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Beata Zagórska-Marek;
University of Wrocław, Poland;
<https://orcid.org/0000-0001-6385-858X>

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REVIEW in POLISH BOTANY CENTENNIAL

Kraków Geobotanical School During 1859–2020: Main Achievements

Piotr Köhler ¹, Alina Stachurska-Swakon ^{2*}

¹Prof. Zdzisław Czepe Polar Research Laboratory, Institute of Botany, Faculty of Biology, Jagiellonian University, Gronostajowa 3, 30-387 Kraków, Poland

²Department of Plant Ecology, Institute of Botany, Faculty of Biology, Jagiellonian University, Gronostajowa 3, 30-387 Kraków, Poland

* To whom correspondence should be addressed. Email: alina.stachurska-swakon@uj.edu.pl

Abstract

Kraków Geobotanical School is considered one of the oldest and longest-operating botanical schools in Europe; it was active from 1859 to 2020. The purpose of this article is to summarize the achievements of the school. We divided the history of the school into six periods: (i) the Formation period (1859–1903); (ii) the Romantic period (1903–1917), wherein long-term research projects were completed and with M. Raciborski considered as the first headmaster of the school; (iii) the Classical period (1917–1970), wherein new ideas and research techniques were developed with W. Szafer as the headmaster; (iv) the Duumvirate period (1971–1993), with J. Kornaś and A. Jasiewicz as the headmasters; (v) the Descendant schools period (1994–2010), wherein traditional (morphological) methods were utilized; and (vi) the Decline period (2011–2020). Each of these periods was characterized by the names of the headmasters or leaders, their roles, and their main achievements. We suppose that Kraków Geobotanical School, in its present structure, has finished its scientific activity, for which we present a few arguments. We have attached to the main text of the article, an extensive tables containing the topics of geobotanical research carried out in each of the six periods, along with publication samples. The most important scientific achievements of Kraków Geobotanical School are the following: several thousand publications, including monographs and syntheses of knowledge on Polish flora and vegetation; introduction of new disciplines in Poland (e.g., paleobotany, nature conservation, phytosociology, palynology, study on synanthropization); description of new plant and fungus taxa; and identification of syntaxonomic units in Poland and abroad.

Keywords

Polish botanical research; geobotany; paleobotany; nature protection; history of botany; scientific schools

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1. Introduction

The establishment of science schools is important in promoting scientific literacy. A science school administration consists of a community of scholars who share similar ideas and approaches to solving specific scientific problems. Moreover, science schools are usually associated with a place (city), research center (university), or an outstanding scientist who serves as the headmaster of a given school. The headmaster leads the entire school, plays an inspiring role, is an authority on the subject, and author of original, groundbreaking scientific discoveries. The headmaster is usually assisted by fellow academics who are respectful and supportive of him or her.

A science school aims to train its students to challenge an existing paradigm or a prevailing idea in light of new evidence and develop new approaches to solving specific scientific problems (Opalek, 1983). The two types of science schools can be distinguished based on their organization: the first type is characterized by a network of scientists who regularly interact with each other to discuss current research trends; the second type is usually associated with academic science (A. Zemanek, 2007, pp. 26–27) in which the headmaster gathers students and followers around him.

Geobotany is a branch of botany that deals with the interrelationship between plants and the geographical environment. It includes floristics, phytogeography, plant ecology, and phytosociology (Szweykowska & Szweykowski, 2003). At Kraków Geobotanical School, paleobotany, nature protection, and history of botany are also being taught and practiced aside from the aforementioned subdisciplines of geobotany. This article presents the history and accomplishments of Kraków Geobotanical School.

Kraków Geobotanical School is considered one of the oldest and longest-operating botanical schools in Europe (A. Zemanek, 2007, p. 35). It has been active for 150 years since its foundation. Since the name of the school has not been formally registered, the first person who referred to the school in its present-day name is still unknown. This name was consistently used by Professor Jan Kornaś (1923–1994), one of the headmasters of the school. An outline of the history of the school and some important letters between the scholars of the school and botanists from other institutions are presented in a recently published monograph (A. Zemanek & Zemanek, 2007). The history of Kraków Geobotanical School can be broken down into several periods (A. Zemanek, 2007, pp. 37–51). These periods are redefined and briefly described in following paragraphs.

2. The Formation Period of Kraków Geobotanical School, 1859–1903

2.1. Research Headmasters and Organizers

In the early years following the establishment of Kraków Geobotanical School, searching for a botanist qualified to serve as the headmaster was difficult. Listed below are the names and contributions of four botanists who were involved in planning and implementing the pioneering research projects conducted at the school. However, they were not distinguished geobotanists, and they lacked leadership qualities to be appointed as headmasters.

Franz (Franciszek) Herbich (1791–1865), a medical doctor, military physician, and an excellent botanist, witnessed the early years of Kraków Geobotanical School. From 1825 until 1856, Herbich lived and worked in various cities in Galicia (the southern part of Poland, then under Austria's rule); in 1856, he transferred to Kraków, where he spent the rest of his life until his death. During that time, he gained a large group of collaborators, most of which were great botanists: Feliks Berdau (1826–1895), Edward Hüchel (1830–1896) (Köhler, 2008a), Wincenty Jabłoński (1824–1895) (Köhler, 2016), Antoni Rehman (1840–1917), and Aleksander Zawadzki (1798–1868). They exchanged herbarium specimens with Herbich; in addition, Herbich advised and instructed them on botanical matters. The main goal of Herbich was to describe the flora of Galicia; unfortunately, he failed to do so. He was the originator of the Physiographic Commission – the first institution in Poland to conduct scientific research, including botanical research, over many years (Köhler, 2002, 2009a, 2015a, 2015c).

Ignacy Rafał Czerwiakowski (1808–1882) graduated with a doctorate in Medicine from the Jagiellonian University in 1833. To further his knowledge, he enrolled at the University of Berlin, where he met Franz Meyen (1804–1840), an anatomist and a phytogeographer; and Carl Sigismund Kunth (1788–1850), a systematist and an associate of Alexander Humboldt (1769–1859), the well-known co-creator of phytogeography. In 1843, Czerwiakowski became a botany professor at Jagiellonian University and took over the chair of the natural history, from which the chair of botany was separated in 1847. He was a professor of botany and director of the Botanical Garden of the Jagiellonian University until 1878, during which he

published university textbooks on botany (A. Zemanek, 2000b). In 1865, he co-organized the Physiographic Commission within the Kraków Scientific Society, which conducted scientific research, including botanical research (Köhler, 2002, 2015a). Czerwiakowski created the first botanical research program of the Commission, which operated within the edifice of the Academy of Sciences and Letters from 1873 (Czerwiakowski, 1867a, 1867b). The program used (was based on) new scientific ideas. It covered the following four disciplines (according to current terminology):

- Floristics – an inventory of all plant species and lower-rank units (subspecies, varieties, and forms) growing in Galicia, including local mutations and endemics;
- Systematics – description of recently discovered or previously unknown plant taxa in accordance with the principles of systematics;
- Phytogeography – examination and description of the horizontal and vertical distribution of species; determination of the geographical ranges of individual species and plant formations; demarcation of the phytogeographic units of Galicia and description of their boundaries; and comparison of the flora of Galicia with neighboring floras; and
- Ecology – analysis of the habitat and climatic factors that determine the occurrence of given plant species and formations; investigation of the causes behind the similarities and differences in species composition of different areas in Galicia; examination of the dynamics and evolution of individual plant formations; and collection of phytophenological data to determine phenological periods (Czerwiakowski, 1867b; Köhler, 2008c, pp. 159–160).

In addition, the program emphasized the need to document the flora of Galicia in the form of herbaria and museum collections. The program supported the development of floristics and phytogeography in Poland. Czerwiakowski was also the author of the Commission's second plan for botanical research, which began in 1876 (Köhler, 2002, pp. 99–102). He directed the research during 1866–1869 and 1873–1877, when he headed the botanical section of the Physiographic Commission (Köhler, 2002, p. 55).

Antoni Rehman (Rehmann; 1840–1917) was the successor of Czerwiakowski in managing field botanical research. He was a student of Czerwiakowski and a graduate of the Jagiellonian University, where he obtained his doctorate (1865) and habilitation (1868). He worked at the Jagiellonian University as an assistant to the chair of botany (1863–1867) and a *privat dozent* (1868–1880, with breaks for trips to various parts of the world) (A. Zemanek, 2000a). During 1869–1872, he supervised the botanical research as the chairperson of the botanical section of the Physiographic Commission (Köhler, 2002, p. 55). He was the first botanist of the emerging Kraków Geobotanical School to conduct botanical research outside Galicia: in Europe (southwest Russia – Bessarabia, Podolia, Kherson Gubernya, Crimea), Asia (the Caucasus), and Africa (from the Cape of Good Hope through the deserts of Karoo, Kalahari, the Drakensberg Mountains, and Natal to Durban, along with the northeastern part of the Transvaal).

Józef Rostafiński (1850–1928) was another botanist who actively conducted research at that time in Kraków; he studied at Warsaw Main School (then the University of Warsaw) and in German universities (in Jena and Halle). Before coming to Kraków to work at the Jagiellonian University, he had already published his works in the field of geobotany: the flora of vascular plants in Polish lands under Russian rule (Rostafiński, 1872) and a world monograph on slime molds (Rostafiński, 1874a, 1874b). While in Kraków, he spent his time studying the history of botany as well as other natural and medical sciences and conducting interdisciplinary research involving botany, linguistics, ethnology, and history (A. Zemanek, 2000c). He managed the botanical section of the Physiographic Commission during 1877–1903 (Köhler, 2002, p. 55). At the end of the nineteenth century, he began working on the descriptive Polish *Flora*. Unfortunately, he got preoccupied with activities related to the celebration of the 500th anniversary of the renewal of the Jagiellonian University in 1900; thus, he was not able to concentrate working on the *Flora* (Köhler, 2002, p. 143).

2.2. Research Projects and Their Results

The first geobotanical research conducted in Kraków was the flora in the vicinity of Kraków (Table 1), written by Feliks Berdau (1859) – Herbich's associate and former assistant of Professor Czerwiakowski. The publication of that research hinted at the future establishment of Kraków Geobotanical School. In the following decade, before the activity of the Physiographic Commission began, Franz Herbich published two geobotanical works on *Xanthium spinosum* and contributed to the phytogeography of Galicia. In the latter case, he made the first proposal to divide Galicia into geobotanical units: he designated a characteristic species to serve as a landmark for each of those units. Rehman published a comparable number of works on mosses, liverworts, and vegetation of the Beskidy Zachodnie Range (Table 1). When the botanical research plan of the Physiographic Commission was announced, several experts and amateur botanists, including high school teachers, priests, and pharmacists, conducted their own research and sent their results to Kraków. The areas of Galicia were often selected as study sites, especially the Beskidy Zachodnie Range, Eastern Carpathians, and Tatra Mountains. Over 700 papers were published from those studies, nearly half of which reported the results of phytophenological observations. Among the non-phytophenological studies, most papers reported the floristics of various groups of plants and fungi. Initially, only floristic notes had been published; since 1870, regional floras containing data on more than 600 species have also been published. Additionally, studies on the systematics of various groups of plants and fungi have been published. However, few studies have been conducted in the field of phytogeography (Table 1).

The early years following the establishment of Kraków Geobotanical School were characterized by an increase in the number of amateur botanists and significant representation of school participants across Galicia. Most of the participants were former associates of Herbich, who later collaborated with the Physiographic Commission. The collection of herbarium specimens and preparation of the inventory of the flora of vascular plants began during the early years of scientific activity at Kraków Geobotanical School. Based on these resources, the first geobotanical hypotheses were proposed – for example, concerning the phytogeographic boundary between the Eastern and Western Carpathians. The study of lower plants and fungi began with the collection and description of specimens belonging to newly identified taxa. The research plan defined by Czerwiakowski was implemented in the subsequent periods; however, some aspects of the plan have not yet been implemented (Köhler, 2008c).

Table 1 The areas and topics of geobotanical research conducted by Kraków Geobotanical School in 1859–1903.

Area of research	Topics of research	Authors of major studies
Galicia	Flora	Knapp (1872)
	Flora of the Bóbrka/Bibrka County	Gustawicz (1880)
	Flora of the inter-river of the Zbrucz/Zbruch and the Seret	Śleńdziński (1878, 1879, 1881)
	Flora of the vicinity of Lwów/Lemberg/Lviv	Gutwiński (1892, 1893)
	Flora of the vicinity of Stanisławów/Ivano-Frankivsk and Kołomyja/Kolomyia	Rehman (1873)
	Flora of the vicinity of Tarnopol/Ternopil, Czortków/Chortkiv and Złoczów/Zolochiv	Rehman (1874, 1875)
	Janów Foothills, Podole/Podilla	Król (1878)
Carpathians	Phytogeography	Herbich (1864, 1866); Rehmann (1864)
	Vegetation of Beskids Range	Rehmann (1866)
	Vegetation of the vicinity of Oporów/Oporiv and Łomnica/Limnycia River (Eastern Carpathians)	Wołoszczak (1892)
Kraków – vicinity	Flora	Berdau (1859)
	New species of slime molds	Raciborski (1884)
Africa	Geobotany of southern part of the continent	Rehman (1880)

3. The Romantic Period: The Completion of Long-Term Research Projects, 1903–1917

3.1. Headmasters

After Rostafiński, Edward Janczewski (1846–1918) supervised the botanical research during 1903–1913, as the chairperson of the botanical section of the Physiographic Commission. Janczewski graduated from the University of St. Petersburg (1868) and continued his education in German universities (1869–1872). In 1875, he became a professor of plant anatomy and morphology at the Jagiellonian University (Majewski, 2000). Aside from his accomplishments in the field of his specialty and genetics, he also had important contributions to plant systematics, including a monograph on the genus *Ribes* (Janczewski, 1907; Kulpiński, 2011). Janczewski organized the preparatory work for the descriptive Polish *Flora* (Köhler, 2002, p. 143).

The aforementioned botanists were not the headmasters of the geobotanical school. They did not gather a group of students and supporters around them. Therefore, they created a science school of the first type: a network of scientists – experts and amateurs – who pursued a common goal in conducting a research project.

The botanist who could be considered the first headmaster of Kraków Geobotanical School was Marian Raciborski (1863–1917); he continued the organizational activities of his predecessor from 1913 until his death in 1917. Raciborski graduated from the Jagiellonian University. He obtained his doctorate from the University of Munich and worked at the Jagiellonian University during 1885–1892 as an assistant at the chair of botany and the Botanical Garden; from 1912 until 1917, he served as a professor and director of the Botanical Institute (from 1913) and the Botanical Garden. For nearly 4 years, (1896–1900) he stayed in Java (then the Dutch East Indies, now Indonesia), where he conducted research, mainly in the field of fern systematics, mycology, and phytopathology. After he had returned to Galicia, he became a professor at the Agricultural Academy (until 1901, the National School) in Dublany, near Lwów/Lemberg, and then at the University of Lwów (1903), where he established the Biological-Botanical Institute in 1907. He became a professor at the Jagiellonian University in 1912; in 1913, he established the Botanical Institute (Piekiełko-Zemanek, 1986, pp. 30–38). For many years, Kraków Geobotanical School has been associated with this institute.

3.2. Research Projects and Their Results

Several long-term research projects were completed during the brief Romantic period, which only lasted from 1903 until 1917. These include the descriptive *Flora polska* [Polish flora], *Atlas flory polskiej (Florae polonicae iconographia)* [Atlas of Polish flora], and *Flora Polonica Exsiccata*.

The development of the Polish *Flora* began in 1904 under the direction of Franciszek Błoński (1867–1910), a doctor and botanist in Ukraine (then Russia), and then under the direction of Franciszek Kamiński (1851–1912), professor at the University of Odessa (Russia). The planned *Flora* was to cover all Polish lands under partition and all groups of plants, fungi, slime molds, and bacteria. The development of the *Flora* was to be carried out by a team. Simultaneously, Hugo Zapałowicz (1852–1917), a retired military lawyer and an excellent botanist, began checking the correctness of determination of the herbarium collections of the Physiographic Commission (Domański, 1998; Köhler, 2015d). Zapałowicz collaborated with the Physiographic Commission since 1880. He was also the author of a geobotanical study conducted in Babia Góra (Zapałowicz, 1880). Due to insufficient funding for the publication of the *Flora* in 1909, the planned number of volumes was reduced to three, and its scope had been limited to plants. This time, further revisions of the *Flora* had to be managed by Józef Paczoski (1864–1942), who was working in Kherson, Ukraine (then Russia). The work on the *Flora* was interrupted by World War I (Köhler, 2002, pp. 143–146).

Marian Raciborski initiated the development of the *Atlas of Polish Plants* (illustrated flora) in the spring of 1914, the second project planned during this period. Several

Table 2 The areas and topics of geobotanical research conducted by Kraków Geobotanical School in 1903–1917.

Area of research	Topics of research	Authors of major studies
Galicia	Epilithic lichens	Malinowski (1911)
	Flora	Wierdak (1916); Zapałowicz (1906, 1908, 1911)
	Geobotany of Polish lands	Raciborski (1912b, 1912c, 1912d)
	History of vegetation of Polish lands	Raciborski (1912a)
	Mykobiota	Namysłowski (1909, 1910, 1911, 1914); Rouppert and Wróblewski (1911); Wodziczko (1911)
	Pontic element	Raciborski (1916)
	Taxonomy and distribution of chosen vascular plants	Malinowski (1910a, 1910b); Żmuda (1915b, 1915c, 1916a, 1916b)
Carpathians	Flora of bryophytes	Kulesza (1914)
	Flora of caves	Żmuda (1915a)
	Tatras – Flora of algae	Gutwiński (1909)
Kraków	Flora of bryophytes of the vicinity of Wieliczka (near Kraków)	Żmuda (1912)
	Genus <i>Viola</i>	Żmuda (1913)
	Mykobiota of the vicinity of the town	Namysłowski (1906)

people began illustrating the domestic plant specimens. Unfortunately, the project was discontinued because of World War I and the untimely demise of Raciborski.

The third project begun during this period involved exsiccates. The first Polish serial exsiccate, *Flora Polonica Exsiccata*, was published in Lwów by Antoni Rehman and Eustachy Wołoszczak (1835–1918), with the help of Władysław Dybowski (1838–1910) (Mandecka et al., 1998). Raciborski organized a network of associates who collected enough plant specimens, which were intended to be used for future sets of herbarium exsiccates. Unfortunately, this project was interrupted by World War I and the untimely death of Raciborski.

The phytogeographic study of Polish lands was another proposal planned during this period. It was only completed in the subsequent period as a monograph – *Szata Roślinna Polski* (A. Zemanek, 2007, p. 39; B. Zemanek, 1986, pp. 90–94).

The last area of scientific activity planned by Raciborski was natural protection. As one of the first advocates of natural protection in the world, he lectured in universities in Lwów and Kraków. He wrote important works in this field and instilled the idea of nature protection to a large group of students (Mirek & Piękoś-Mirkowa, 2007; A. Zemanek, 2007, pp. 39–40).

A list of geobotanical studies conducted from 1903 until 1917 is presented in Table 2.

4. The Classical Period: New Ideas and Research Techniques, 1917–1970

4.1. Headmasters

From 1917 to 1960, Władysław Szafer (1886–1970) headed Kraków Geobotanical School. He studied at a university in Vienna and graduated from a university in Lwów, where he obtained a doctorate. During 1918–1960 (with a break during World War II), he served as a botany professor at the Jagiellonian University and the director of the Botanical Garden. In 1953, he managed the Institute (until 1956, Department) of Botany at the Polish Academy of Sciences in Kraków. In 1952, he organized the Department of Nature Conservation, which has been operating within the Polish Academy of Sciences since 1953 (Köhler, 2009b).

After Szafer's retirement, Bogumił Pawłowski (1898–1971) headed Kraków Geobotanical School for nearly a decade. He graduated from the Jagiellonian University, where he obtained his doctorate and habilitation; he also served there as a professor from 1951 to 1965. During 1965–1969, he was the director of the Institute

of Botany at the Polish Academy of Sciences, succeeding Szafer. He was an excellent systematist and expert on the flora of the mountains of Europe (Kornaś, 2000).

4.2. Research Projects and Their Results

From the end of World War I to the end of the 1960s, scientific activities at Kraków Geobotanical School were focused on the completion of the multivolume descriptive *Flora polska* [Polish flora]. The creation of the *Flora* was planned during the preceding period. The first volume was released in 1919, while the eleventh volume was published in 1967. While working on the *Flora*, Szafer suffered from financial difficulties and inadequacy of qualified systematists to collaborate with (Köhler, 2002, p. 147). At the same time, the *Atlas flory polskiej (Florae polonicae iconographia)* [Atlas of Polish flora] was being developed. The *Atlas* was published less regularly than the *Flora*. In 1930, Volume 3, Issue 2 of the *Atlas* was the first to be published. Twenty issues had been published until the end of the 1960s. Throughout this period, Szafer encountered enormous financial problems in printing the individual issues (Köhler, 2002, p. 147).

Since a handy field flora has not yet been developed at that time, Szafer, Pawłowski, and Stanisław Kulczyński (1895–1975) published *Rośliny polskie* [Polish plants] in 1924 (Table 3). According to Janusz B. Faliński (1934–2004), an outstanding geobotanist, it was not only a field flora that provided keys to the determination of all vascular plants but also a summary of research on the flora of Poland; it contained hypotheses about how certain species might have occurred (Faliński, 2007, p. 90). In 1953, *Rośliny polskie* was published in a revised form; since then, it was subsequently edited until 1992. At the same time, floristic and taxonomic studies of other groups of plants, including mosses and algae, were created (seven volumes of Polish freshwater flora from 1963 to 1968); the popular key for the determination of mushrooms was also developed (Table 3).

4.2.1. Phytosociology

On Szafer's initiative, phytosociology was introduced in Poland in 1923. It was developed by Josias Braun-Blanquet (1884–1980), a Swiss-French botanist. The first studies using this method were conducted in the Tatra Mountains by Szafer, Kulczyński, and Pawłowski. Phytosociology, as defined by Braun-Blanquet, is one of the “pillars” of Kraków Geobotanical School. During the interwar period, this method was utilized in research conducted in the Tatra Mountains, selected areas of southern Poland, the Eastern Carpathians, and the Balkans. The phytosociological map developed by Szafer et al. for the Tatra Mountains was the first phytosociological map in the world based on the method developed by Braun-Blanquet (Table 3). The application of the phytosociological method resulted in hundreds publications in Poland and other countries (A. Zemanek, 2007, p. 43). In the Stalinist era, “creative Soviet Darwinism” (later called Lysenkoism) was promoted in Poland. Lysenkoism challenged phytosociology as “imperialist science.” To counter this, several conferences were organized in Kraków; the conference participants demonstrated that phytosociological and typological forestry methods could be reconciled. As a result, phytosociology has continued to be applied in Poland (Köhler, 2008b, pp. 109–110, 2010c, p. 330; Stachurska-Swakoń et al., 2022).

Phytosociological studies were carried out in Małopolska Upland, including Ojców National Park; in the Western Carpathians, including the Tatra Mountains, Pieniny Mountains, Gorce Range, Beskid Niski Range, Babia Góra Mountain, Gubałówka Mountain, and Polica Mountain; and in the Eastern Carpathians, including the Czywczyn Mountains. More important research topics are summarized in Table 3.

4.2.2. Paleobotany

Another method that Szafer introduced into Polish science was pollen analysis. This method was developed in 1916 by Lennart von Post (1884–1951), a Swedish geologist. Immediately after 1922, Szafer organized an informal group of

paleobotanists at the Botanical Institute of the Jagiellonian University. The team worked on the numerous sites using the pollen analysis method.

Their aim was to recreate the postglacial history of forests in Poland. Based on these data, Szafer was able to draw the first isopollen map. In 1935, he first used the isopollen map method to interpret the dispersal of species of trees. Isopollen maps reflect the statistical dispersal of a given plant species (initially trees) over a given area. This method was accepted by the scientific community, described in palynology textbooks, and is still being used today (Köhler, 2021). The reconstruction of the history of the flora of Poland during the Pleistocene and Holocene epochs was initiated in these studies (Table 3). Archaeobotanical research was also initiated at Kraków Geobotanical School under the supervision of Szafer. The objective of this research was to replant the plant specimens recovered from archaeological excavations.

4.2.3. Ecology

During this period, several research topics in plant ecology were explored. The most frequently studied plant communities were the following: rocky and xerothermic grassland complexes in Kraków-Częstochowa Upland, including Ojców National Park; the Cieszyn Foothills; and various ranges in the Western Carpathians, including Beskid Niski, Beskid Wyspowy, Bieszczady, and the area around Nowy Targ. In North America, such studies were conducted in southeastern Canada and North Carolina, United States.

Meadow communities were studied in the upper Vistula Valley, northern Tatra Mountains, Podtatrze region, and Gorce Range. Weed communities were investigated in Kraków-Częstochowa Upland, Vistula Valley, Tatra Mountains, Pieniny Mountains, and Gorce Range. Moreover, other plant community types, including the underwater community at the bottom of the Baltic Sea, were also investigated. Research on the productivity of plant communities was also conducted in connection with the International Biological Program (1964–1975). Some of these studies were conducted at Ojców National Park. Of the less frequently chosen topics, the succession of plant communities on the riverside of mountain streams and the ecology of plant dispersal have been investigated. The upper forest border in the Tatra Mountains (Western Carpathians) and Czarnohora Range (Eastern Carpathians) was surveyed. Plant species ranges were also studied in the Lublin Region. The biology of flowers in Kraków-Częstochowa Upland was studied. As part of the creation of *Flora Europaea* (1964–1980), Pawłowski prepared several taxonomic studies of important genera (*Alchemilla*, *Delphinium*, *Symphytum*). A list of these issues is provided in Table 3.

4.2.4. Plant Geography

During the Classical period, the main achievements garnered in the field of phytogeography include publications on a majority of plant elements, including boreal and Arctic-mountain, steppes, and mountain element in the lowlands. Pawłowski developed the concept of distinguishing vegetation belts based on the ranges of climax communities and, strictly related to it, the classification of high-altitude elements: lowland and mountain (mountainous, subalpine, alpine, and mountain) (B. Zemanek, 2012). Detailed floristic data were collected and regional geobotanical monographs were published. The best template for such a geobotanical monograph was developed and has been commonly adopted in Polish literature. The publication of regional geobotanical monographs ensured the comparison and synthesis of the results of geobotanical studies.

Due to several published monographs, the Carpathians became one of the most geobotanically studied mountain systems in the world (Kornaś & Medwecka-Kornaś, 2007, pp. 121–122). At that time, the creation of the *Atlas of the Distribution of Vascular Plants in the Polish Carpathians* began, but it has not been published yet. The aim of geobotanical research during that period was to determine the individual Carpathian mountain ranges. Research on the causal relationships between the components of phytocoenoses, between vegetation and habitat,

Table 3 The areas and topics of geobotanical research conducted by Kraków Geobotanical School in 1917–1970 (examples).

Area of research	Topics of research	Authors of major studies
Poland	Atlas of Polish vascular plants	Kulczyński (1930, 1931a, 1931b, 1932, 1936a, 1936b)
	Biology of flowers	Szafer (1969)
	Elements of flora	A. Kozłowska (1931); Kulczyński (1927); Szafer (1930a)
	Identification keys to freshwater flora	Mrozińska-Webb (1969); Siemińska (1964); Starmach (1963, 1966, 1968a, 1968b)
	Identification keys to mosses	Szafran (1957, 1961, 1963)
	Identification keys to mushrooms	Gumińska and Wojewoda (1968); Wojewoda (1977)
	Identification keys to vascular plants	Pawłowski (1963, 1967); Raciborski and Szafer (1919); Szafer (1921, 1927, 1930b, 1935, 1947); Szafer et al. (1924); Szafer and Pawłowski (1955, 1959, 1960)
	Vegetation	Szafer (1959, 1965)
	History of botany in Kraków	Szafer (1964)
	Phytogeography	Szafer (1949, 1952)
Baltic Sea	Bottom plant communities of the Gdańsk Bay	Kornaś and Medwecka-Kornaś (1948); Kornaś et al. (1960)
Carpathians		
– Babia Góra	Plant communities	Walas (1933)
– Beskid Niski Range	Forest communities	Grodzińska and Pancer-Kotejowa (1965)
– Beskid Wyspowy Range		Staszkievicz (1964)
– Bieszczady Mts		Zarzycki (1963)
– Carpathian Foothills	Plant communities by mountain streams	Zarzycki (1956)
– Cieszyn Foothills	Plant communities	A. Kozłowska et al. (1936)
– Czywczyn Mts (Eastern Carpathians)	Upper edge of forest	Środoń (1948)
– Gorce Mts	Flora, geobotany, and synanthropic communities	Kornaś (1955, 1957, 1968)
	Forest communities	Medwecka-Kornaś (1955)
	Non-forest communities	Kornaś and Medwecka-Kornaś (1967)
	Plant communities	Medwecka-Kornaś and Kornaś (1968)
– Gubałówka Range		Grodzińska (1961); Pancer-Kotejowa (1965)
– Nowy Targ Basin	Peat bog algae	Wasylik (1961)
– Pieniny Mts	Plant communities, phytosociological map	Kulczyński (1928)
– Polica Mt	Forest communities	Stuchlik (1968)
– Sądecczyzna (Nowy Sącz region)	Geobotany	Pawłowski (1925)
– Tatras	Flora	Pawłowski (1956)
	Migration of mountain plants along rivers	Walas (1939)
	Phytosociological studies and maps	Pawłowski et al. (1928); Szafer et al. (1923)
	Plant communities of hay meadows	Pawłowski et al. (1960)
	Population studies	Kotańska (1967)
	Upper edge of forest	Sokołowski (1928)

Continued on next page

Table 3 Continued.

Area of research	Topics of research	Authors of major studies
Kraków-Częstochowa Upland	Biology of flowers in saxicolous communities	Kornaś (1949)
	Bryoflora	Szafran (1955)
	Communities of cultivates areas	Kornaś (1950)
	Forest communities	Medwecka-Kornaś (1952)
	Psammophilous communities	Kornaś (1957)
	Saxicolous and xerothermic grasslands, forest complexes	A. Kozłowska (1923, 1925, 1928)
	Saxicolous communities of lichens	J. Nowak (1960)
– Ojców National Park	plant communities (map and descriptions)	Medwecka-Kornaś and Kornaś (1963)
Upland of southern Poland	Bryoflora and geobotany	Kuc (1964)
Roztocze Range	Tree ranges depending on the environment	Brzyski (1959)
Arctic (Spitsbergen)	Bryoflora	Kuc (1963)
France	Garrigue vegetation of Montagra de la Gardiole	Kornaś (1958)
North America	Forest communities	Kornaś (1970); Medwecka-Kornaś (1961)

competition among higher plants, autecological research, and population research on both native and alien species received increasing attention as time went by (Grodzińska et al., 2013, p. 112). Handbooks, including *Zarys ogólnej geografii roślin* [The outline of plant geography], *Szata roślinna Polski* [The vegetation of Poland] (English version: Szafer, 1966), and *Zarys paleobotaniki* [The outline of paleobotany] were published (Table 3).

4.2.5. Nature Conservation

Since the start of his scientific career, environmental protection has been at the core of Szafer's activities. As early as 1919, he organized and headed the government's Provisional State Commission for Nature Conservation; since 1926, it has been referred to as the State Council for Nature Conservation. Aside from inspiring numerous researchers and activists, Szafer is one of the most distinguished figures in nature protection in Poland. He published hundreds of articles and was the founder of the journals *Ochrona Przyrody* [Nature protection] (1920) and *Chrońmy Przyrodę Ojczystą* [Let's protect our native nature] (1945). He was the editor of the pioneering worldwide handbook *Ochrona przyrody i jej zasobów* [Protection of nature and its resources] (Szafer, 1965). Through his initiative, six national parks and several hundred nature reserves were established. Other members of Kraków Geobotanical School (including Adam Jasiewicz, Jan Kornaś, Anna Medwecka-Kornaś, Bogumił Pawłowski, and Jan Walas) were also involved in the creation of national parks in southern Poland, study of nature, and preparation of protection plans.

The achievements of Kraków Geobotanical School include the development of the concept of active protection of seminatural communities. A number of projects were undertaken: collection and processing of data on the diversity of all groups of Polish flora and preparation of national as well as regional synthetic studies on various aspects of protection. The significance of these projects reached far beyond the developed region (Table 3) (Mirek & Piękoś-Mirkowa, 2007; Parusel & Stachurska-Swakoń, in press).

4.2.6. History of Botany

After his retirement, Władysław Szafer applied the scientific method in conducting research on the history of botany. The findings of his research were compiled in

Zarys historii botaniki w Krakowie na tle sześciu wieków Uniwersytetu Jagiellońskiego [An outline of the history of botany in Kraków on the background of the 6 centuries of the Jagiellonian University] (Table 3).

5. The Duumvirate Period, 1971–1993

5.1. The Headmasters

From the death of Pawłowski in 1971 to around 1993, the eighth-generation botanists at Kraków Geobotanical School had already become leaders. During the Romantic period, the Institute of Botany and the Department of Nature Conservation at the Polish Academy of Sciences were established. At that time, the Department of Plant Systematics and Geography at the Jagiellonian University was already operating (since 1970 the Department of Plant Systematics and Geography has become a part of the Institute of Botany). Two closely coordinating botanical research centers started to function. At that time, these centers were managed by different persons (hence, the title of the chapter: duumvirate): Jan Kornaś headed the Institute of Botany at the Jagiellonian University, while Adam Jasiewicz headed the Institute of Botany at the Polish Academy of Sciences.

Jan Kornaś (1923–1994) graduated from the Jagiellonian University, where he obtained his doctorate degree; he served as a professor from 1963 to 1993. He completed his education at the SIGMA Geobotanical Station (1957) and in the United States of America (Duke University in Durham, North Carolina, and Washington State University in Pullman, 1961). Aside from working in Kraków, he worked for several years in Africa: at the universities in Lusaka, Zambia, (1971–1973) and Maiduguri, Nigeria (1977–1978). He was a leading Polish botanist in the second half of the twentieth century (A. Zając, 2000).

Adam Jasiewicz (1928–2001) supervised geobotanical research at the Institute of Botany at the Polish Academy of Sciences from 1966 to 1992. He graduated from the Jagiellonian University, where he obtained a candidate's degree in 1958 (equal to a doctorate). He continued his education at the SIGMA Geobotanical Station (1958). From 1973 to 1992, he served as a professor at the Institute of Botany at the Polish Academy of Sciences. The main area of his research was plant systematics (Köhler, 2010b).

5.2. Research Projects and Their Results

During this period, the last volumes of the descriptive *Flora polska* were compiled and published: Volumes 12, 13, and 14 were published in 1971, 1972, and 1980, respectively (Table 4). Another 12 issues of the *Atlas flory polskiej (Florae polonicae iconographia)* were also published. The last issue was published in 1990, after which the publication was discontinued. During 1985–1992, new editions of Volumes 3, 4, and 5 of *Flora polska* were published under the revised title, *Flora Polski. Rośliny naczyniowe* [Flora of Poland. Vascular plants] (Table 4). Jan Kornaś, together with a group of collaborators, contributed to the creation of the atlas of the distribution of species of European flora (*Atlas Florae Europaeae*, 1972) by collating the geobotanical data collected in Poland. Keys covering other groups of plants, algae, and fungi were also published. During 1972–1983, another six volumes of *Flora słodkowodna Polski* [Polish Freshwater Flora] were produced; these provided the most complete keys to the determination of algae (Wołowski et al., 2013, p. 159). Further volumes of *Polish Flora: Fungi (Mycota)* were also prepared. In the 1980s, Ryszard Ochyra conducted taxonomic and phytogeographic research on bryophytes in the southern hemisphere. These studies include, inter alia, taxonomic reviews of water mosses belonging to the Amblystegiaceae family sensu lato. At the end of the 1980s, Maria Olech began researching polar lichens, mainly on King George Island (western Antarctica) (Köhler & Olech, 2011a, 2011b).

Ecological research was conducted on plant species in Poland, including those inhabiting the Bieszczady Mountains and the forests in the Carpathians, and in Antarctica, mainly on King George Island (western Antarctica). Population studies have been performed since 1976. Research on the succession of natural vegetation

(e.g., in the Niepołomice Forest) and synanthropic communities was conducted. Plant dispersal in the forests of southern Poland was also investigated. Research on various types of communities in the Carpathians, including forests, meadows, and arable lands was conducted. Weed communities in Małopolska Upland were appraised. Outside Poland, research on forest communities was carried out in Macedonia, the Khangai Mountains of Mongolia, and India. Phytosociological studies on the Pieniny Mountains, lichens in high-mountain calcareous grasslands of the Tatra Mountains, and numerical classification of forest communities in the Polish Carpathians and Małopolska Upland were also published. The objective of the phytosociological research conducted in the Pieniny Mountains was to determine the vegetation and factors shaping the species composition of phytocoenoses. Studies on the role of archaeophytes in a synanthropic flora were also conducted. The abovementioned studies have led to the understanding of the biology and ecology of the population of perennial species, mechanisms of plant community succession, and the role of the seed bank in the dynamics of vegetation (Grodzińska et al., 2013, p. 116). On the occasion of research on the biology and ecology of vascular plants *Ecological Indicators of Vascular Plants in Poland* was developed (Table 4). As part of the International Biological Program (1964–1975), some research on the productivity of plant communities and ecosystem characteristics was continued. The results of those research led to the describe and explain of biomass and productivity of the meadows in the Gorce Range.

Since 1986, “red lists” of Polish vascular plants, mosses, lichens, fungi, and algae have been published (Grodzińska et al., 2013, p. 116); the first of which to be published was the *Red Book of Polish Algae*. The series also include the *Polska czerwona księga roślin* [Polish red book of plants] (Table 4). A monograph on Marian Raciborski, one of the leading figures of Kraków Geobotanical School, was published. The most important handbooks published at that time were *Szata roślinna Polski* [The vegetation of Poland] and *Geografia roślin* [The geography of plants] (Table 4).

6. Descendant Schools: Completion of Great Works With Traditional (Morphological) Methods, 1994–2010

6.1. Research Headmasters and Organizers

From 1994 to 2010, the function of the headmaster at Kraków Geobotanical School had gradually disappeared. During this period, the school structure had undergone a final revision. A particular research team – supervised by specialists, most often by professors – was assigned to conduct research on each group of organisms: plants, algae, and fungi. Such restructuring was necessary to keep pace with a rapidly advancing specialization in each research field; one person (formerly a headmaster) could no longer conduct research in all major branches of botany. The role of the headmaster was assumed by three professors who conducted geobotanical research: Adam Zajac and Maria Zajac (1955–2018) at Jagiellonian University and Zbigniew Mirek at the Institute of Botany at the Polish Academy of Sciences. By the end of the 1950s, the students of W. Szafer and B. Pawłowski began conducting scientific activities. During 1963–1968, Professor Bronisław Szafran (1897–1968) was at the forefront of biological research (Köhler, 2009c). Ryszard Ochrya conducted his research in 1976. The following scientists conducted ecological research at two renowned research institutions in Poland: Kazimierz Zarzycki and Krystyna Grodzińska at the Institute of Botany at the Polish Academy of Sciences and Anna Medwecka-Kornaś, Zbigniew Dzwonko, Stefania Loster, Krystyna Towpasz, Helena Trzczińska-Tacik (1936–2020), Eugeniusz Dubiel (1939–2021), and Bogdan Zemanek at the Institute of Botany at Jagiellonian University. Phycological research was first conducted by Karol Starmach (1900–1988) in 1953; he was succeeded by Jadwiga Siemińska (1922–2018) and later on by Konrad Wołowski. In 1969, lichenological research was conducted simultaneously by various scientists at two different institutions: Janusz Nowak (1930–2004) (Köhler, 2010a); Maria Olech at the Institute of Botany at Jagiellonian University; and Józef Kiszka (1939–2007) (Köhler, 2015b) at the Pedagogical University in Kraków. Mycological research was conducted by Władysław Wojewoda (1932–2010), followed by Andrzej Chlebicki at the Institute of

Table 4 The areas and topics of geobotanical research conducted by Kraków Geobotanical School in 1971–1993 (examples).

Area of research	Topics of research	Authors of major studies		
Poland	Adaptation of the scale of indicator species to the conditions in Poland	Zarzycki (1984)		
	Biosystematics of genus <i>Viola</i>	Kuta (1991)		
	Identification keys to algae	Starmach (1972, 1974, 1977, 1980, 1983)		
	Identification keys to fungi	Wojewoda (1977, 1981)		
	Identification keys to lichens	J. Nowak and Tobolewski (1975)		
	Identification keys to vascular plants	Jasiewicz (1980, 1985, 1987, 1992); Pawłowski and Jasiewicz (1971, 1972)		
	List of threatened plants	Zarzycki and Wojewoda (1986)		
	Modeling of population growth and dynamics	Dzwonko (1981)		
	Origin of archaeophytes	A. Zając (1979)		
	Red book of plants	Zarzycki and Kaźmierczakowa (1993)		
	Red list of algae	Siemińska (1986)		
	Vegetation	Szafer and Zarzycki (1972, 1977)		
	History of botany	Kornaś (1986)		
	Phytogeography	Kornaś and Medwecka-Kornaś (1986)		
	Manual Carpathians	Forest communities	Dzwonko (1984)	
		– Beskid Mały Range	Flora	Kotońska (1991)
		– Beskid Niski Range	Forest communities	Staszkiwicz (1973)
– Beskid Wyspowy Range		Flora, geobotany	Towpasz (1974, 1975)	
– Beskidy Zachodnie Range		Communities of epiphytic lichens	Bielczyk (1984)	
		Distribution of lichens	J. Nowak (1972)	
– Beskid Żywiecki Range		Flora of Pilsko Mt	Białecka (1982)	
– Bieszczady Mts		Flora, geobotany	B. Zemanek (1989)	
– Gorce Mts		Plant dispersal in segetal communities	Kornaś (1972)	
		Communities changes	Kotańska (1977)	
– Kolbuszowa Plateau		Flora, geobotany, methodology	Dubiel et al. (1979, 1983a, 1983b, 1983c)	
– Nowy Targ Basin		Forest communities, vegetation	Staszkiwicz (1958, 1992)	
– Pieniny Mts		Forest communities	Dzwonko (1977)	
		Mosses	Ochyra (1982)	
		Nature	Zarzycki (1982)	
		Plant communities	Grodzińska (1975)	
		Populations of rare and endangered species	Zarzycki (1976)	
– Słonne Mts		Geobotany	B. Zemanek (1981)	
– Strzyżów Foothills			Towpasz (1990)	
– Tatras		Ecology of meadow species	Kotańska (1985)	
		Lichens of alpine grasslands	Olech (1985)	
– Valley of the Biała Dunajcowa		Geobotany	Medwecka-Kornaś (1976)	
– Valley of the Dunajec		Vegetation of the banks of dam reservoirs	Loster (1976)	
– Valley of the upper Raba		Water and mud flora	Loster (1973)	
– Wieliczka Foothills		Succession in seminatural meadow communities	Dubiel (1984); Kotańska (1993)	
		Population studies	Towpasz and Szyska (1983)	

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Table 4 Continued.

Area of research	Topics of research	Authors of major studies
Małopolska Upland		
– Dulowa Forest	Flora	B. Zemanek (1974)
– Karst sink-holes in the vicinity of Staszów	Flora, vegetation	Ochyra (1979, 1980, 1985)
Kraków	Map of vegetation	Dubiel (1991)
	Flora	Trzcińska-Tacik (1979)
Niepołomice Forest	Water and mud communities	Dubiel (1973, 2003)
Oświęcim Basin	Flora, geobotany	M. Zając (1989, 1990a, 1990b, 1992a, 1992b)
Skawina (city W of Kraków)	Population studies	Loster (1981)
Africa (Zambia)	Ecology of pteridophytes	Medwecka-Kornaś and Kornaś (1985)
Antarctic (King George Island)	Map of vegetation	Furmańczyk and Ochyra (1982)
Arctic (Spitsbergen)	Map of tundra of Sørkapp Land	Dubiel and Olech (1991)
Asia (Mongolia)	Forest communities of Khangai Mts	Pacyna (1986)
Europe (Macedonia)	Forest communities	Medwecka-Kornaś et al. (1986)

Botany at the Polish Academy of Sciences and by Barbara Gumińska and Katarzyna Turnau at the Institute of Botany at Jagiellonian University. Paleobotanical research was conducted by Krystyna Wasylkowa, Leon Stuchlik, and Magdalena Ralska-Jasiewiczowa (1934–2017); it was carried out by Kazimierz Szczepanek (1931–2021) at the Institute of Botany at Jagiellonian University.

6.2. Research Projects and Their Results

During this period, several important synthetic studies summarizing many years of research were published (Table 5), including the fifteenth volume of *Polish Flora*, which contained indices. Finally, this colossal, 76-year project was completed. The development of the subsequent volumes of the *Flora of Poland* continued (but nothing was published) (Mirek, 2013, p. 271). Another great achievement during this time was the publication of *The Atlas of the Distribution of Vascular Plants in Poland*, which summarizes the research conducted for several years by florists from all over Poland. Serving as the reference for future phytogeographic considerations, it has been greatly valued in Poland and abroad. Another equally important study was the *Checklist of Flowering Plants and Pteridophytes*. The *Ecological Indicators of Vascular Plants in Poland* was developed and published (Table 5). The elaborate description of the geographical elements in the flora of Poland was summarized in classic phytogeographic research. The collective work on the *Atlas of Contemporary Vegetation of Kraków* – a detailed phytosociological map of the city – was the achievement of Kraków Geobotanical School. Until now, this atlas has served as the reference for planning the spatial development of cities. The co-authorship of *Atlas Flora Europaea* by the faculty and staff of Kraków Geobotanical School and other botanists across Europe heralded the school's involvement in international scientific research.

Many regions of the Carpathians and Małopolska Upland served as study sites in several geobotanical monographs. These studies focused on rocky and xerothermic grassland, and meadow communities. Forest communities outside Poland, including those located in the Balkan Peninsula and North America, were surveyed; in those forest communities, new syntaxa units for science were identified. The succession processes on heaps containing heavy metals in southern Poland and in areas exposed to a retreating Antarctic glacier were also studied (Table 5).

The paleoecological monograph of Lake Gościąg and a new monograph using isopollen maps were important achievements in paleobotany. A textbook entitled *The Guide to Archaeobotanical Research* was also published (Table 5).

Table 5 The areas and topics of geobotanical research conducted by in Kraków Geobotanical School in 1994–2010 (examples).

Area of research	Topics of research	Authors of major studies		
Poland	Atlas of distribution of fungi	Chlebicki (2008); Wojewoda (2000, 2002, 2005)		
	Atlas of distribution of lichens	Bielczyk et al. (2002, 2004)		
	Atlas of distribution of mosses	Ochyra and Szmajda (1990a, 1990b, 1991, 1992, 1994)		
	Atlas of distribution of vascular plants	A. Zając and Zając (2001); A. Zając et al. (1997)		
	Checklist of flowering plants and pteridophytes	Mirek et al. (2002)		
	Checklist of larger Basidiomycetes	Wojewoda (2003)		
	Checklist of slime molds	Drozdowicz et al. (2003)		
	Geographical element of native flora of Poland	M. Zając and Zając (2009)		
	History of vegetation	Ralska-Jasiewiczowa et al. (2004)		
	Identification keys to vascular plants	Mirek (1995)		
	Modification of the adopted scale of indicator species to the conditions in Poland	Zarzycki et al. (2002)		
	Monograph of genus <i>Racomitrium</i>	Bednarek-Ochyra (1995)		
	Red book of Polish pteridophytes and flowering plants	Kaźmierczakowa and Zarzycki (2001)		
	Taxonomy of plants	Zalewska-Gałosz (2008)		
	Carpathians	The red book of the Polish Carpathians. Vascular plants	Mirek and Piękoś-Mirkowa (2008)	
		– Beskid Niski Range	Non-forest communities	Dubiel et al. (1999)
		– Beskid Sądecki Range	Nature	Staszkiwicz (2000)
		Distribution of lichens	Śliwa (1998)	
– Bieszczady Mts		Communities of mountain pastures	Winnicki (1999)	
		Flora	B. Zemanek and Winnicki (1999)	
– Ciężkowice Foothills		Flora	Kornaś et al. (1996)	
– Gorce Mts		Meadow communities	Kozak (2007)	
– Jasło-Sanok Basin		Geobotany	Oklejewicz (1996)	
– Przemyśl Foothills		Succession in seminatural meadow communities	Barabasz-Krasny (2002)	
– Tatras		Taxonomy and distribution of lichens	Krzewicka (2004)	
		Nature	Mirek (1996)	
		Scree communities	Kosiński (1999)	
– Western Carpathians		Population studies on plants	Tumidajowicz (1995)	
		Vegetation changes	Trzcińska-Tacik and Stachurska-Swakoń (2002)	
– Wieliczka Foothills		Flora	Pacyna (2004)	
		Forest communities	Stachurska (1998)	
Małopolska Upland		Euglenophytes	Wołowski (1998)	
		– Heaps near Olkusz	Vegetation and succession	Grodzińska et al. (2000)
		– Iłża Foreland	Flora	M. Nobis (2007); Piwowarczyk (2010)
		– Proszowice Plateau	Flora	Towpasz (2006)
Sandomierz Basin		– Eastern part of the basin	Flora	A. Nobis (2008)
			Mycoflora	Wojewoda et al. (1999)
	– Niepołomice Forest	Flora	Dubiel (2003)	
	– Radomyśl Region	Flora	Wayda (2001)	
	– Tarnów Plateau	Flora	Wayda (1996)	

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Table 5 Continued.

Area of research	Topics of research	Authors of major studies
Kraków and its vicinity	Atlas of distribution of vascular plants (legally protected, vanishing, vulnerable, and rare species)	M. Zając and Zając (1998)
Szczecin Seashore	Atlas of the vegetation	Dubiel and Szwagrzyk (2008)
Antarctic	Flora, atlas	M. Zając et al. (2006)
	Flora of bryophytes	Ochyra et al. (2008)
	Flora of liverworts	Bednarek-Ochyra et al. (2000)
King George Island	Flora of bryophytes	Ochyra (1998)
	Map of lichen communities	Olech (1994)
Asia	Biogeographic relationships between fungi and plants in northern Asia	Chlebicki (2002)
North Korea	Macrofungi	Wojewoda et al. (2004)
Europe	Biogeographic relationships between fungi and plants	Chlebicki (2002)
	Taxonomy of plants	Mitka (2003)
Balkan Peninsula	Forest communities	Dzwonko and Loster (2000)
Carpathian Mts	Syntaxonomy	Stachurska-Swakoń (2009)
North America		
Greenland	Biogeographic relationships between fungi and plants	Chlebicki (2002)
USA	Forest communities	Stachurska-Swakoń and Spribille (2002)
	Euglenophytes	Wołowski and Walne (1997)
	Taxonomic revision of the complex <i>Lecanora dispersa</i>	Śliwa (2007)
Earth	Atlas of euglenophytes	Wołowski and Hindák (2005)
	World monograph of the genus <i>Codriophorus</i>	Bednarek-Ochyra (2006)

In the field of bryology, numerous systematic studies on Holantarctic mosses, the subfamily Racomitrioideae of the moss flora of North America, were published. A study of the bryophyte flora of sub-Saharan Africa, Antarctica, and the islands of the Southern Ocean and South America was conducted. A valuable flora of Antarctic bryophytes was published, including *The Moss Flora of King George Island, Antarctica* (Ochyra, 1998), which was the second flora in Polish literature on a specific group of plants from an exotic area written by a Polish author. Other monographs such as *The Liverwort Flora of Antractica* (Bednarek-Ochyra et al., 2000) and *The Illustrated Moss Flora of Antarctica* (Ochyra et al., 2008) were the first descriptive floras of Antarctic bryophytes. During this period, nine issues of the *Atlas of the Geographical Distribution of Mosses in Poland* (ATMOS) were also published (Ochyra, 2013, pp. 65, 76–80).

The subjects of mycological research were the fungi of glacial relics of Europe, Greenland, and northern Asia; mushroom biota of cities and industrial areas; fungi in caves and mines (2005–2008); and aphylophoroid fungi in the Kashubian Lake District (2007–2010). The *Atlas of the Geographical Distribution of Fungi in Poland* was also published (Table 5).

7. The Period of Decline, 2011–2020

Conducting scientific research within narrow specializations implies that the earlier division of Kraków Geobotanical School into “successive schools” (A. Zemanek, 2007) was justified. Botanists who were not affiliated with Kraków Geobotanical School participated more often in school research. The new research interests of individual scientists as well as the retirement of the previous generation of botanists resulted in less interest in conducting geobotanical research among the faculty and

staff of Kraków Geobotanical School. At that time, there were only a few projects that united botanists to work in teams. However, in other fields, research has developed from the individual research interests of botanists or their participation in research projects conducted by institutions outside Kraków. Researchers from various centers in Poland and abroad collaborated to publish their research in the form of articles or book chapters. New research methods have been developed, particularly those based on molecular techniques. These molecular techniques are particularly important in taxonomy and phytogeography. Examples of published works during this period include studies on, inter alia, *Aconitum*, *Stipa*, and *Potamogeton*. Molecular methods have also been applied to solve the problems of taxa range history, search for refugial areas, and analyze population diversity (Table 6).

Table 6 The areas and topics of geobotanical research conducted by Kraków Geobotanical School in 2011–2020 (examples).

Area of research	Topics of research	Authors of major studies	
Poland	Atlas of distribution of vascular plants	A. Zając and Zając (2019)	
	Invasive species	Bartoszek and Stachurska-Swakoń (2016); Pliszko (2018); Stefanowicz et al. (2017); Tokarska-Guzik et al. (2012); A. Zając and Zając (2015)	
	Manuals of monitoring of plant species and natural habitats	Mróz (2015); Perzanowska (2012)	
	New taxa to Polish flora	K. Kozłowska et al. (2011); Pliszko (2018); A. Zając and Zając (2015)	
	Plant ecology	Barabasz-Krasny et al. (2018); Durak et al. (2015); Kostrakiewicz-Gierałt et al. (2018); Stachurska-Swakoń et al. (2018)	
	Red books and red lists of plant species	Kaźmierczakowa et al. (2014, 2016)	
	Taxonomy of lichens	Krzewicka (2012)	
	Taxonomy of plants	Posz (2014); Zalewska-Gałosz and Kwolek (2014)	
	Carpathians	Plant communities	Vončina (2017)
		Taxonomy of lichens	Wilk (2012)
– Beskid Sądecki Range		Flora	Stawowczyk (2017)
– Carpathian Foothills			Jaźwa and Stadnicka-Futoma (2017); Wolanin (2014)
– Gorce Mts		Ecology of plant communities	Bucała et al. (2015)
– Silesian Beskid Range / Beskid Śląski		Flora	Binkiewicz (2017)
– Tatras		Plant phylogeography	Sutkowska et al. (2017)
Kaszuby	Mycoflora	Karasiński (2016)	
Małopolska Upland	Ecology of plant communities	Dzwonko and Loster (2011); Dzwonko et al. (2018); Towpasz and Stachurska-Swakoń (2012)	
	Flora	Łazarski (2019); Piwowski (2014); Trojecka-Brzezińska (2017)	
		Pliszko (2014)	
Western Suwałki Lakeland			
Asia			
Kazakhstan	Taxonomy of plant species	M. Nobis and Gudkova (2016)	
Tajikistan	Plant communities	A. Nowak et al. (2017)	
Europe	Phylogeography of plant species	Baiakhmetov et al. (2020); Cieślak (2014); Cieślak and Drobnik (2019); Stachurska-Swakoń et al. (2013, 2020); Suchan et al. (2019)	
	Phylogeny of plant species	Boroń et al. (2020); Mitka et al. (2015)	
	Taxonomy of lichens	Śliwa et al. (2012)	
	British Isles	Phyllum Euglenophyta	Wołowski (2011)
	Central Europe	Floristical records	Dudaš et al. (2020)
Other continents	Lichens records	Szczepańska et al. (2019); Śliwa et al. (2014)	

Floristic studies based on traditional field studies were still conducted but to a much lesser extent than in previous periods. These studies were conducted mainly in the Carpathians, Małopolska Upland, and Masurian Lake District. Data on new taxa discovered in the flora of Poland were collected by conducting field research. Botanical research conducted in Central Asia provided data on newly identified taxa (Table 6).

Floristic research has often been conducted together with species mapping. An example of such a research was an atlas illustrating the contemporary distribution of kenophytes in the Carpathians, which was published in 2015. The importance of this study was appreciated by researchers in Poland by awarding the authors the honorable Z. Czubiński Medal. In 2019, a supplement to the *Atlas of the Distribution of Vascular Plants in Poland* was published (Table 6).

However, research on plant communities continued but to a lesser extent. Such studies were carried out in the Carpathians and Małopolska Upland, especially in the context of changes taking place in plant communities (Table 6). In terms of the ecology of plant communities, original studies on the succession of forest communities after wildfires were published. Research on the structure and dynamics of xerothermic grasslands as well as the dynamics related to climate change continued. Several papers on plant communities in Central Asia, including their ecology and the newly discovered taxa were also published (Table 6).

Research on the ecology of plants is concerned with various species, mainly in terms of their features under various environmental conditions as well as reproduction. An important direction in the field of ecology was the research on the ecology of invasive species (Table 6).

At that time, Kraków Geobotanical School developed synthetic studies on the importance of nature protection. Such publications include the *Polish Red Book of Plants*, lists of endangered species, and methodological manuals for monitoring natural habitats and plant species (Table 6).

8. Conclusions and Final Remarks

Kraków Geobotanical School spearheaded the development of botany in Poland and had a great impact on botanical science abroad. The most important scientific achievements of the school are the following: several thousand publications, including monographs and syntheses of knowledge on the Polish flora and vegetation; introduction of new disciplines in Poland (e.g., paleobotany, nature conservation, phytosociology, palynology, study on synanthropization); description of new plant and fungus taxa; identification of syntaxonomic units in Poland and abroad; and development of floristic cartography and history of botany using the scientific method.

In the current formula, Kraków Geobotanical School had ended its scientific activity. This was due to the following factors:

- The leaders retired, and the next generation of scientists faced difficulties in continuing the research initiated by the headmasters (see below). Thus, optimistic forecasts for the future of Kraków Geobotanical School, formulated a decade earlier, did not come true.
- Younger botanists (the present middle generation) did not take the achievements of their predecessors seriously, which is normal in the absence of expert scientists. In the case of Kraków Geobotanical School, this was one of the factors that influenced the termination of the school's operation.
- The policy of the ministry responsible for financing science. This ministry awards gratuities (scores) to research other than geobotany. Young botanists who either want to keep their jobs or be promoted must deal with topics other than geobotany. Doing so enables them to gain points, which serve as the basis for periodic positive assessments and promotions.
- Geobotanical research usually takes a long time to be completed; thus, conducting geobotanical research is discouraged because funding agencies require the completion of a research within a short period (maximum 4 years).

Due to some or a combination of these factors, Kraków Geobotanical School has failed to operate in its current formula. It is unclear whether this would go on temporarily or permanently; nonetheless, it can be said with certainty that Kraków Geobotanical School was a very interesting phenomenon in the history of botany in Poland. It was one of the longest-operating science schools in this part of Europe. Its scientific activity has produced at least several thousand publications. With such a huge contribution and impact to botany, Kraków Geobotanical School deserves a comprehensive historical study.

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