88 | 23.8 | 23.8 | 23.8 | 23.8 | 23.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 76.2 | 0.0 | 100.0 |
| 89 | 31.0 | 31.0 | 28.6 | 28.6 | 29.3 | 2.4 | 2.4 | 0.0 | 0.0 | 2.4 | 2.4 | 100.0 | 0.0 | 69.0 | 100.0 | 100.0 |
| 90 | 43.2 | 43.2 | 40.5 | 40.5 | 41.7 | 2.7 | 2.7 | 1.4 | 1.4 | 1.4 | 1.4 | 50.0 | 0.0 | 56.8 | 100.0 | 100.0 |
| 91 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 69.4 | 0.0 | 100.0 |
| 92 | 41.7 | 41.7 | 39.6 | 39.6 | 40.4 | 2.1 | 2.1 | 0.0 | 0.0 | 2.1 | 2.1 | 100.0 | 0.0 | 58.3 | 100.0 | 100.0 |
| 93 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 54.5 | 0.0 | 100.0 |
| 94 | 36.2 | 36.2 | 34.5 | 34.5 | 35.1 | 1.7 | 1.7 | 0.0 | 0.0 | 1.7 | 1.7 | 100.0 | 0.0 | 63.8 | 100.0 | 100.0 |
| 95 | 28.9 | 27.0 | 23.7 | 24.3 | 25.0 | 5.3 | 2.7 | 0.0 | 0.0 | 2.6 | 2.7 | 100.0 | 2.6 | 71.1 | 50.0 | 97.4 |
| 96 | 72.9 | 72.5 | 67.1 | 68.1 | 71.2 | 5.7 | 4.3 | 4.3 | 4.3 | 0.0 | 0.0 | 0.0 | 1.4 | 27.1 | 75.0 | 98.6 |
| 97 | 64.4 | 63.3 | 49.5 | 51.0 | 58.1 | 14.9 | 12.2 | 5.9 | 6.1 | 5.9 | 6.1 | 50.0 | 3.0 | 35.6 | 80.0 | 97.0 |
| 98 | 61.7 | 61.3 | 56.4 | 57.0 | 59.6 | 5.3 | 4.3 | 2.1 | 2.2 | 2.1 | 2.2 | 50.0 | 1.1 | 38.3 | 80.0 | 98.9 |
| 99 | 85.7 | 85.4 | 73.3 | 74.8 | 83.7 | 12.4 | 10.7 | 5.7 | 5.8 | 4.8 | 4.9 | 45.5 | 1.9 | 14.3 | 84.6 | 98.1 |
| 100 | 86.0 | 86.0 | 75.4 | 75.4 | 84.3 | 10.5 | 10.5 | 8.8 | 8.8 | 1.8 | 1.8 | 16.7 | 0.0 | 14.0 | 100.0 | 100.0 |
| 101 | 69.8 | 69.1 | 54.5 | 55.7 | 64.3 | 15.3 | 13.4 | 10.4 | 10.7 | 2.6 | 2.7 | 20.0 | 2.2 | 30.2 | 85.4 | 97.8 |
| 102 | 35.8 | 35.1 | 33.7 | 34.0 | 34.4 | 2.1 | 1.1 | 1.1 | 1.1 | 0.0 | 0.0 | 0.0 | 1.1 | 64.2 | 50.0 | 98.9 |
| 103 | 70.2 | 69.8 | 59.6 | 60.4 | 66.7 | 10.7 | 9.5 | 5.8 | 5.9 | 3.6 | 3.6 | 38.1 | 1.3 | 29.8 | 87.5 | 98.7 |
| 104 | 71.0 | 70.6 | 57.5 | 58.5 | 66.5 | 13.5 | 12.1 | 8.3 | 8.5 | 3.6 | 3.6 | 30.0 | 1.6 | 29.0 | 88.2 | 98.4 |
| 105 | 85.9 | 85.7 | 59.8 | 60.6 | 80.9 | 26.1 | 25.1 | 20.5 | 20.8 | 4.3 | 4.3 | 17.2 | 1.3 | 14.1 | 95.1 | 98.7 |
| 106 | 78.5 | 78.1 | 62.3 | 63.3 | 74.3 | 16.2 | 14.8 | 11.5 | 11.7 | 3.1 | 3.1 | 21.1 | 1.5 | 21.5 | 90.5 | 98.5 |
| 107 | 58.5 | 58.5 | 57.4 | 57.4 | 58.1 | 1.1 | 1.1 | 1.1 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 41.5 | 100.0 | 100.0 |
| 108 | 61.9 | 60.8 | 49.5 | 51.0 | 56.5 | 12.4 | 9.8 | 1.9 | 2.0 | 7.6 | 7.8 | 80.0 | 2.9 | 38.1 | 76.9 | 97.1 |
| 109 | 81.3 | 81.3 | 69.2 | 69.2 | 78.7 | 12.1 | 12.1 | 10.3 | 10.3 | 1.9 | 1.9 | 15.4 | 0.0 | 18.7 | 100.0 | 100.0 |
| Mean | 71.6 | 71.3 | 59.8 | 60.4 | 69.2 | 11.8 | 10.9 | 8.4 | 8.5 | 2.4 | 2.5 | 26.7 | 0.9 | 28.4 | 84.6 | 99.1 |
| Max | 98.8 | 98.8 | 84.1 | 84.1 | 98.1 | 58.7 | 58.7 | 57.1 | 57.1 | 13.3 | 13.3 | 100.0 | 4.9 | 76.2 | 100.0 | 100.0 |
| Min | 23.8 | 23.8 | 23.7 | 23.8 | 23.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.2 | 0.0 | 95.1 |
| SD | 18.9 | 19.0 | 13.8 | 13.9 | 18.7 | 9.9 | 9.8 | 8.4 | 8.4 | 2.4 | 2.5 | 28.2 | 1.2 | 18.9 | 27.2 | 1.2 |

Explanations: $WS_t$ – total synanthropization index, $WS_p$ – permanent synanthropization index, $WAp_t$ – total apophytization index, $WAp_p$ – permanent apophytization index, $Wap$ – spontaneophyte apophytization index, $WAn_t$ – total anthropophytization index, $WAn_p$ – permanent anthropophytization index, $WAr_t$ – total archaeophytization index, $WAr_p$ – permanent archaeophytization index, $WKn_t$ – total kenophytization index, $WKn_p$ – permanent kenophytization index, $WM$ – flora modernization index, $WF$ – floristic fluctuations index, $WN$ – flora naturalness index, $WT_a$ – anthropophyte permanence index, $WT_t$ – total permanence index