TWO CENTURIES

of the

Białowieża Forest

in

Sylwan Journal

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Preface

In this entire forest nature
there were moments of such peace that
would be sought in vain beyond.
In this peace, one could forget
everything,
even about oneself; one can fall for this
forest…

Henryk Sienkiewicz,
From the Białowieża Forest,
Gebethner & Wolff Publishing House,
1905

Sylwan as a journal is exceptional, and so is the Białowieża Forest, some referring to it as a Temple of Nature.

In Polish literature, the Białowieża Forest was being mentioned in the 15th century by the chronicler Jan Długosz. Władysław II Jagiełło, the first member of the Jagiellonian dynasty, the King of Poland and Grand Duke of Lithuania, hunted with his entourage in theBiałowieża Forest, and then sent the trophies to Kraków. We may assume that the royal procession often traversed the road between Kraków, the capital of the Polish Crown, and Vilnius, the capital of the Grand Duchy of Lithuania, stopping on its way at the hunting manor in the Białowieża Forest. Two visits were described by Jan Długosz. The first of these took place in 1409, when the king spent eight days hunting and then ordering the game he killed to be salted and sent down the rivers in barrels to Płock, so as to have it stocked for the upcoming war with the Teutonic Order. The second time the king visited the forest was in 1426, when he and his wife, Queen Zofia, sought refuge there from a plague. Thus the forest was a both a provider and a refuge. However, the first recorded nature study about the forest, by Gabriel Rzączyński, a Jesuit, occurred in the 18th century, in a work entitled *Natural History of the Kingdom of Poland and the Grand Duchy of Lithuania*, published in 1721.

In the preface to the current book, which contains a selection of articles about the Białowieża Forest published in *Sylwan* over the past two centuries, it is worth recalling several rarely mentioned authors of significant publications about the Forest. They include writers that published their works abroad in the period between the National Uprisings of 1830–31 and 1863–64.

In 1835 and 1836 a three-volume work by Leonard Chodźko was published in Paris under the title *Picturesque Poland*, with some chapters devoted exclusively to the Białowieża Forest. In 1846, a study by Michał Baliński and Tymoteusz Lipiński appeared, which began with the following words to describe the forest: 'This magnificent monument…'

Piotr Szretter, born in the Świetliczyska manor, located on the north-eastern edge of the Białowieża Forest (today's Belarus), is almost completely forgotten. His father came from Hajnowszczyzna, today's Hajnówka, and was, alongside the Superintendent of the Forest, Eugeniusz de Ronke, the leader of the November Uprising in the Białowieża Forest. The main base for the uprising was in the Podcerkiew wilderness (now within the Białowieża Forest District). Piotr Szretter, who knew the forest perfectly, was forced to emigrate to France in the aftermath of the November Uprising. Though having had no formal education in the natural sciences, he is considered by some scientists to be one of the pioneers of forest phytosociology. In his work *A Historical Outline of the Uprising in the Białowieża Forest in 1831*, in passages describing the Białowieża Forest, Szretter presented forest plant formations excellently. What is noteworthy about Szretter's work is the fact that he tended to perceive the Białowieża Forest and its inhabitants as a single organism in which Man plays a vital role by skilfully managing the forest resources.

During the period of Lithuanian-Polish rule, it was the rulers' privilege to hunt big game, as well as to use the wood harvested in the forest. However, the Dukes of Lithuania and Kings of Poland respected the previously acquired rights of local inhabitants. Local people were allowed to enter the forest and benefit from its offerings to satisfy their own needs, while the ruler, in order to guarantee continuity of use, protected the forest and cared for its sustainability. The use and the protection of the forest always went hand in hand.

The oldest known method of exploiting the forest was hunting, organised to supply the state treasury with fur, an alternative to money at the time. The most valuable game species included bison, beaver and elk. Therefore, the Act of 1557 enforced the death penalty for killing big game. Bison were already protected before the Act, since the beginning of the 16th century. Thanks to such solutions, the species survived in the Białowieża Forest, despite being exterminated throughout Europe.

Trade in timber gained in importance when the forests of Western Europe became depleted, while the vast forests located in the East were still abundant in wood of excellent quality. It is likely that timber was harvested and floated down the rivers to Gdańsk as early as the turn of the 15th century, with the income generated from this activity entering the royal treasury. For a fee, local people could obtain wood for the construction of houses and for heating purposes.

Beekeeping was also of high importance, as honey was used as a substitute for sugar and beeswax to make candles, the latter being an important export commodity throughout

Eastern Europe. Beekeepers and honey collectors *podłaźnicy* were occupied with beekeeping, the word used to define the latter profession in Polish being derived from the word *podłaz*, meaning a honeycomb cut from a wild beehive, without harming the bees. In 1796 there were 632 active wild hives in the forest, and 6601 empty hives.

Potash, obtained from wood ash, constituted another benefit of the forest. It was used for bleaching canvas and manufacturing soaps and dyes. It became an export commodity much earlier than wood, and was sent to Gdańsk and Królewiec (Königsberg). Some historians claim that by the 15th and 16th centuries, a huge potash manufacturing industry had been established in the forest, and that the 'colliers', who settled in the villages of Teremiski, Pogorzelce, Budy and Masiewo, were brought to the forest. Tar was used in medicine and to saturate hides. Wood tar, on the other hand, was used as a medication and as a means of impregnating canvas and hides, as a lubricant for axles, for sealing barrels or for attaching arrowheads. Wood tar producers were subject to certain restrictions. They were forbidden, for example, from cutting down trees and were only allowed to dig up roots for calcination. Another commodity made in the forest was charcoal. In 1796, 82 wood tar kilns operated in the Białowieża Forest.

The extraction of dry wood and the picking of mushrooms in the forest were allowed, although attempts were made to limit this exclusively to wardens and shooters who lived in the vicinity of the forest. It was established that strangers were to be denied entry to the forest, especially to tear bast. Linden bast and *łubie*, a product derived from the bast by drying it, were used in the weaving of mats, baskets and primitive footwear, as well as for making ropes. The right to mow meadows constituted one of the most valuable privileges enjoyed by the local population. It was both a form of income for the royal treasury, and was conducive to the protection of animals as well as the entire forest. Cattle's grazing was subject to certain restrictions and could not be done with the use of dogs, and herders were forbidden to work further than a quarter of a mile into the forest. Moreover, herders were also not allowed to light fires. Notwithstanding the restrictions, cattle grazing continued up until the 1960s. Local people were also allowed, with the king's permission, to take advantage of the forest waters and fish.

The Białowieża Forest, the heritage of the local population, both protected and used, retained its identity until the 21st century. Discussions about the forest are ongoing and concern the ways the forest should be defined, how it was formerly, and the role that human beings played in its history. This is especially important today, when it has become apparent how unfortunate decisions have led to the disintegration and dying out of the forests across very large areas. It is easy to see how the landscape is undergoing dramatic changes resulting from human activities. It can also be noticed how the nature of the habitats is changing, how the threats to protected species within the Natura 2000 network are rising, as well as the threats to the people visiting the Białowieża Forest as tourists or as residents of nearby towns.

Contemporary foresters still rely on *Sylwan*, a journal today celebrating its 200th anniversary. The journal has always been involved in issues concerning the Białowieża Forest. An example of this can be found in the decisive opposition by Szymon Wierdak, the longstanding editor of *Sylwan* and an eminent botanist, to the activities of The Century European Timber Corporation, which was destroying the Białowieża Forest. The event took place on 14 September 1925, during the general meeting of the Małopolska Region Forest Society, shortly after a contract with the British company was concluded. Wierdak's speech, in which he condemned this contract, was published in *Sylwan* in the same year.

Only in this, the oldest Polish forest periodical, can articles of great scientific value be found, emphasizing the role of foresters in maintaining the sustainability and beauty of the Białowieża Forest. Sylwan often publishes the results of scientific research, including that conducted by the Department of Forest Silviculture of the Faculty of Forestry at the SGGW [Warsaw University of Life Sciences], which emphasises the crucial role played by foresters for the Białowieża Forest. It is especially worth quoting one opinion from there: 'A well-performed prevention, consisting of the systematic removal of trees infested with tree-boring insects (known as bore-dust trees), thus to limit the depredations of such harmful insects, conducted by the forest administration, which exerted a significant impact on maintaining the spruce stands in the forest' (Brzeziecki et al. 2012, *Sylwan* No. 9).

Two Centuries of the Białowieża Forest in Sylwan Journal, a book published to celebrate the 200th anniversary of this deserving forestry journal, is certain to exert a positive impact on the quality of the ongoing discussion concerning the ways to manage the Białowieża Forest, the adopted methods of forest protection, as well as on the future of the forest itself. Currently, the discussion has moved from Poland to the international arena. Some of the people expressing opinions have never visited the Białowieża Forest, and their opinions are based solely on what they know from literature or the media. In this day and age, when attempts are being made to discredit the achievements of Polish forestry, hunting and nature conservation, it is time for us to consider whether we are treating our heritage adequately well. What course of action should be taken in a situation where the dying out of forests, caused by the negative synergy of many biotic and abiotic factors, takes place and leads to the wilting of millions of the Białowieża Forest's trees? It is worth recalling at this point that the Białowieża Forest has been present on the UNESCO World Heritage List for 40 years, as it encompasses 'the most unusual natural phenomena or areas of exceptional natural beauty and aesthetic significance' (criterion VII).

I wish to encourage readers to familiarize themselves with the articles from *Sylwan* about the Białowieża Forest published in this book, to reflect on the issues contained therein, as well as to attempt to answer some vital questions. What is important to us? What should we pass on to future generations? Which functional model and management methods will be adequate and beneficial to the Białowieża Forest? Will this model and method respect the historically natural, cultural role of the local population, the documented presence of people in the forest of several centuries standing, as well as their harmonious coexistence with the forest?

My hope is that readers will engage in analytical reflection and arrive at accurate answers to these and many other questions. I wish you a satisfactory read.

God bless you and, as the old Polish foresters' saying goes, let the forest bestow its riches upon you.

Andrzej Konieczny, PhD, BEng
Director General
of the State Forests

Warsaw, April 2019

Foreword

The Polish Forest Society has been present in the history of Polish forestry for nearly 140 years. *Sylwan*, a journal focused on forestry-related topics, whose publishing mission was assumed by the Society and has continuously been implemented from the inception of the association to the present day, constitutes a fine jewel within the Society's area of activity. Over its 200-year history, across the pages of *Sylwan*, scientific publications and articles have been published describing issues and dilemmas encountered by forestry, mainly with regard to the Polish lands, which at present form a valuable resource of historical knowledge of supportive and frequently even of an indispensable nature for solving forestry-related problems.

Two Centuries of the Białowieża Forest in Sylwan Journal is a publication that appears under auspicious circumstances. It reaches the readers in the middle of a fierce dispute over how to manage and protect an exceptional natural resource, namely the Białowieża Forest. This dispute is not only of local dimension, but it also confronts the broader problem, namely the concept of nature and biodiversity conservation in forests. At the same time, the discussion assumes the nature of an ideological debate on a national and European scale.

However, the concept of large-scale, active nature protection by means of multifunctional forest management methods, encompassed within the concept expressed by 'Multifunctional forest management as a contemporary form of nature conservation', that has been developed and implemented in recent decades in Polish forestry by the community of foresters is being confronted nowadays with the ideologically and organisationally aggressive idea of dividing the forests into numerous separated areas that would be left to natural processes with the dominance of passive conservation, and other forests oriented towards an intensification of wood production and fulfilling primarily economic functions.

The ideological chaos created in this dispute by the media, who often tend to be interested in the current political game, highlights the need to make the debate more substantive, with reference to scientific and historical knowledge. Against this background an idea has emerged, to benefit from the achievements of scientific thought contained in many articles published in *Sylwan* throughout its entire publishing period. The book *Two Centuries of the Białowieża Forest in Sylwan Journal* is an execution of this thought. It is precisely in this, the oldest forestry journal in Europe, the publication of which has continued for the last 200 years, that numerous pieces of writing may be found which chronologically reflect the facts, the state of knowledge, the dilemmas and the concerns of scientific communities and ideological forestry elites, for the condition of the Białowieża Forest and the ways to treat and manage this unique forest ecosystem. One hundred and thirty articles on this topic, which have appeared over the past two centuries in *Sylwan,* enrich the collection of scientific literature dedicated to the Białowieża Forest and join other numerous publications in this respect, both domestic and foreign. The reading of texts published over the centuries illustrates the changing economic roles and ecological significance of the forest, the changes in its boundaries and of state borders, the multitude of generations of owners and administrators, the variations in its size, methods of forest use and nature protection, the needs and various social expectations in relation to this area, which today is the UNESCO Cultural and Natural World Heritage Site.

Reading the book also leads one to the reflection that the high natural values of the Białowieża Forest observed so far result from both the richness and mosaic nature of its habitats, as well as from the unique history of its use. Since the beginning of mankind, people have been present in the forest and have taken advantage of its riches in many different ways, all of which are well documented in the literature. Considering the basic knowledge concerning the past of the Białowieża Forest, the claim, quite common today, that it constitutes 'the last primeval woodland in lowland Europe' is simply not true. The natural values of the Białowieża Forest are not so much the result of a lack of human activity within it, but rather the effect of the limited scale, scope and intensity of these activities.

The present dispute about the forest and the methods used in nature conservation should not be conducted apart from the historical facts and data or from in-depth scientific analysis. However, if scientific knowledge fails to provide unequivocal solutions in terms of how to protect such a unique resource as the Białowieża Forest, then the resolutions adopted should, with the precautionary principle in mind, outline a compromise between active and passive protection measures, and should leave space for theory and practice to settle the dispute in the future.

The book *Two Centuries of the Białowieża Forest in Sylwan Journal* corresponds well with the celebration of the 200th anniversary of the oldest forestry journal in Europe, which has been a witness to the history of Polish forestry, its organizational changes, numerous problems, silviculture and conservation dilemmas, successes and failures. In 2020, the establishment of this exceptional journal will be celebrated.

One hopes that the publication, prepared by the State Forests Information Centre, created in cooperation with the Polish Forest Society, will offer an opportunity for a more comprehensive application of historical knowledge in order to help society improve its understanding of the complexity of the problems that the Białowieża Forest faces. The publication might also serve as an element to support the formation of lasting, sustainable development for the exceptional area known as the Białowieża Forest.

Janusz Dawidziuk, PhD, BEng
Chairman of the General Board
of the Polish Forest Society

Warsaw, May 2019

Introduction

Sylwan, as a journal, belongs to the small group of the world's oldest scientific periodicals in the field of forestry and forest nature conservation. It has always been published in Polish. In the period between 1820 and 1918, under the Partitions and foreign forest administration, the journal contributed to a sense of national unity among foresters and built both a bond and professional solidarity. Especially in the last century, following the regaining of independence by Poland in 1918, the periodical played a significant educational and popularizing role by raising the levels of knowledge and skills of the foresters. Moreover, the periodical has contributed to the highly appreciated level and state of the forestry in present times. Since 1820, *Sylwan* journal has continuously provided information on innovative achievements in forest economics, the results of scientific research, the activities of the foresters' community, the Galician Forest Society, and later on the Polish Forest Society, as a scientific publication for the last 137 years. In the past, the journal familiarized its readers with aspects of forestry, as it contained translations of important publications from international forestry (mainly German and French). Today, the periodical presents the achievements of foreign scientific institutions as well. It can be said that *Sylwan* has played a major role in shaping the patriotic attitudes of past and present generations of foresters by promoting the idea of service for the benefit of Polish forests and nature. The journal can undoubtedly be seen as a well-known fixture in the landscape of Polish science and research periodicals, a serious, 'live' medium that is constantly being developed.

The history of *Sylwan*, divided into individual periods, has provided the subject for numerous studies. The researchers who have written about the history of the journal include (in alphabetical order): Broda (2000, 2007), Grzywacz (2008), Heymanowski (2008), Kasprzyk (1984), Szczerbowski (1907), and Zarzyński (2000). Significant studies on this topic can be found in the work *Dzieje lasów, leśnictwa i drzewnictwa w Polsce* (1965) [History of Forests, Forestry and Woodworking in Poland], a publication whose subsequent chapters dealing with the historical development of forest literature were prepared by: Tadeusz Marszałek, Wacław Krajski, Antoni Żabko-Potopowicz, Edward Więcko and Nikodem Godera. A comprehensive entry concerning *Sylwan* can be found in *Mała Encyklopedia Leśna* (1991) [Small Encyclopaedia of Forestry]. In 1970, to commemorate the 150th anniversary of the first publication of *Sylwan*, a special, double jubilee issue of the journal (numbers 8 and 9) was prepared, with an imprint on the cover that announced the celebration. In 2002, for the Foresters' Cruise on the Great Masurian Lakes, reprints of the 1st and 2nd issues of *Sylwan* from the 11th volume of 1835 were published. They contained a dissertation by P. Haczewski, 'O Spławie drzewa, z dodatkiem terminologii Orylów, Flisów, Majtków, oraz dwoma tablicami objaśniającemi' [About timber floating, with an addendum on the terminology of log drivers, bargees and deckhands, with two explanatory tables].[1] In 2006, the publication *Ochrona środowiska leśnego na łamach »Sylwana« w latach 1820–1939* [Forest Environment Protection in *Sylwan* in 1820–1939] was published by Łukasz Kontowski and Tomasz Nowak, based on their master's theses (2004) supervised by Professor Bohdan Ważyński. It was published by the State Forests Information Centre.

Sylwan was honoured by the Polish Post with several editions of postcards: on the occasion of its 150th anniversary, marked with '150th anniversary of *Sylwan* forestry journal 1820–1970'; for the Congress of Polish Foresters in Warsaw, on 26 April 1997, with the Congress logo and an image of Silvanus, the Roman deity of forests and wild nature, the same image that the individual title pages of the journal have been embellished with since the first issue of 1820; for the 125th anniversary of the Polish Forest Society, commemorated with a postcard showing a photograph of a tree stand, the cover to volume I of *Sylwan* journal, a photograph of 'Bartek', the monumental oak from Zagnańsk and the Polish Forest Society emblem – the postal stamp of the card featured the traditional badge worn by members of the Galician Forest Society.

In 2020, to celebrate the 200th anniversary of *Sylwan*, the Polish Forest Society is planning to organize a scientific symposium on the state and development prospects of scientific and industry journals in the field of forestry. It is also planned to honour and disseminate this deserving periodical in various ways, as well as to take actions to increase its level and its international bibliometric prestige.

Throughout its entire existence, *Sylwan* has been published under the same title. The subtitles, however, have changed and included: *Sylwan. Dziennik nauk leśnych i myśliwych* [Sylwan. Journal of Forest Sciences and Hunters] (1820); *Sylwan. Dziennik nauk leśnych i łowieckich* [Sylwan. Journal of Forest and Wildlife Sciences] (1830), *Sylwan. Zbiór nauk i urządzeń leśnych i łowieckich* [Sylwan. Selection of Forest and Hunting Sciences and Practices] (1834), *Sylwan. Czasopismo miesięczne dla leśników i właścicieli ziemskich. Organ Galicyjskiego Towarzystwa Leśnego* [Sylwan. Monthly Periodical for Foresters and Landlords. Organ of the Galician Forest Society] (1888), *Sylwan. Czasopismo miesięczne dla leśników i właścicieli ziemskich. Organ Małopolskiego Towarzystwa Leśnego* [Sylwan. Monthly Periodical for Foresters and Landlords. Organ of the Małopolska Region Forest Society] (1919), and *Sylwan. Organ Polskiego Towarzystwa Leśnego. Publication de la Société Forestiére de Pologne* [Sylwan. Organ of the Polish Forest Society…] (1926). In recent years, the title page has consisted solely of the inscription: *Sylwan. Miesięcznik Polskiego Towarzystwa Leśnego założony w 1820 r.* [Sylwan. Monthly Periodical of the Polish Forest Society since 1820].

[1] The dissertation was authored by Józef Haczewski (J. Haczewski). In 1838, the author published another work, 'O Bursztynie' [About Amber] in the pages of *Sylwan* (Vol. 14, p. 191, p. 358). Haczewski worked as the secretary at the Forestry Section of Płock Voivodeship Commission.

For decades, the cover has been decorated with an engraving presenting the face of Sylwan, the deity of forests and wild nature, as well as the motto 'Nobis placeant ante omnia silvae' ('We delight in the forests the most'), a quotation from the *Eclogae* (or *Bucolica*) collection, Pastorals II, by Virgil, the eminent Roman poet (Publius Vergilius Maro, born 70 BC, died 19 AD).

The frequency with which *Sylwan* has been published has varied. It has been a periodical (4 issues a year), a journal appearing at random intervals (depending on the materials and financial resources available), a regularly published month periodical (sometimes appearing as a double issue). In 1935–1939 two series of *Sylwan* journal were published, namely series A – of a scientific nature that mainly contained dissertations in the field of forestry and related sciences, and series B – with popular science articles and information on the activities of the Society.

The circulation of *Sylwan* has undergone changes as well, which seems obvious from a historical point of view, and is related to the increase in the number of educated foresters over time. In the Warsaw period, the circulation ranged from several dozen to 200–300 copies; in the L'viv period it varied and amounted to 700 copies on average; after World War II it ranged from 1,600 to 2,300 copies; and currently it is 1,200–1,300 copies (a lot for a scientific journal), with the State Forests subscribing to 1,000 copies.

In the 200 years of its existence, *Sylwan* has seen 169 years of publishing activity and a total of 31 years of breaks in its operation. In the period between 1859 and 1882 the pauses happened due to social and economic recessions caused by repressions in the aftermath of the November Uprising, the Russification policy, and the aversion of the tsarist Russian authorities to any community work, including that of Polish foresters. The years 1940–1946 saw another publishing break, caused by World War II and the Soviet and German occupation of L'viv, where the editorial office and the printing house of *Sylwan* were located.

For 111 years, *Sylwan* had been published in Warsaw, for 57 years in L'viv and 1 year in Kraków. The current editorial office (postal address, distribution unit, meetings of the editorial committee and program committee) is located in the premises of the General Board of the Polish Forest Society, on Bitwy Warszawskiej 1920 roku Street, No. 3, in Warsaw.

The owners and publishers of *Sylwan* have included a variety of institutions, such as the Governmental Commission of Revenue and Treasury of the Kingdom of Poland (Congress Poland) (when *Sylwan* was a semi-official government magazine); Kazimierz Glinka-Janczewski and Franciszek Elsner, a private publishing company; and the Galician, Małopolska Region and Polish Forest Society. The Polish (Galician) Forest Society has owned the journal for 147 years. Over this period, the publishing of *Sylwan* has been financed from membership contributions and from money earned by the Society, including subscriptions from forest districts, institutions and individuals. From 1955 to 1966, the Polish Academy of Sciences acted as a co-publisher, whereas in the years 1966–1991 it only provided partial financial support. Later, *Sylwan* benefited from the financial support of the Scientific Research Committee, and then received a subsidy from the Ministry of Science and Higher Education. The amount of annual financial subventions only amounted to around 5–7% of the total publishing costs.

The purchase of one thousand copies by the State Forests for the needs of its organisational units provides an invaluable financial help in the regular monthly appearance of *Sylwan*. The subscription is conducted on a 'non-profit' basis, with a commission, under an annual contract between the Polish Forest Society (PTL) and the State Forests Information Centre. Owing to the fact that 66 copies of *Sylwan* journal are sent abroad, in exchange we receive industry magazines on forestry from other countries for the needs of the PTL library. At the same time, this exchange informs major forest societies and libraries about our activities and the research progress of Polish scientific institutions (by delivery of free copies). Polish libraries receive about 40 copies to enrich their resources.

Sylwan is subject to evaluation by the Ministry of Science and Higher Education. For many years, it has boasted a high category among Polish scientific journals. Previously, this category was expressed as 6 points or as an 'A'. In June 2010 this was increased to 9 points, and for several years now it has been 15 points (the highest rating for journals published in Polish). *Sylwan* has been added to the Philadelphia List (ISI), which was created in the USA by the Institute of Scientific Information in Philadelphia (Thomson Institute).[2] The list comprises the world's most valued, prestigious scientific journals that represent all scientific disciplines and industries. The citation of articles increases significantly following such an entry. The impact factor of a given journal on global science (significance) considerably increases the rating of the journal and of the articles of the individual authors. In 2010, the Institute of Scientific Information in Philadelphia calculated the impact factor (IF) for *Sylwan* for the first time, at 0.142, which was then recalculated in 2017 at 0.7. The improvement is a great success of the editors and authors of the articles, who increasingly tend to represent non-forest scientific institutions, with foreign authors among them. Owing to the emerging needs, it is planned that *Sylwan* will be published in English, to increase its impact and to promote Polish researchers in global forestry.

So far, as many as 15 people have performed the function of editor-in-chief, which given the 200-year-long activity of the magazine proves the stability of the editorial teams, their full commitment to non-profit activities and their great dedication to the good of forests and forestry. The editors-in-chef who performed this function the longest include: Stanisław Tyszkiewicz, Szymon Wierdak, Arkadiusz Bruchwald, Kazimierz Glinka-Janczewski and Stanisław Sokołowski. Among all the editors-in-chef, only one, Hipolit

[2] Founded by Eugene Garfield in Philadelphia in 1960, acquired by Thomson Institute in 1992, since sold on. [translator's note].

Ciesielski, also worked as a forestry clerk employed by the Forest Department of the Governmental Commission of Revenue and Treasury of the Kingdom of Poland (Congress Poland). The other editors-in-chef included lecturers at forest colleges or people who combined the functions of highly-ranked officials in the forest administration and lecturers (Juliusz Brincken – director general of government forests and lecturer at the Warsaw Special School of Forestry, Aleksander Nowicki – forest inspector, forestry counsellor and associate professor at the Jagiellonian University, as well as Kaźmirz Acht (who later changed his name to Kazimierz Tarłowski) – a highly-ranked forest official, forest director in L'viv and a lecturer at the Forest School in Bolechów, later at the L'viv Polytechnic). As far as academic teachers or academics are concerned, the following names should be mentioned: Kazimierz Glinka-Janczewski, a lecturer at the Institute of Agronomy, later at the Institute of Rural Economy and Forestry in Marymont; Władysław Tyniecki, a lecturer at the National School of Forest Economy in L'viv; Stanisław Sokołowski at the Higher Forestry School in L'viv and, later, at the Jagiellonian University; Wacław Niedziałkowski at SGGW [Warsaw University of Life Sciences]; Tadeusz Włoczewski at SGGW; Tadeusz Gieruszyński at L'viv Polytechnic, later at the Jagiellonian University and the Agricultural Academy in Kraków; Stanisław Tyszkiewicz at the Forest Research Institute, previously also at SGGW; Zbigniew Sierpiński at the Forest Research Institute; Tadeusz Marszałek at SGGW; Arkadiusz Bruchwald at SGGW and currently also at the Forest Research Institute.

It would be difficult to name everyone who has worked on *Sylwan* (editors, authors of articles, members of the program committee). Among those who have actively contributed to the publication include not only the authors, editors and members of the program committee, but also the article reviewers, translators of abstracts into English, editorial secretaries, technical editors, printers, administrative service staff and the Directorate General of the State Forests, as well as the State Forests Information Centre, which has purchased most of the monthly circulation.

TABLE

Editors-in-chief (managing editors) of *Sylwan* journal

Warsaw Period	**Years**
Juliusz Brinken (Brincken)	1820–1833
Hipolit Ciesielski (Cielecki, Cieleski)	1834–1841
Kazimierz Glinka-Janczewski	1841–1858
L'viv Period	**Years**
Aleksander Nowicki	1883–1886
Władysław Tyniecki	1887–1891
Kaźmirz Acht (Kazimierz Tarłowski)	1892–1895
Władysław Tyniecki	1896–1904
Stanisław Sokołowski	1905–1920
Szymon Wierdak	1920–1939
Contemporary period	**Years**
Szymon Wierdak	1947
Wacław Niedziałkowski	1948–1949
Tadeusz Włoczewski	1950–1955
Tadeusz Gieruszyński	1955–1956
Stanisław Tyszkiewicz	1956–1979
Zbigniew Sierpiński	1979–1985
Tadeusz Marszałek	1985–1991
Arkadiusz Bruchwald	from 1991

It is worth noting that the team of authors who have written articles for *Sylwan* consists of outstanding foresters and naturalists, whose authority was and is highly valued, not only in the forest sciences but in the world of science in general, e.g. Jan Hausbrandt, Władysław Jedliński, Cyryl Kochanowski, Jan Miklaszewski, Marian Raciborski, Józef Rivoli, Stanisław Sokołowski, Władysław Szafer and, in the period after World War II, Eugeniusz Bernadzki, Józef Broda, Zygmunt Czubiński, Tadeusz Gieruszyński, Jerzy Grochowski, Wiesław Grochowski, Jan Jerzy Karpiński, Simona Kossak, Franciszek Krzysik, Leon Mroczkiewicz, Marian Nunberg, Zygmunt Obmiński, Kazimierz Suchecki, Andrzej Szujecki, Tadeusz Trampler, Stanisław Tyszkiewicz, Edward Więcko, and other scientists who work today in various forest and natural science institutions.

The Białowieża Forest forms one of the most valuable natural resources in Europe. This is due to the extraordinary richness of the species and habitat biodiversity, the multitude of various old-growth forests with a rich species composition, close in its nature to natural forests, the wide variety of soils in terms of fertility and hydration, unprecedented in other forest areas, and the huge number of old trees, monumental in dimensions. The Białowieża Forest is a UNESCO Cultural and Natural World Heritage Site and a MAB International Biosphere Reserve.

In the past, these areas, much more extensive than they are today, separated Lithuania from the Crown in the Kingdom of Poland. The history of the Białowieża Forest, from the point of view of the rulers, owners, tenants, users, administration and forest services as well as of its size and methods of its use were described in detail by Otto Hedemann (1939). In his document *Opisanie Puszcz Ekonomii Brzeskiej* [Description of Forests of the Brześć District], dating from 1796, a comprehensive list can be found of names in accordance with a triple classification that divides the area into wild forests, forests and backwoods. Thirteen forest guard district units were distinguished at that time (to some extent these units could be compared to the forest districts of today). The course and extent of both spontaneous and state-controlled colonisation of these areas can be indirectly demonstrated by the materials collected by Jan Jerzy Karpiński and associates (1935), with nearly a thousand different names for historical and contemporary wild forest areas in the Białowieża Forest.

Following the Third Partition of Poland (1795), the Białowieża Forest was annexed to the Russian Empire as the Grodno Governorate, and in 1888 it became the private property of the Romanov Tsarist family. In 1843, the forest was comprehensively mapped, and a network of roads and compartment boundaries was marked. After Poland regained its independence in 1918, the entire area of the Białowieża Forest was subject to Polish administration, under the State Forests. As a result of the territorial decisions following World War II, the forest was divided by the state border with Belarus, which was part of the Soviet Union.

Currently, the Białowieża Forest covers an area of over 150,000 hectares, of which only 42% are in Poland. It consists of the Białowieża National Park, 10,700 hectares, which operates on the basis of the Nature Conservation Act (2004), and of three forest districts that belong to the State Forests and have a total area of 52,700 hectares: Białowieża, Browsk and Hajnówka, which conduct a multifunctional, sustainable forest management based on the Forest Act (1991).

The bibliography of the Białowieża Forest is abundant, starting with compact materials on the topic, with such titles as: Juliusz Brincken (1828), *Mémoire descriptif sur la Forêt Impériale de Białowieża, en Lithuanie* (in 2004 the second edition was published in Paris, with annexes and comments by Daszkiewicz, Jędrzejewska and Samojlik); Aleksander Połujański (1854), *Opisanie lasów Królestwa Polskiego i gubernij zachodnich Cesarstwa Rossyjskiego pod względem historycznym, statystycznym i gospodarczym* [Description of Forests of the Kingdom of Poland and Western Governorates of the Russian Empire in the Historical, Statistical and Economic Aspects], Vol. II (reprint published in 2016 by Libra Publishing House in Olecko); Józef Paczoski (1930), *Lasy Białowieży. Monografie naukowe* [Forests of Białowieża. Scientific Monographs], PROP, Poznań; Otto Hedemann (1939), *Dzieje Puszczy Białowieskiej w Polsce przedrozbiorowej (w okresie do 1798 roku) w opracowaniu Wiktora Hartmanna* [History of the Białowieża Forest in Pre-Partition Poland (period till 1798) by Wiktor Hartmann] (the reprint was published in 2018 by the

Regional Directorate of the State Forests in Białystok at the instance of the 118th Congress of the Polish Forest Society in Supraśl); Edward Więcko (1984), *Puszcza Białowieska* [The Białowieża Forest], PWN, Warszawa. A web-based *Encyklopedia Puszczy Białowieskiej* [Encyclopaedia of the Białowieża Forest] also exists (collective work, with updates).

A historical query conducted in 2017 by the employees of the Forest Culture Centre (Ośrodek Kultury Leśnej) in Gołuchów included 1,042 items. The study revealed new documents and maps discovered in the archives of St Petersburg, Moscow, Vilnius, Grodno, Białystok and Warsaw. This abundance of documentation and publications makes it possible to access quite detailed knowledge concerning at least the most recent 250 years of the Białowieża Forest history, including information on the course and effects of major fires, hurricanes and storms, tree diseases, insect infestations, as well as the presence of the bark beetle in spruce stands. It provides data on the volume of timber harvested and other forms of forest use, such as major logging operations for exploitation purposes in the area of the forest conducted by the Germans during World War I; on the scandalous episode of The Century European Timber Corporation (Britain), which was given a licence to harvest wood between 1924 and 1934 (in 1929 it was decided to terminate the contract, which was accompanied by the obligation to pay substantial compensation to this company); and on the mass logging operations that took place during the Soviet occupation in World War II. Detailed information can also be found on timber harvesting and forest management in the modern period, covering the past 75 years.

For some time now, a dispute has been taking place over the most favourable model to be applied for the management of the Białowieża Forest, so as to account for all the values and functions of the forest. The argument has now been transformed into a social conflict of a serious and acute nature. The forest is subject to various forms of protection and regimes of conservation, including the Białowieża National Park, 23 nature reserves that cover a total area of over 12,000 hectares, with many elements of flora, fauna and fungi species found in the forest being legally protected, whereas many others remain under individual protection. The forest is part of Natura 2000, the European ecological network.

The ongoing conflict originates from contradictory interests represented by various groups operating in the area, as well as in the buffer zone of the forest. It is difficult to reconcile forest economy, the expectations of local communities and forestry municipalities, tourism organisers (hoteliers, restaurant keepers, travel agencies) or hunters with views on and visions for the future of the forest presented by activists of ecological movements and organisations. However, scientific knowledge in the field of forest ecology and nature conservation provides no unequivocal suggestions in this regard. Should priority be given to the naturalness of the ecosystems or rather to the richness of biological diversity? Or should perhaps the age and structural diversity of tree stands be prioritised? Would it be better to pursue dynamic sustainability in terms of these aspects? Should the exceptionally valuable forest ecosystems be protected in a (strictly) passive manner that would ensure the unrestrained flow of ecological processes, or rather in an (partly) active way, by taking only certain actions and performing specific treatments, such as limiting bark beetle infestation by removing the affected spruces ('active deadwood') and also by removing the standing dead trees in the vicinity ('barren deadwood'). Similar problems and dilemmas are also to be encountered in other countries, including the Czech Republic (Šumava), Germany (Bavaria) and Austria.

The dispute concerning how to treat the commercial forests of Białowieża, for which the State Forests is responsible, in addition to the legal, scientific, ecological and social aspects, is of a media-related and political nature, one accompanied by very strong emotions. Opinions on the problems related to the environmental challenges in the Białowieża Forest are frequently expressed by politicians, artists, journalists and celebrities, who generally lack appropriate competences and do not carry legal or economic responsibility for their opinions and proposals. Therefore, on the initiative of Andrzej Konieczny, PhD, BEng, Director General of the State Forests, as a voice in the ongoing discussion and dispute, a selection of publications about the Białowieża Forest have been prepared that have appeared in *Sylwan* throughout its existence, i.e. from 1820 until 2018.

Over this period, *Sylwan* featured 130 articles that dealt specifically with various aspects of the nature and woodlands of the Białowieża Forest, the total volume of these publications amounting to over 1,200 pages of text, mostly in B5 format. In the period from 1820 to 1918, or almost 100 years of the existence of *Sylwan*, when Poland was subjected to partitions by foreign powers, only 4 articles about the Białowieża Forest were published in the journal. In the interwar period, when the entire area of the forest was under the administration of the Polish state-run forest services, seven articles were published in *Sylwan*, whereas the contemporary period (1946–2018) boasts as many as 119 such articles. It may be assumed that the relatively insignificant number of publications that were issued in the first century of the publication of *Sylwan* resulted from the fact that the Białowieża Forest was located outside the borders of the former state. Following the Third Partition of Poland, the areas occupied by the Białowieża district were included in the Grodno Governorate, part of the Russian Empire. At that time, *Sylwan* became a semi-governmental journal managed by the Governmental Committee of Revenue and Treasury of the Kingdom of Poland, and hence it refused to deal with 'foreign' forests. Later, in the years between 1883 and 1918, both the editorial staff and its group of collaborators were located in L'viv, Galicia, in the Austria-Hungarian Partition, while the Białowieża Forest was located under the rule of another state, namely Russia.

As it would be difficult to re-publish the 130 articles in full, a challenging selection process was undertaken on the principle of assigning priority to old publications, most of which tend to be less readily available to the contemporary reader, and to subjects of a more general nature in contrast to presentations of specialised, detailed research results focused on individual components of the forest's ecosystems, e.g. fungi, lichen and insects or the results of meteorological observations. This means that the resulting book contains only 38% of all the articles contained in the query and comprises the same amount of their total volume.

Attention should be paid to the fact that the 11th issue of *Sylwan* from 2018 is entirely filled with articles related to the Białowieża Forest. It seems obvious that numerous scientific and popular science publications about the forest are also found in other Polish and foreign periodicals. Since *Sylwan* is Poland's oldest forest journal, whose 200th anniversary will be celebrated in 2020, a decision was made to recall the articles that have appeared in the magazine, in historical order.

The publication was prepared by the State Forests Information Centre based on the library resources of the Polish Forest Society, both the owner and the publisher of *Sylwan*. The authors would be pleased to see the publication contribute to a better understanding of the complexity of the problems the Białowieża Forest faces, by illustrating the historical context of the area and the multifaceted environmental and social issues related to the forest. It is also hoped that the publication will contribute towards outlining a vision for the future as well as a program, the implementation of which will ensure the sustainable development of both the Białowieża Forest and the entire region, thereby enabling the functioning and conservation of its precious forest ecosystems.

Professor Andrzej Grzywacz, PhD, DSc
Polish Forest Society

Warsaw, February 2019

17. O Puszczy Białowiezkiéy.

Przez Juliusza Barona Brinken.

(z Dziennika Warszawskiego Nr. 11 roku 1826.)

On the Białowieża Forest by Baron Juliusz Brincken (from *Dziennik Warszawski* No. 11 of 1826)

Mr. Brinken, the Forest District Governor in the Kingdom of Poland, has recently written a work in French, entitled *Mèmoire descriptif sur la Forêt de Białowieża* (which was printed by Glücksberg publishing house, with engravings). The work is divided into four sections, or units: the first one contains a topographic description of the Białowieża Forest, the second one addresses its plants, the third one the animals inhabiting it, while the fourth one concerns the forest administration. Before this fascinating work is translated by someone into Polish,[1] I believe it is decent to provide my fellow countrymen with some information about this publication, at the same time doing justice to Mr. Brinken, for his undertaking, which is worth mentioning for many reasons. I will now go briefly through the work and quote some passages from it.

Having passed the north-eastern frontier of the present Kingdom of Poland, says Mr. Brinken, and having crossed the Bug River near the town of Granów, it takes an entire day to pass across the Białystok region, travelling through fertile, carefully cultivated fields, somewhat overgrown with trees, and beautifully built-up villages. Then, a vast forest emerges in the distance which becomes clearly visible for the first time from atop the hills rising above the town of Orla: it is the Białowieża Forest. To the east, a huge space overgrown with forests is exposed, whereas to the north and south, the woods meet the horizon. When looking in any direction, one can see only sky and forest, whose gloomy and blackening picture besides the beautiful fields forms a pleasant view, so that two so much contradictory sights are created. Near the forest itself, we arrive at the village called Haynowczyzna, where the *former forest administration office and a forest guard lodge* are located.[2] This was

[1] The work was printed in both languages, Polish and French, but because of certain obstacles, it has not been published yet; this will happen shortly. From where did the reviewer obtain the French copy before it was published? The author does not know. (Author's footnote)

[2] The former customs office and the forest warden's lodge 'ancienne douanne et l'habitation d'un gar-de foret.' (P. R. S.)

once the border between Poland and Lithuania. The Pahonia and Bull coats of arms, painted on a post, herald our arrival at the Grodno Governorate, and, in particular, at the Prużana Poviat. The forest that begins at this point, stretches seven miles long and six miles across; it covers 25 square miles, and, according to a map attached to Mr. Brinken's publication, it lies between the latitudes of 52°29' and 52°51' north, and between the longitudes 41°10' and 42° east of the meridian of the Feroe Island [probably erroneous translation into Polish – the longitude is given in relation to the Ferro prime meridian – Ed.]. The forest is surrounded by villages and fields which sometimes even separate the forest from other woodlands. The western part, which used to adhere to the Polish borders on the one side and to the Lithuanian ones on the other, is marked by posts, ditches and barrows. The forest demarcated in this manner used to be owned for the most part by the Kings of Poland. Following the Partition of Poland, however, Tsarina Catherine II, when granting benefits to the lords at her court, transformed a part of the forest into a private property. Yet a part of the forest has belonged for centuries to the Lithuanian noble family of Tyszkiewicz. Other small, privately owned parts are in similar condition to today's Tsarian Forest, which is far more extensive in size than all the smaller parts, and marked on Mr. Brinken's map with a different colour.

The Tsarian Forest borders the Narew River, which separates it from the estate of Mr. Tyszkiewicz, and other, privately owned parts of the Białowieża Forest, which are separated by a straight line running between the trees.

Immediately after the Partitions of Poland, the Governor of Grodno ordered the measuring of the tsarian part of the Białowieża Forest. A general outline was made and certain characteristics were mapped, like rivers, roads, villages and so on. According to this measuring, the Tsarian Forest covers an area of 22.67 geographical square miles. As it was impossible for Mr. Brinken to find out the extent of the privately owned sections, he assumes 7.51 square miles as the best approximated size, and, based on the above, claims that the entire Białowieża Forest covers an area of 30 square miles. As for the climate, Mr. Brinken remarks that the harsher climate compared to other European countries located in the same zone is not caused by the latitude of Poland and Lithuania, but rather by the shortage of mountains and the abundance of forests. From the shores of the Baltic Sea to the Tatra Mountains lies the great Sarmatian plain, barely featuring minor hills and providing a field for northerly and north-easterly winds to play. The first type of wind, before it reaches Poland, blows through snow-covered and permanently ice-covered areas. The second type, however, comes from Moscow and the Tatar deserts, and when passing through forests and ravines becomes dry and cool, thus it brings more chill than the northerly winds do. Even the Tatra Mountains themselves experience the influence thereof, because, as soon as from the side of northern Slavs a slight change in the air occurs, on the other side Hungarian vineyards and the fruit of the South ripen. Apart from that, huge forests make the climate more unpleasant, which becomes milder as the forests become depleted. A sudden increase in population forced the inhabitants to destroy the forests massively and made the air milder. It also caused the same sort of changes as observed in Germanic countries by comparing them with the Epochs in which the ancient Germans lived. Hence, Mr. Brinken estimates the air temperature in Lithuania at 5.4° Reaumur, which is the mean value of the temperature in Poland, 6° and in Russia, 4.8°, according to the observations made in the last 80 years, and concludes that the temperature in the Białowieża Forest must be around 5 degrees. Comparing the surroundings of Białowieża with northern Germany, it appears that the spring begins later there and lasts for a far shorter period. Summer is rarely mild, always foggy, often rainy, either cold or unbearably hot. The autumn, dry and mild, replaces the summer, but it is marked with hot days and cold nights. The winter, on the other hand, is long and unpleasant. Many of the plants and fruits of northern Germany grow in this climate, but their growth is faster there, whereas here it is slowed down, and even full ripeness is not always reached. The closer to the forest, the colder it gets, and harvests commence here 8 to 15 days later. This difference becomes more apparent at the beginning of spring, with sledges still being used in the forest, and the peasants working on the more distant of the surrounding fields.

An observation made long ago was that large forests exert an influence on the climate and provide water that fertilizes distant lands, which proves to be especially applicable to the Białowieża Forest.

Countless streams have their source in the Białowieża Forest, while various muddy waters slowly flow in from the surroundings of the vast forests. Therefore, in hydrographic terms, the Białowieża Forest contains many springs that supply water to the Vistula River through the Narew and the Bug Rivers.

The Narew River, which has its source there, gives its name to a small town in the Białystok region. The Narew is the greatest of the Białowieża Forest rivers, of which the Narewka River is the most significant part. The Lśna River, reinforced by the waters of the Biała River, flows into the Bug River near the town of Pratulin at the border with the present Kingdom of Poland. The Narew and the Bug, from their confluence near Serock bearing the name the Narew, flow into the Vistula River near Modlin. Both rivers are navigable,[3] the first almost from its source. In the middle of the Białowieża Forest, the Narewka and the Biała are accessible by canoe.

The surface of the land on which the forest grows, as well as the area around it, is described by the inhabitants as hilly, but incorrectly so. It is even difficult to distinguish the higher spots from which the waters flow. The soils in the Białowieża Forest are differentiated, with the dominance of sandy soils, which, given the lakes scattered around the country, and many other geognostic observations, allows us to suppose that this land was once, if not a seabed, then at least an area subjected to frequent floods. The gravel found there at a depth of 10 to 12 feet

[3] A comprehensive and elaborate description of the Niemen, the Bug and the Narew Rivers, especially of the latter, by Mr. Wiecki, is already at the publisher's; hence, in following issues, it will undoubtedly be made available to the reader. (Footnote: R. D. W.)

makes this more likely to be true. In the forest, sand mixed with clay can be seen, whereas in the vicinity, where the air facilitates the decay of the bonded particles, the clay often turns to dust. In depressed areas, as well as on the banks of the rivers, the moisture and number of aquatic plants form a chernozem soil. Though it often sinks under human feet, no bogs can be found there, except for in a single location in a privately owned part of the forest. It is in these bogs, stretching far to the east, beyond the forest, where the sources of the Narew River can be found. The widely differentiated soils, dry and light in one area, turning into moist and heavy elsewhere, display various gradations. However, the most striking places are those scattered around the forest, where the ground level is higher than the surface of the rivers, but lower than the soil surface on which the trees grow. The moisture is conducive to the plants sprouting there on fertile soil of considerable depth. The soil is black, greasy, always moist and, when rubbed in the hand, releases a pleasant smell. The fertility of these areas scattered across the forest makes them like fertile islands, or fruitful hills amongst sandy deserts. It would not be far from the truth if the ratio of fertile soils in the Tsarian Forest to the sandy areas located in it was estimated at 1 to 4.

Similar areas are rarely abundant in natural mineral or fossil treasures, at least the area of the Białowieża Forest is devoid of them, and apart from iron ores, not uncommon in Poland and Lithuania, nothing similar can be found there. While amber is found in Prussia and today's Kingdom of Poland, around Ostrołęka, Łomża and elsewhere in Lithuania, none has been discovered in the Białowieża Forest. Yet, it would seem that searching for it could have successful outcomes, as, according to Rzączyński, amber used to be found on the banks of the Narew River. Since the Narew flows largely through the forest, this assumption is very likely to be true. Of all the inhabited places, including hamlets and villages, inside the Białowieża Forest or in its immediate vicinity, the village of Białowieża, which can be considered the *main forest administrative centre*[4] of the forest, is worthy of first mention. This village, situated amidst the Tsarian Forest, is the first open space to be seen after passing for half a day through the dark and dense forest. On the bank of the Narewka River, which winds its way under the shade of willows and alders, is a hill which towers above the village and the surrounding country. King August III ordered a hunting lodge to be built here, while his successor, King Stanisław August, added two pavilions. Though made exclusively of wood, the lodge contains all the comforts that an exhausted hunter could demand. There is a spacious room with two fireplaces, and several smaller rooms around. From one of them it is possible to leave and climb a hill from which the top has been removed, overgrown with oaks, where the remains of a beautiful garden can be seen. Today, together with all the buildings, the garden is abandoned and emptied, which promises its complete destruction. The yard itself, where hunters would gather, where *numerous whippers-in*[5] with

[4] As the main forest village 'comme le chef-lieu'. (P. R. S.)

[5] Countless hunters' 'des piqueurs nombreux' assistants, in the hunting-related meaning. (P. R. S.)

their packs of dogs would eagerly wait the signal to leave, exists no longer – a skilful peasant's coulter has turned it into a fertile field. Around this hill, on both banks of the Narewka River, the village of Białowieża stretches, in which there is a church, 56 cottages and a tavern. Some of the numerous houses at the foot of the hill form a reasonable street, while other cottages lie scattered randomly, forming another part of the village (a representation of this description was included by Mr. Brinken [the correct spelling is Brincken – Ed.]). In addition to the village of Białowieża, the interior of the forest includes two new settlements, namely the villages of Teremiski and Pogorzelce, situated not far from each other, each with 20 to 22 houses. A third village, Masewa [Masiewo], is situated on the outskirts of the forest. Twenty-four other villages lie scattered around the Tsarian Forest, (apart from the side where the forest borders private properties) and these settlements are subjected to the sovereignty of the forest. The people who live there are as modest as their houses, as simple and uncouth as the forest growing nearby. Which nation they belong to is as yet unknown,[6] as they are neither Polish nor Russian. The easiest way to convince oneself is from their speech, this shapeless mixture of these two Slavic languages and from their religion, known as the Greek Uniate rite (!!).[7] Nevertheless, the customs and habits displayed by the inhabitants of the Białowieża Forest possess elements of so many nationalities, i.e. characteristic features that they seem to carry the stigma of the ancient wild peoples who once inhabited these lands, as well as the forests that used to be seen as the image of ancient Sarmatia. These are people of strong nature, during each season of the year dressed in short clothing made of thick brown cloth strapped with a wide leather belt, shod with a kind of sandal made of lin-

[6] I do not know how the author, who quoted so many Polish books in this work, could say such a thing the people are Ruthenian, who inhabit a large part of Lithuania, the same nation as those living in Galicia, today in Volhynia, Podolia, Ukraine, Little Rus and White Ruthenia. Their language is Ruthenian, similar to Polish, but different from Russian, Czech, Serbian and the like. The people belong to a very large branch of the giant Slavic tribe. Around 3,300,000 were present in Poland in 1772, which was after the detachment of many countries by the Truce of Andrusovo. This is almost the same as the population of the present-day Kingdom of Poland, as mentioned above; see *Dziennik Warszawski* [The Warsaw Daily], Vol. I. pp. 374, 375, and 376. (P. R. D. W.)

[7] In the French copy, the period is described in the following way:

> 'C'est la que l›on trouve un peuple
> dont la nation même n'est pas *determinée*
> et qui tient le milieu entre la russe et po
> lonaise; on voit cela sm-tout par sa langue,
> melange grossier de ces deux langues sla
> vonnes et par sa religion connue sous le
> nom de rit grec-uni.'

The author's intention was not to write the history of the nation, so he considered it unnecessary to mention that the area is inhabited by Ruthenians, who belong to the Slavic tribe, which is known to him as well as to the reviewer. The word *indeterminée* stands for *uncertain* rather than unknown. Namely, in terms of nationality, the Ruthenians constitute a transition between the Polish and Russian people known today. Can this fact not be felt by their language and their religion? (P. A.)

den bark.[8] These people can endure any climatic harshness; they willingly dwell in the woods where honey, many kinds of wild fruit, mushrooms and cattle fodder may be found, rather than working the fields, as their neighbours do. And this way of life is suitable for any type of occupation in forestry and hunting. Therefore, they are even taken on as shooters and guards in the Tsarian Forest.[9] Afterwards, Mr. Brinken makes other remarks, and concludes the topic with the following words: 'finally, this not populous, agricultural country, does not know the industry that used to be the fruit of greater enlightenment. As for industry, if it were to arrive there, this rich in forest area would provide an extensive field for active and lively people. It would be in vain to enter the depths of the forest in search of industry that should revive the wealth of the forest; we will hear no strong hammer blows coming from forges, no rustle of sawmills, no chopping coming from *rafters*,[10] we will not see smoke from ironworks or coal burning; even walking villagers are hard to come by on open roads. The mutual relations, the condition of most villages at the forest edges, their small number and scanty population are the reasons for this unusual silence, giving the Białowieża Forest the nature of a primeval forest (*forêt primitive*). Therefore, all kinds of animals that have lived in the forest, perhaps for centuries, sustain it and live freely. There are twelve guard districts in the Białowieża Forest: Augustowska, Narewska, Browska, Hajnowska, Leśnianka, Starzyńska, Stołpowiska, Krukowska, Okolnicka, Świetliczańska, Pobielska and Dziadowlańska. For those who wish to learn more about their sizes, please consult the work of Mr. Brinken.

* * *

In the Browsk Guard District, according to the author, in the Kletnia Poviat, there is a place called *The Old Białowieża*, and *Zamczysko* is not too distant from it. It can hardly be denied that a castle for Polish Kings while hunting was erected in this place and that the name of the village, as well as of the entire Białowieża Forest was derived from its whitening towers. The permanent wars have destroyed even the last remnants of the castle. However, minor fragments of the walls and broken pottery, which occur abundantly in the depths of the ground, testify to its existence. In the Hajnówka Guard District, on the road from Hajnowszczyzna to Białowieża, almost a mile away from the first of them, there is a place elevated slightly above the terrain level, called *Batorowa Góra*, whose name is derived from the king [Stefan Batory] who organized a great hunt there. The Augustowska Guard District, on the other hand, assumed its name from the two Saxons, Kings of Poland, who often

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8 These sandals are called clogs, *kurpie*, bast shoes in Volhynia, and 'paws' in Lithuania. (P. R. D. W.)

9 It is not pointless here to mention that during the times of the Polish-Lithuanian Commonwealth, the duties of the Great Hunter included authority over the Royal Forests. In Lithuania, Great Hunters also kept separate villages, where royal hunting dogs were kept. People of these villages were not called peasants, but hunters, and their elders were called *Podłowczy* [Deputy gamekeepers]. (P. R. D. W.)

10 The rafters do not harvest wood, in the French copy it reads 'ni les coups de hache des bucherons'. (P. R. S.)

visited for the hunting, and took this forest area under their special care. The area of the *Jelarki* spring in the Browsk Guard District is called *Zwierzyniec Królewski*, which indicates that once there must have existed an animal preserve. But considering the abundance of wild animals in the forest, it may well be assumed that the place hosted the rarest of forest animals, *apprehended*[11] alive in order to protect them. Finally, in the Leśnianka Guard District, is a large area called *Nieznanów*, long inaccessible owing to numerous windfallen and wind-broken trees.

Having given such a topographic description of the Białowieża Forest, Mr. Brinken accedes to a description of the plants and animals found therein.

The forest as described above, says the author, exhibits plants in such a condition on which the culture of Europe, and therefore *the theory of the forest economy*[12] had exerted no impact as yet. Numerous tree species can be seen there, which grow wildly on appropriate soils, age and finally by ending their existence left space for, so to speak, new generations. It is in vain to search there for *axe-hewn* trees,[13] the dense nurseries and excellent tree plantations which foresters elsewhere boast about. In vain, the amazing multitude of trees, shrubs and herbs provides suitable materials for technology, the economy and benefits for the medical arts of humanity with helpful produce! Indeed, such a vast forest overgrowing wildly, in its natural state, is not only a rare spectacle in Europe, but also becoming an immense field for exciting observations. When, in front of their eyes, historians can witness the lowest level of culture that a country can possibly achieve, (!!)[14] or a complete abandonment, a person devoted to the forest science can observe the way in which nature, with no human help, cares for the forests, sows them, helps them grow, determines the time of their death; and how the corpses, so to call them, of trees fallen from old age serve as a cradle for new tribes. It is there that the forester, or to use this word, the forestry legislator, can learn the needs and *characteristics*[15] of trees, from which to derive abundant conclusions for his discipline.

As for animals, Mr. Brinken maintains that no forest in the world contains so many different species as the Białowieża Forest does. When southern and western Europe is almost completely devoid of game; when in France a scarcity of roe deer was left that still managed to escape the ferocity of wolves and foxes; when in scientific Germany, where the

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11 Why were they not simply *caught*? (P. R. S.)

12 Understood as a forest farm, 'l'economie forestiére raisonnée'. (P. R. S.)

13 Limbed. (P. R. S.)

14 Thirty miles of forest, in which only three small villages are situated, with no trace of industry, exposes almost the same view, as a country completely abandoned and devoid of culture. So what is so remarkable here? (P. A.)

15 Inborn properties, 'proprietés innées'. (P. R. S.)

hunting was raised to the level of a science,[16, 17] hardly any traces of animals in rare forests can be sighted; when a painted motley[18] or accidental killing of a wolf or a lynx from the Slavic Forest are enough to occupy the feathers of one hundred scholars, numerous herds of wild oxen graze here, strong moose run peacefully through the woods, fierce boar crumble the moist ground with their feet, fearful roe deer flee across the lush forest meadows, the cunning beaver lives on the banks of the rivers, bear, lynx and wolf cross wild woodlands, inaccessible thickets and branches of fallen trees, the sly fox ruts in winding burrows, the magnificent eagle flitters over the tops of the tallest trees, whereas *crawling vermin breeds in the lowlands*.[19] This place provides the zoologist, as well as the forester, with a large field for remarks. A hunting enthusiast can experience here most elevated contentment at the very sight of animals. He is under the impression of being transferred to those bygone centuries, when the hunt was the most effective employment of nomadic peoples, who would constantly fight against wild animals and consume their flesh as the only available food, whereas they would use animal hides as clothing. In terms of looks, the Białowieża Forest resembles ancient forests. Its extensive vastness and the deaf silence in it have made it the home of ancient animals that Polish kings have hunted. In this place, hunting has retained its former simplicity, whereas the ability to create inventions, as well as the long-standing experience of other peoples, which has been used to make this entertainment more enjoyable, is at least despised, if not completely neglected here.

I omit the advantages that are perhaps demanded by Mr. Brinken to be demonstrated and shown to the world by me,[20] a person familiarized with his work, and I leave this task to *Sylwan*, or to those skilled in forest science. Nevertheless, it is appropriate to mention some details.

The author mentions almost all the animals living in the Białowieża Forest. Firstly, he deals with wild animals (animaux sauvages). He lists the characteristic features of the

[16] It was not in Germany, but in the ancient scientific Greece that Xenofon in his Cyropaedia mentions hunting and devotes a separate treaty to hunting. Following the separation of the country, the Romans wrote poems about the art of venery and fishing. The French also wrote poems and prose on the topic. A few works were published in our country, namely *Myślistwo z Ogary* [Hunting with Scent Hounds] by Ostroróg. At present, special attention should be paid to the work of Wiktor Kozłowski, a forest clerk in the Kingdom of Poland, or to *Nauka Łowiectwa* [Theory of Hunting] by Ignacy Bobiatyński, published in two volumes with engravings. (P. R. D. W.)

[17] The reviewer misunderstood the notion; The author, to whom not only works by Xenofon and Kozłowski, but also works on venery by all nations are familiar, did not intend to flatter the Germans, but to rebuke them, as in parallel to their need to write about the Venery, they neglect the conservation of useful game animals. (P. A.)

[18] In the French copy it is 'on cummence à ne trouver les traces du gibier des forêts germaniques que dans les peintures bariolées etc.' (P. R. S.)

[19] No mention of *vermin* is contained therein, as it has been expressed 'et les poules sauvages dont l'espéce est variée y habitent les charmilles épaisses de la forêt'. (P. R. S.)

[20] This objection was not expected by the Author. (P. A.)

animals in comparison to the same species living elsewhere. He offers his perceptions and local traditions. He talks about animals that have always been considered a great rarity in Poland and nearby Lithuania. He quotes Polish authors, benefits from Czacki, but argues more extensively about bison and elk. What does he say about this first one? The readers shall discover in the forthcoming issues of *Dziennik Warszawski* [The Warsaw Daily], if no one, having explained the entire work, discusses the issue before me. In a similar way, the author devotes several pages to describing the more peculiar herbs and flowers of the forest. He makes numerous interesting remarks on this subject, discussed the condition of the forests and their renewal, the growth and durability of trees, a diligent calculation concerning the amount of time needed by trees like pine, fir, oak, hornbeam, birch and sycamore maple to mature, or to reach old age. He discusses the soil on which they grow, either in open areas or in thickets. He mentions the heights of the trees, their diameters and volumes, and what is the annual growth of each. He talks of cases harmful to the tree, such as fires, storms or vermin etc. Finally, after having made all this, the author, and I along with him, embarks on the description of hunting for bison, which, owing to the lack of space, I shall postpone.

Zygmunt Gloger

The Białowieża Forest

(Extracts from the work entitled *Białowieża w albumie* [Białowieża in Pictures])

A powerful wave of war approached the borders of the [Polish-Lithuanian] Commonwealth, reaching the primeval forests, still untouched by human foot or hand. The roar of cannons and the cracking of rifles disturbed the eternal silence of Białowieża. The dying generation of bison watches in amazement what is happening in the woods, sees the unknown figures, listens to the strange thunder and takes flight anxiously, searching for refuge to spend its probably last moments.

Therefore it is worth, following in the footsteps of the tireless explorer of the monuments of our past, taking a look at this area, the only such place in Europe for which the heart of the Polish forester longs, in which the memories of the Jagiellonian hunter and former power are combined.

There were times when the agricultural system throughout Central Europe consisted mainly in burning certain forest spaces and sowing them with grain for several or more than a dozen years. As soon as the new area became barren and stopped yielding a satisfactory crop, it was left to the forest, with fresh places sown after preparation by fire and axe. In many forests of Central Europe traces of field beds remain from those times. German researchers attribute such forest beds in Bavaria to ancient Roman culture, but in my opinion they move their antiquity too far. On the Lechia plains, between the Carpathians and the Baltic Sea, similar forest beds originate from more recent centuries. The Białowieża Forest was the first great forest beyond the borders of agricultural Lechia, towards the east, to remain unaffected by the ploughing economy for the longest period.

This forest belonged to the primeval, almost uninhabited, virgin forests, located between Mazovia, Ruthenia and, still pagan then, Lithuania, which stretched from the north, from today's Augustów Lakes, the Hańcza and the Biebrza, towards the south, to the upper Narew, and further through the Bug towards the valley of the Wieprz. Divided into principalities among the numerous descendants of Bolesław III the Wry-mouthed, Lechia lost the resilient strength of a homogeneous state. It was then that the aggressive tribe of the Letto, the bellicose Yotvingians, whose home was around today's towns of Ełk and Augustów, between the rivers Hańcza, Łęk and Biebrza, a brave people who, nevertheless, lived on pillage and plunder, who turned the forests into a safe trail to the south to be used for attacks on the fertile agricultural Małopolska region, around the towns of Lublin and Sandomierz. Of the above-mentioned forest trail, the extensive Augustów Forests, Zielona Forest, Kłyszawska Forest, Zabłudów Forests in the Białystok District, the Białowieża Forest, the Ruckie Forests and the Bialska Forest on the left side of the Bug River still exist today. The latter was home to the last bears in Congress Poland, several decades ago. Of all these forests, only in the Białowieża Forest have oaks been preserved to this day. The trees date back to the times close to the Yotvingians and, among the peasants in the villages located in the forest, stories about the Yotvingians can still be heard.

From the most ancient times, the forest has always been the property of the monarchs that ruled the country, and hence it was called royal, as all such were domains of the crown. In the 16th century, the area was measured for the first time by geometers and was assigned a forest guard, the duties of which were inherited from father to son. It goes without saying that the guard's duties, rather than being related to preventing the theft of timber, mainly concerned big game and its protection against poachers and the organisation of hunts whenever the ruler arrived with this intention. For the liberty to hunt other animals, the guards were obliged to pay a 'fur tax'. The charge, however, was later abolished and hunting forbidden altogether.

Long ago (apparently, during the first geometrical measurement), the forest was divided into 12 guard districts, separated from each other by lines, cut 12 cubits wide, running radially from the centre of the forest in which the village of 'Nowa-Białowieża' was situated. In this way, each 'guard' was given the contour of its boundaries in the shape of a triangle whose apex and acute angle coincided with all other triangles in Białowieża, whereas its base equalled roughly a twelfth part of the external perimeter of the forest.

Antoni Tyzenhaus, Treasurer at the court of Stanisław August, is considered to have introduced a separate era in the management planning in the forest. It is known that since his time in office, the district forest manager lived in Królowy Most and supervised 12 guards, each of whom was in charge of one local 'guard district'. For their work, the guards did not receive remuneration in money, but were given two voloks of plough land (about 30 morgen) instead and had it worked by peasants from several nearby cottages, the so-called 'gardeners', obliged to work for the guard two days a week.

Each guard oversaw between 5 and 15 subordinate shooters, depending on the extent of his 'guard district'. Their duty was to watch and count the bison, and exterminate wolves, lynxes and bears as its enemies. In total, there were 122 shooting huts in the forest. Additionally, in five villages, namely: Kiwaczyn, Kamienniki, Różkówka, Ćwirki and Panasiuki, lived the *osocznik* workers, whose duty consisted in repairing the roads in the forest, using spears to herd animals while hunting and preparing haystacks to provide the bison with more abundant fodder in the winter months. In general, the relatively scarce population of the forest could be divided into the following 4 categories: guards, gardeners, shooters and colliers. The latter group occupied themselves with burning for tar, turpentine, birch tar and potash. They had been brought to the forest from the lands bordering the Vistula River and settled in the wilderness by Tyzenhaus.

The Białowieża Forest is the largest forest located in Central Europe. The former crown lands covers an area of 22 and ⅔ square miles. The Świsłocz Forest, which had belonged to the Tyszkiewicz family before 1831, was attached to it. The Świsłocz Forest, with its 7 square mile area, is separated from the Białowieża Forest only by the Narew River. At present, the total area of these two forests is up to 30 square miles. Topographically, the area is a plateau, located on a water divide, where the western ones flow into the Vistula River and on to the Baltic Sea, while the eastern ones into the Dnieper River and on to the Black Sea. The Narew River has the largest catchment area in the forest. Its spring should be sought on the eastern edge of the forest, in the Orłowe błoto [Eagle marsh] wild forest. The confluence with the Narewka River is on the left bank, which flows through the middle of the forest, near the new and old Białowieża. The Leśna River, a tributary of the Bug, collects waters from the southwestern part of the forest.

The ground in the forest varies and tends to be swampy in some places. Mostly, however, the soil substratum is of sandy loam, perfectly permeable (which contributes to the lush growth of trees). Upon this base lies a thick top layer of a light, fertile humus that was formed by the decomposition of herbaceous plants, leaves, as well as by fallen trees, not removed for centuries, destroyed by storms and age, and still decaying today owing to the lack of buyers for fuel wood in the area. In some guard districts, huge logs are found every dozen or so steps, which are sometimes piled up, to resemble barricades, consisting of rotting pine, oak, linden, birch, hornbeam and spruce. Strangely, the bark holds onto fallen hornbeams and birches for a long time, so a decayed core can only be noticed once the leg falls into such a log up to the knee, or when a stick pierces it through.

Once we went into the forest with a huge hayrick cart, over which a roof on rods, resembling a canopy, was arranged to protect against rain. Since there were nine travellers of all ages sitting in this amazing vehicle, the Jews of small towns considered our group to be either artists of a provincial theatre, or travelling acrobats, and helpfully indicated the tavern where we could find the 'largest room' for carrying out the performance. Further on the road from Bielsk to the forest, rural people considered our canopy and six harnessed horses to be signs of travellers of high dignity. They hurriedly stepped behind the road ditches into the field, where they gave us their timid obeisance, by bending their foreheads to their knees.

A mile before reaching Hajnówka, situated at the very border of the forest, from the hill, a black strip of the forest emerged to close the horizon. Henryk Sienkiewicz, who participated

in this trip and described his impressions afterwards, says the great depth of the forested areas results in the forest being distinguished from the horizon immeasurably, in black.
The Sun was already setting and the night in the forest had arrived when, having left the vehicle behind, we entered the forester's settlement. The moon had risen into the starry sky, illuminating the tops of giant soaring spruces and pines, and played with them, as it had done hundreds of years ago, clawing its way into the gaps between the branches and falling onto the ground of the forest, taking the shape of long white sheaves and highlights. One could say that ghosts, deep shadows and vibrating silver spots were wandering among giant columns. Genuine forest magic.

After having spent a day in the forest, one could take a good look at it. First of all, the mixture of trees is striking, and distinguishes the forest from other woodlands, as a uniform pine forest is rarely found in the area. In contrast, almost everywhere there are pine, oak, ash, aspen, spruce, linden and hornbeam, growing next to each other in the immediate vicinity. In the distance one can see all shades of green, from a saturated dark to pale yellow. This variety amuses the eye and frees the forest from its gloomy nature. Another unusual feature of the forest lies in the unusual height of its trees. Striving for the light, which, in a dense forest, can only be enjoyed by the trees' peaks, no tree grows their boughs in width, but shoots up a lofty, ideally straight, branchless trunk, which spreads into a small tree crown only at the top. The young forest, with all the strength of its lush sprigs, strives to get into the light, as the locals say 'to talk to the skies.' So, it grows thin, spindly and, as Sienkiewicz said, each tree considers thickness here only once it has settled itself in terms of height and its top can bathe in the sun.

On average, however, pine prevails throughout the forest. Pine, whose growth rings are so thin, compact and tarry, like no other trees in the entire area of Slavic countries. Pine that provides the best material for string instruments in the world, the boards of which are well known to cabinetmakers of Western Europe and dearly paid for in London. The history of this pine dates back further than it was previously thought. Professor Adolf Pawiński, an acknowledged history researcher, conducting archival searches in Madrid and Lisbon, came unexpectedly across reports of local merchants from the turn of the 15th century about the trade in timber to be used in the construction of ships and masts, as well as on the waterway to float the timber by the Narew River, the Vistula River and the sea.

Though no mention of Białowieża is made there, only that the material for masts in Madrid or Lisbon were transported on the Narew, it should be considered already sufficient proof that they were from Białowieża, masts that held the stretched sails that moved brave sailors across the open oceans to conquer unknown parts of the world and retrieve the treasures of the earth for European civilization.

Besides pine, oak is the second most common tree in the Białowieża Forest. However, it is not the stocky and gnarly oak, most widespread in the forests of the Kingdom, but a sky-high one, devoid of knots, as straight as the Białowieża pine, sometimes reaching up to six meters in circumference. In the forest, I encountered once a giant that had not a single dry twig, while a plaque nailed on it by a forest worker announced its age to be 300 years and indicating a trunk length of 45 archins up to the crown with a volume of 750 English cubic feet and priced for sale at 90 silver roubles. A few dozen steps away, we were shown a far more immense trunk, which had been cut down a dozen or so years ago. 'This one was the father of this one that is still standing', our guide told us. Since the growth rings of the felled tree were quite distinct, I decided to count them in order to find out its age. And I counted about five hundred of them.'

The spruce ranks third in the forest population. In terms of its thickness, it is close to the most magnificent pines and oaks, however, in terms of loftiness, it surpasses all the trees found in the forest and is definitely the highest tree species in all the woodlands of Europe. Then, ash and the Białowieża sycamore follow. Ash trees in lowland, humid places were formerly more common here than oaks, as magnificent as oaks, equally straight and even smoother; however, beautiful specimens are nowadays rare. Another tree that deserves mention is the melliferous linden, which grows here as high and as straight as a pine tree, carrying its small crown formed from branches on its top. Those who know linden trees that grow in gardens, usually branchy from the ground, if they stood among the Białowieża linden trees might wonder what tree it is. On these lofty crowns, bees collect pollen to produce honey. Not just the one as white as cream butter, but in the Białowieża Forest, the linden honey differs significantly from the one from gardens by its special aroma and taste, and is sold for a fabulous price. Could this be attributed to the fact that only a small number of the inhabitants occupy themselves with beekeeping?

Or could the reason lie in the fact that the linden honey produced here is sought by enthusiasts from distant corners of the world? Whatever the reasons, the price of a pot (because here they are still unable to sell by weight) often reaches 15 roubles.

Among the most peculiar trees the silver fir (*Abies alba**) should be noted, not known anywhere else between the Dnieper and the Bug, known as the 'white yew' among local people. Several hundred grow in an inaccessible clump in the wilderness called 'Cisówka', 'Cisowik' or 'Cisanka'. Another peculiarity that Mr. Brincken mentions is the yew *Taxus baccata*, located on the opposite side of the forest, in the Nieznanowo wilderness. Also, in this case, our botanists Błoński, Drymmer and Eismund only managed to encounter two bushes of it, as villagers cut this rare tree down for its supposed feature of being a cure for rabies.

The most common forest trees include birch, hornbeam, aspen, black and grey alder, and finally elm, wych elm, rowan, crab apple, pear and hazel. The birch, reaching the

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* *Abies pectinata* (editor's note [of the original version - Ed.]).

height of the pine, and straight as a candle, is just as different from the birch of ordinary groves as the Białowieża linden from the linden of our gardens. Hornbeam trees appear in the same ratio, but do not grow as high. Still, compared to the garden hornbeam, the one found here is a giant. In addition, its trunks are covered with lush furry moss, *homalothecium*, which fact can be explained by the abundance of calcium in the deeper layers of the soil substratum.

There are only two places in the Old World where the bison, once so ubiquitous across the globe, survive in the wild. The third location is found in the New World, in the United States of America. In Europe, the last refuge of this king of European wild animals is the Białowieża Forest.

In the 15th century, according to Długosz, outside the Białowieża Forest, the bison was known in the Volhynian part of Polesie, also in the Kozienice and Jedlińsk Forests in the Radom region, and also in between the Vistula River and the San River, near Przyszów, and in the Niepołomice Forest near Kraków. In the 16th century, Kromer no longer lists the bison as one of the animals living in the Niepołomice, Kozienice and Jedlińsk Forests. Herberstein, passing through these countries, saw, described and presented drawings of the aurochs, as the wild ox of Mazovia and the bison of Lithuania. He saw bison in the zoo of Troki. He is outraged by the unconsciousness and explains the terms to those who confound these two species of animals. In 1634, Święcicki writes that in Mazovia, bison were still found in the area of today's Myszyniec Forest.

No big game was as numerous as the bison, that is, the American bison in the United States, and none was exterminated at such a fast pace. The increasing demand for bison hides reinforced the obstinacy of hunters, who slayed about two and a half million of them in the period between 1871 and 1874!

Hunting these animals was facilitated by the exceptional gentleness, timidity and stupidity of the American bison, a feature that distinguished the animal remarkably from the Białowieża bison. Endowed with strength as great as that of the Białowieża bison, physically not much different, it was far gentler and less brave. Numerous descriptions of bison hunts in America prove that the Białowieża bison would not allow, even today, when it is much accustomed to seeing humans, to play such tricks as was the case in America. It was, for example, not uncommon to conduct the so-called 'silent hunt', during which the hunter crept up to the herd and began by accurately shooting the bison that led the herd. Once the stupid animals gathered to sniff the killed one, the hunter would successively kill other heads. Nothing similar could take place in case of the Białowieża bison, whose sense of smell is so vigilant that it allows the animal to snoop an approaching man from the distance of 80–100 steps and to escape from the enemy right away or to attack him if necessary. This strange stupidity of American bison became the main reason why it was almost completely exterminated with unprecedented speed once railways had been built across the interior of the United States. Today, apparently, in this entire vast country, the number of the bison amounts to no more than in the beautiful forests of Białowieża.

According to the claims of contemporary zoologists, currently across the globe there exist eleven separate species of the ox, of which our Białowieża bison seems most peculiar and rarest.

The bison of North America were somewhat different from the Lithuanian ones, whereas such a studious naturalist as the late Władysław Taczanowski doubted the existence of the bison in the forests of the Caucasus. Therefore, it is demonstrated that the only place on the mainland, that is from Kamchatka to Gibraltar and the Cape of Good Hope, where the bison can be seen in the wild is Białowieża. That is why it is written that in the past this animal was nothing of an oddity, as in the Middle Ages it inhabited all the larger forests of Central Europe. However, as populations increased and culture developed, the bison disappeared everywhere and finally retreated to its last mainstay of the wild woods at the source of the Narew and the Narewka Rivers where, as early as in the 16th century, it received royal protection.

It is quite shameful to Polish literature that people from other nations were relatively more occupied with bison and Białowieża than we were, that our gross ignorance is sometimes simply indecent, such that, for instance, so little is known about the fact that in the 15th and 16th centuries a trade was conducted in timber from Białowieża for masts to drive the Portuguese and Spanish fleets, in accordance with the interesting findings of Professor Pawiński performed in the archives of the Iberian Peninsula.

The colouration of bison, regardless of gender or age, is coffee-grey in the summer and dark brown in the winter. For this reason, those who attempt to describe the bison define it as chestnut-coloured or almost black, according to whether they saw it in the summer or in the winter. Its coat is short, soft and woolly.

The composition of its entire body impresses at the front and amazes with the development of its muscles. In the front half of the body, the bison is much larger and taller than the strongest European oxen, with front legs and an athletic build resulting from the efforts of the nature, the back of the body is no larger than that of the average cow. In any case, the bison is the king of the Quaternary fauna of European forests.

The eyes have a peculiar arrangement: the pupil seems to be perpendicular, whereas the corneum membrane is black. When the bison is exasperated, its eyes protrude almost to the top, and the whites are shot with blood. The bison emits a strong, unpleasant smell, like musk. This fragrance, as I was assured in the wilderness, is stronger in the winter months than in the summer. Apparently, it comes from the shags on the animal's forehead. I saw local hunters examine the fresh trail of the bison in the summer season by sniffing, bent to the ground. I could smell the odour myself in a hollow of black, damp soil, where a bison had just left its den.

The bison cows roam together with the young in herds of a dozen or so, sometimes numbering up to 30. Old males leave the herd, as if they despised the company of females and the young, and roam alone, as wild boars do. Sometimes they walk in pairs, rarely in groups of three. When two herds meet, the smaller one gives way to the larger without a fight. The bison in herds tend to be extremely cautious and fearful, especially in the summer when fodder is found everywhere. Once we met a herd of bison that comprised 17 animals, including mothers and males; they surrounded the calves and began to run away shyly. Wishing to follow them unnoticed again, we wandered through the marshes, jumped over huge, decaying wind-broken trees, covered with lush moss, climbed over the slippery remains of giant trees, felled by storms, as if we were crossing bridges, and we passed through swamps of pitch-black mud. The bison, for whom these obstacles were nothing, disappeared soon from our eyes with an amazing facility.

But an old individual, having become attached to a certain area, tends not to run away from a man and commonly refuses to give way to humans. It does halt, when it sees someone approaching, and forces them to skirt around. In these cases, the animal impresses with its calmness and terror. The bison, if not enraged, rarely starts a fight, but rather seems to lay the challenge to fight, trusting in its own enormous strength. Then it may be approached to 20 or up to 30 paces away and skirted around. If the bison stands on a narrow road and it is impossible for the wagon to pass it by, one needs to stop and wait until it decides to give way. The bison, like other horned cattle in general, at the sight of the red colour, is ignited to anger.

In the winter, when a group of peasants, armed with poles, attempts to drive an old bison away from their haystacks, the King of the Forest, irritated by the screaming of the peasants standing nearby, will sometimes rush the group and cause panic. As soon as the inhospitable defenders of the haystack disappear in all directions, the bison returns seriously to the haystack. If such a situation repeats persistently, the struggle for survival often ends tragically, mysteriously… not in the daylight, but rather in the night hours, when the noise of the huge forest, when the sound of a strong wind blowing obscures that of a firearm, which cannot even be heard a few leagues away. And then the mighty male, who was said to have lived in this wilderness for 20 or 30 years, never returns to the fragrant haystacks in the den.

By the autumn the bison is always fat, but gets thinner again by the spring. In the summer, it feeds on the lush vegetation of the forest, whereas in the winter it preys on dry leaves, sprigs, bark and the buds of trees, their own or someone else's hay, i.e. from the royal stacks or from the peasants' supplies, the former purposefully placed there for the bison. However, this hay is not abundant, hence the bison feeds predominantly on grass excavated from under the snow. Of all the different types of bark, the bison prefers that of the ash, thereby causing considerable damage to the young trees in the ash stands. Among the sprigs, the bison prefers those of the linden, grey and goat willows, aspen (cut for the bison kept in preserves), hazel, hornbeam and euonymus.

In the summer and autumn, bison remain in the humid and densest wild woods, while during the winter and spring, they choose higher located and less overgrown areas. Unlike domestic cattle, bison do not like bathing or entering water, but cross streams and forest rivers with great ease, if needed. Owing to the enormous strength of their muscles, these heavy animals manage to cross swampy marshes and muddy steams in a quick and effortless manner.

Bison are the most populous in the following guard districts: Augustowska, Hajnowska and Kurkowska. In times past, bison were counted once a year, in the winter, on one day for the entire forest. This is because in winter the herds remain close to certain areas near springs, rivers and haystacks, and each guard is fully aware of the whereabouts of the individuals of each herd. Since bison leave the new den at the break of the day to set off to feed in the forest, at the beginning of the winter, following the first major night snowfall, at 11 a.m., every shooter serving in the forest was obliged to inspect each herd and the boundaries of his territory, being equipped with two sticks, a long and a short one, and to cut notches on one stick to represent the observed head and on the other stick the ones that arrived or stayed, which could be easily recognised by the number of lines on the fresh snow.
Around noon, all the shooters arrived in Białowieża with their sticks, where the calculations were completed and the number recorded in the books, with a maximum possible error of only a few head.

The bison herds experienced considerable hardship in the times between 1793 and 1807 when the border of 'New East Prussia', which only existed for 11 years, ran along the western edge of the forest. At that time, in the villages adjacent to the forest in the west, but located already in the Prussian Partition, bands of armed poachers formed by peasants from Podlasie raided the forest in order to capture the big game previously bred there in large quantities. In those years, the number of the bison is considered to have dropped from 700 to 300. Had this situation persisted for longer, bison would have faced the threat of complete eradication.

Generally speaking, the living conditions of bison have significantly deteriorated in modern times.

CONSIDERATIONS.

A description of the Białowieża Forest
based on the work by E. Eichwald

In 1830, in Vilnius, the Józef Zawadzki publishing house published a work by E. Eichwald under the title *Naturhistorische Skizze von Lithauen, Volhynien und Podolien in geognostisch-mineralogischer, botanischer und zoologischer Hinsicht*. [Environmental Sketch of Lithuania, Volhynia and Podolia in Geognostic-Mineralogical, Botanical and Zoological Respects]. The latter work originated in a four-month vacation trip, from Grodno along the Niemen River in Lithuania, through Volhynia and Podolia along the Bug and the Dniestr to the Black Sea. And because these countries are at the moment before the eyes of the whole world, it will be reasonable to bring to the attention of all foresters a faithful translation of the issues of interest contained in this, generally unknown, work.

According to Eichwald, the appearance of the forest was at that time as follows.

Of the cats, the lynx (*Felis lynx*) is common in all forests of Lithuania, but for a few years now strongly reduced in number. Two subspecies of lynx may be found in the Białowieża Forest, one of which is large with small spots, while the other is small with much larger spots. The fur obtained from the latter is much cheaper. In former times, wildcats were supposed to live here as well.

Wolves and foxes are to be found everywhere, whereas the black wolf (*Canis lycaon* L.) with a white throat is very rare here. It is commonly encountered in France.

The bear (*Ursus arctos*) is just as common here, usually it is brown, often black, and frequently of extraordinary size. Sucking its paws, the bear can be heard in the winter throughout the day, and therefore it hibernates little or not at all. It never nests on trees, contrary to what Cuvier reports (!) Together with the bear, the badger (*Meles vulgaris*) is widespread, but not the wolverine (*Gulo vulgaris*), which has certainly lived in some forests around Pinsk and Volhynia.

As far as rodents are considered, the mountain hare (*Lepus timidus*), the hare (*L. variabilis*) [translator's note: *Lepus variabilis* is the synonym of *Lepus timidus*] and the rabbit (*L. cuniculus*) are the most common. Sometimes, completely black hares with brownish-red ends of jumps and 4 brownish-red spots on the forehead are encountered here. The beaver (*Castor fiber*) was formerly a far more frequent sight in Lithuania and Volhynia than is the case today. It is most common in the Bracław Poviat, where in certain communities it builds 3-level lodges, whereas in Pina near Pińsk it lives only in groups of 3–4 and, as a result of being heavily chased and eradicated, does not build lodges anymore. Lithuanian beaver clothing, which gives off a strong fragrance, is of excellent quality indeed, and has many advantages compared to the Canadian. For several years, its price has jumped up considerably, due to the decreasing number of beavers. Currently, their price is up to 50 roubles in silver for 3 lots. In former times, beavers used to live in the Białowieża Forest, as well as in neighbouring areas, but nowadays they are nowhere to be found in the area. They are caught with the help of large fox snares with long prongs, rather than in nets that could easily be bitten through.

The flying squirrel (*Pteromys volans*)[1] formerly a resident of Lithuanian forests, nowadays cannot be seen at all. The common squirrel (*Sciurus vulgaris*), however, is very common everywhere. In winter, it is usually grey. The fat dormouse (*Myoxus glis*) is much rarer than *M. nitela* and *avellanarius*, which are found in many forest areas of Lithuania.

Of the ungulates, only wild boars inhabit the area, but they are very common in all the forests of Lithuania, Volhynia and Podolia.

Finally, the forests are very rich in the cloven-hoofed animals. The deer and the elk are found in almost all the forests of Lithuania and Volhynia. In Podolia, the latter species is disappearing, while only the generally widespread roe deer remain there. Red deer are nowhere to be found these days, although they used to be quite common in Lithuanian forests. They are supposed to have been widespread in the Białowieża Forest about 50 years ago. The inhabitants of the area, who are 70–80 years old, remember very clearly that in their youth they would see them in the forest. They were believed to have come here from Prussia at the beginning of the Seven Years War, and to have returned there later, driven out by the wolves.

During the reign of August III, the King of Poland, many low columns made of clay and sand mixed with salt (called in Polish *lizy)* [translator's note: derived from the verb *lizać* – to lick], were placed in the forest, to get red deer used to one place, as most commonly they would came here to lick salt, which caused them to always remain together. It is not uncommon to find quite fresh antlers here today. They can be generally found in many forests of Lithuania and Volhynia, not necessarily dug out, but they rather provide the best proof that red deer have ceased to be inhabitants of our provinces not so long ago. Sometimes, very large red deer antlers may be found, the 3 lower branches of which tend to be very long, e.g. in Volhynia, near Słucz.

Probably the most interesting of all domestic animals is the European bison (*Bos urus*), which lives only in the Białowieża Forest in the Prużana Poviat of the Grodno province. It is known to have inhabited Western Europe as well, but it was never a resident of

[1] The first specimen received by Buffon originated from Lithuania, and as it was sent to him under the Polish name, *polatucha* (derived from fly, flitter, fliegen), he named it *Polatouche* in French.

the Caucasus, or at least I was unable to find out there anything certain about it. Towards the north-east, the far smaller forest of Count Tyszkiewicz borders the Białowieża Forest at a distance of one verst, separated by the Narew. About 30–40 bison live there, but the exact population is not known in such detail as in the bison forest, where an accurate count is carried out every year. According to a count conducted in 1828 (in December), there were 696 head, which was the highest number ever recorded. About eight years ago, when the current Crown Forest Warden, Mr. von Ronko,[2] to whom I owe the following remarks concerning bison, was assigned supervision over the forest, the population of the animal amounted to 350 head. In the past, it was believed that the population was even scarcer, but ever since it began receiving special care, the number has been making a steady increase.

While bison are young, no more than 10–12 years old, they tend to live in small herds of 20–40 head. The older ones, on the other hand, separate from the herd and live alone. During the rut, they merge with the herds, and remain with them throughout August. The animals always avoid places and plains where peasants have their cottages. Likewise, they never leave the forest to visit the cereal fields or woodless plains, but they always remain in the thickets. Since the forest is surrounded by a broad plain, bison are unlikely to ever leave their current habitat voluntarily. In the summer or on warm autumn days they favour sandy places, where they spend hours lying in large pits, slinging sand on themselves, partly to cool themselves and partly, by swinging their tails, to free themselves from obtrusive flies. When spring arrives, however, they immediately enter dense thickets to seek the marshy places for the first herbs, anemones and buttercups, which they like very much. In winter, they rarely leave the spruce tree stands, lying there quietly during the day and roaming only by night in search of food.

Although bison feed on the same types of grasses and herbs as cattle in the area, they seem to prefer certain plants to other species. In addition to creeping buttercap (*R. repens*), they favour *Cirsium oleraceum, Hierochloa borealis*, as well as spicy and bitter grasses and herbs in general. They also find the bark of young trees to gnaw on, or, from the break of spring, the young leaves of linden, poplar, elm and willow, as well as certain shrub species, such as *Rhamnus*, *Lonicera* and the like, and moreover, certain species of mosses, including oakmoss. Yet, they avoid the moss found on birch, spruce and other such trees, and do not feed on birch or oak leaves, not to mention spruce needles. In winter, they prefer 2–3-year-old heather (*Calluna vulgaris*) so much that they choose it over the hay mown for them. This was handled in the past by burning the older heather plants every year, so that they would always grow anew and serve as feed for the bison. Bison rarely search for water, sometimes not for entire days. They use small forest rivers even less frequently, preferring

[2] See: final remark.

to drink water in the forest from small puddles, which are quite widespread during the wet seasons.
Bison swim quite skilfully through rivers, similarly to our cattle, especially if they are attacked by wolves.

The bison cow is fertilized in the first half of August and by 25 of August the cow is usually in calf, so that by 1 of September the rut ends, lasting about 2–3 weeks. During this period, fights between bulls are very intense. They fight hard for the cows and often hurt each other dangerously. Old bison are marked with extraordinary body strength, but they are no longer able to breed. Still, as they are victorious in such fights, they keep brawny young bulls away from the cows. It might be advisable to issue an order to shoot such old bulls each year, as they disturb the fertilization of the females.[3]

Bison cows remain in calf until the end of March, when they give birth to only one calf at a time. The calf consumes its mother's milk until the next rut, which is in August, when the bull drives the young away from the females. Thus, a calf follows its mother for about 5–5½ months. Attempts to cross a bison bull or cow with a regular cow or bull have never been successful, because bison avoid cows or butt them to death and in no way will they endure cows in their proximity, as the bison loathes the cow vapour.

In the past, peasants sometimes made attempts to cross the animals in the woods (now it is strictly forbidden), but they never managed to attach bison to cattle. Boars, on the other hand, approach sows in the farmyards to fertilize them. Sows then give birth to piglets that are as wild as their fathers and bite so much that they become dangerous to be kept in the yard. The sex drive of boars in relation to common sows may sometimes be so immense that, as if blind, they slam into a peasant's yard, where they are easy to catch and lock.

As for bison hair, it tends to be thickest and most beautiful in November, as soon as the first snow has fallen. At that time, it has mostly been frosty for about a month, but the hair remains thin and short. The first snow changes everything in that respect so that within a few days the hair grows and turns thick and long. As the snow melts, the winter hair is lost, most often as soon as in February, and as quickly as it grew. One day can make such a big difference that after two to three days (?) no more bison with beautiful winter hair can be seen. According to the peasants, bison can live for 40 years. The age can be calculated quite accurately based on horn rings, although this method is only reliable up to certain age. They

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[3] For the elk, the opposite is true, because younger bulls are stronger than the older, infertile ones. The latter ones develop antlers made of very shallow blades, the ends of which split to a great extent. The number of years can be recognized quite clearly by the number of tines, and up to 30 tines have already been counted. The younger the animal, the fewer tines its antler has, and the stronger the animal can attack and hurt. Very old bulls, however, grow only a short straight beam, therefore no strongly tined antlers, but this beam is also dropped each year. The reason for this is, of course, that reproductive power has decreased to such an extent. Also wild boars are stronger and more solid when they are young, because the old ones become very big and often clumsy.

remain fertile up to the age of about 30 years. Old bulls no longer grow a beard, they turn almost completely gray, their teeth fall out down so badly that the tips of their toes protrude (?)

The thinnest bison can be seen in spring. Afterwards they gain weight, to become fattest in August and this condition holds until January, at which point they gradually lose weight until spring. The number of bulls is always much greater than that of cows. This is probably the reason for the frequent fights between them. On the other hand, cows tend to be so infertile that often only four, up to a maximum of six one-year-olds can be found among 40 adult bison.

The bison is rarely seen along open roads, as they avoid all murmur and escape into the forest. Thus, they should be labelled timid rather than bold. They hate bright and vivid colours, and above all, they loathe red, yellow and similarly vivid shades. They run away from such colours, especially in the winter. In the summer, however, they do not escape, as they see red, yellow and other flowers in front of them. They attack people only if irritated, but they attack not the person who enraged them, but rather the one they see in the closest proximity. Indeed, they often attack someone because of a dog barking at them. Initially, they only shake their mane, threaten with their horns and finally go straight at the man. If a bison is angry, it shows its bluish tongue threateningly and then hides it again, fanning its tail threateningly, while the red of the eyes appear and, shining, they rotate in the orbits.

Owing to their heaviness, bison are unable to run further than half to one verst (?), when they become tired and need a rest. The further they are rushed forward, the more frequently they rest and stick out their tongue to breathe. Walking slowly, a bison is likely to travel up to two versts without stopping. One bison may successfully shoo three wolves away, but double number will soon tire it, so that it gives up and is torn apart.

In order to observe bison, I went to the Browsk Forest Subdistrict with two shooters in the morning on 10 September. We walked in different directions for a long while, unable to approach them, despite the fact that von Ronko had sent a few shooters in earlier in the morning to find out where the animals were most likely to be found. The shooters only spotted two bison, which, having been approached, fled immediately, followed by the herd we were tracking. I could admire the skill of the shooters in finding traces of bison on the swampy forest ground. They touched the traces with the hand several times to learn if they were still warm and whether they had been freshly made by bison.[4] Finally, we heard the treading of hooves from afar. As we approached, even the sound they make, being a murmur like the squealing of pigs, but quieter, could be heard. But they easily sensed our proximity and the whole herd, 10–15 strong, escaped with a terrible rumble, overturning a great

[4] Here Eichwald probably understands too literally the expression 'warm tracks' in hunters' jargon, which should be understood as 'fresh tracks', because after all, he could not have believed that the swampy soil under the feet of the bison actually warmed up [translator's comment].

number of trees. We could hear the breaking of trees and the rumbling of the earth under their feet, which sounded terrifying in the deep silence of the forest. Despite the fact that we always approached them against the wind, their sense of smell is extremely sensitive, such that the closeness of humans can be sensed from considerable distance, and we were unable to force them to stand still anywhere. At those places where they had grazed for some time, we could smell the same odour that remains after the vapour of local cows. In the end, several head with their tails raised and heads down fled rapidly past us at the shooting distance. Having spent nearly two hours on almost completely futile wandering, we reached a place called Dolgije, i.e. a rather thin birch forest with several smaller not regenerated areas, where hay stacks are placed for the bison in the spring. There, we found a whole herd of about 20 head, feeding peacefully. We could watch them for a long while from the shooting distance, but when they noticed us, they fled with a terrible racket.

Most of the animals were chestnut or dark brown in colour. A few of them were very large, while others, much smaller, must have been calves. The front part of the bison body is very thick and wide. The further back, the slimmer and thinner the body becomes, so that hardly any proportion to the front part of the body is retained. The hump visible above the shoulder blades is quite high and, as a result, towards the back the dorsum becomes more and more oblique and lower. The thighs are very thick and strong, while the tibias are thin and slim. Short hair covers the entire body except the skull, neck and chin. At the chin, there hangs long, curly, very thick hair that forms the beard and the mane of the bison.

The osteology of bison was superbly presented by our Bojanus, who died too soon.[5] In the paper, he also mentions the strange number of bison cow ribs. While the male bison has fourteen ribs on each side, the skeleton of the bison cow, the only one Bojanus could examine, had only thirteen pairs. Thus, it could be concluded that the number of ribs was different for each sex. Recently, a second cow was killed for the needs of the University of Vilnius zoological college. This specimen was shown to have the same number of ribs as the bison bull, namely fourteen on each side. Therefore, the bison cow investigated by Bojanus was only an exception to the rule. The same aberration was found a few years ago in Vilnius in the case of a sheep, when instead of thirteen, only twelve ribs were found.

And, instead of six, there were seven lumbar vertebrae noticed as well. The seventh vertebra also had very well-developed transverse processes. Similar exceptions can be observed in other animals.

The Białowieża Forest is located on a large plain, which is encircled on all sides by a flat steppe. The circumference of the forest probably amounts to about 160 versts, and its greatest

[5] *Act. Acad. Caes. Leop. Nat. Cur*. T. XIII, part. II. Bojanus was less lucky in the case of setting the skeleton and in drawing the body. Too significantly did he underestimate the dorsal hump, which should be triggered by the very long processes of the vertebrae. Drawings of the bison in other works were much less successful, and perhaps least so with Mr. von Brincken (German: *descript* de la forêt de Białowieża, Warsaw, 1828 [1826? translation]).

length is about 50, but most often only 40–45 versts. Besides the grounds being tsarian property, the forest contains about 88,000 dessiatines [translator's note: a Russian unit of land area equal to 2.7 acres] of the country. These Crown properties include Białowieża, Mielniko, Niemierza, Tuszamla and Masiewo, together with the German colony of Szoły, consisting of 17 Swabian families, as well as Narewka, Skrupowa, Bernacki Bridge, Lipiny, the village of Orzeszkowa and town of Hurynów. Finally, a small piece of the church field belongs to Białowieża. The forest itself consists mostly of conifers mixed here and there with birch. Willows are not uncommon, because the soil is marshy in many places. An area comprising about a twelfth part of the forest is covered by marshland. Most marshes are accessible, with only a small part of them being inaccessible. Mostly cane plants grow here, and elk, strangely able to jump over the marshy ground without sinking in, is also said to reside there. The rest of the soil is sandy or loamy, mixed with chernozem.

In order to breed the bison more effectively, the forests have been divided into twelve forest subdistricts (in Polish *straże*, in Russian *дачы*), namely: 1) Browska, 2) Narewska, 3) Augustowska, 4) Hajnowska, 5) Świetliczańska, 6) Leśnieńska, 7) Okolnicka, 8) Starzyńska, 9) Stołpowicka, 10) Krukowska, 11) Podbielska, and 12) Dziadowlańska. Centrally is the Crown village of Białowieża on the River Narewka, elevated about 25 fathoms above its level and, most importantly, the former palace of King August III, who had ordered to have it built because of his frequent hunting visits.

The crown village brings in an annual income of about 800 roubles in silver and it has a perimeter of roughly nine versts. No trees in this broad plain can be seen, but rather fertile fields. Three shooters live in the village, whose duty is to watch that peasants do not fell trees. There is also a church there.

The forest is protected by 118 shooters, located around the area, at the edge of the forest, living in places that they were granted by former Polish kings for clearing.
The shooters were supposed to fell trees and to cultivate the fields there so that the bison would never leave the forest. Later, however, clearing was forbidden, therefore fields wider than 600 steps in total can hardly be seen. This is called a chain. First of all, the shooters are supposed to make sure that the bison, under no circumstances, leave the forest, which never happens, as they never go out into the open area. The shooters are also to ensure that trees are not felled, which carries a severe punishment. Nonetheless, the shooters pay the same tribute as other peasants, even for the fields they cultivate. In addition, six more villages are located in the area (namely: Kamienniki, next to the royal bridge, where a forest warden lives and consists of 13 houses; Kiwaczyn, Panasiuki, Ćwirki, Rożkowce, Młynasy Polskie), with 108 houses in total. The inhabitants, called *osacznicy* [translator's note: from Polish verb *osaczać* – to corner] (because in the past they were obliged to corner wild animals for 14 days per year, while the district forest manager was hunting), are under obligation to supply hay for the bison in the places where the animals usually stay. These are usually small

meadows full of beautiful grasses, with some fodder herbs. The mowed grass is stacked around a vertical pole, and quite high stacks can be formed that are well pressed and rounded by patting. The hay amounts to around 750 carts per year, with 20 pood per cart. It is primarily in the vicinity of the haystacks where the bison stay in winter. In addition, these peasants are obliged to stand on public roads in the hot summer and make sure that those passing do not set fire anywhere in the forest, which in the past used to happen so often that extensive areas of the forest were burnt down. The last village, Młynasy Polskie, lies 35 versts away from the forest, but its inhabitants are obliged to come to guard the forest 12 times a year, hence, once a month. They are obliged to pay exactly the same tributes, even for the fields, as other peasants do.

In each forest subdistrict, there lives a forest subwarden, a guard (there are twelve of them in total). They must be noblemen or come from the local nobility. There are several shooters subordinated to each of them. In the time of King August III, the majority of them were Germans. Their descendants still live in the area, by the same German names (e.g. Eichler, Schötter, Wapp), but they are of the Catholic religion and, like other inhabitants of the forest, they speak the Little Russian dialect, which is a little softer than Ukrainian and comes closer to Polish. They do not say *koły, biły* but pronounce them *koli, bili* instead. The forest subwardens are responsible for every event that must be reported to the forest warden, e.g. that a tree has been felled in the forest, that a fire broke out or that a bison has been killed. The latter event, especially, is sometimes severely punished by the order of the superiors and was formerly punished by resettlement to Siberia. Currently, a bison can be killed only by tsarian order.[6,7] The forest subwardens are not paid a salary, but they receive about 60 morgen of fields for cultivation, which they grow with the help of three to four peasants who serve only two days a week. In addition, they bring 20 carts of hay from the forest for their cattle.

The forest warden lives in a house next to the royal bridge, which is made of wood, very simply, and owes its grand name only to the fact that King August III ordered to have it built on the Biała River for hunting purposes. Currently, the forest warden receives nothing

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[6] The greatest bison hunt on record was undoubtedly held under King Augustus III in 1752. On one day, 27 September, 42 bison were shot, among which eleven immense specimens, of which the largest weighed 14 ctn. (Polish hundredweight, about 60 kg) 50 pounds, a further thirteen elks, the heaviest weighing 2 ctw. 75 pounds, and two head of roe deer, or 57 in total.

[7] Obviously, during the present World War numerous foresters and naturalists probably agonized over the fate of the bison, this monument of nature, especially when seeing in illustrated magazines high personalities over a killed bison. It is of course, difficult to predict, how the bison will survive this war, but it should be supposed that they will be respected as a real monument of nature. As such, we could be reassured by the news recently reported by newspapers, namely that Lieutenant General von Seckendorff, the German stage inspector, issued a rule regulating hunting in the Białowieża Forest (translator's comment [of the original version – Ed.]).

more than a salary of 400 banco roubles. In Polish times, the forest warden was owed the village of Białowieża, apart from the 1000 guilders for his salary.

There are two rivers in the forest. The bigger one, the Narew, flows near the northern end of the forest and flows into the Vistula, whereas the smaller one, the Narewka, has its sources in the forest itself, flows by Białowieża and then into the Narew six versts outside the forest in the Białystok Poviat. In the Leśniański Forest Subdistrict, there are also sources of a small river, the Leśna, which joins the Biała at the border of the forest. This river, in turn, has its sources in the Opole estate of Count Chodkiewicz, and flows next past the forest warden's office, where the royal bridge crosses over it. The Biała meets the Leśna and then, 10 versts further down, in Brześć, it flows into the Bug. There are numerous mills along the way and therefore canoes cannot be used on it, while rafts can be used very easily on the Narew and the Narewka. In Polish times, a highly advanced trade in timber was carried out here, which brought about 100,000 guilders annually. The wood went straight to the Vistula and Gdańsk. A lot of potash, tar, turpentine and suchlike were also exported with high benefit.

The entire division and administration of the forest was introduced during the reign of King Stanisław August and, soon, it was developed to such a high level of perfection that can only be noticed in the case of a limited number of forest areas. At that time, there were also thirteen forest subdistricts, but the thirteenth one was granted by Tsarina Catherine II to Field Marshal Count Rumiancow, which destroyed the shape of the forest. At the same time, the clearing of the forest by shooters was ceased and this duty was rescinded. The strange thing is that at the new recording of the forest, a piece of the land, 120 *dessiatines* in size, was overlooked. The area featured small fields with 25 houses: Teremiski, Buda and Nagorzelce. Their inhabitants are called *budnicy* (colliers). They formerly arrived here from the Wielkopolska Region (? aus dem hohen Pohlen), or perhaps from Galicia, to set up large potash operations, and since these were abolished the people were completely forgotten. For this reason, they are under no obligation to deliver any tribute yet.

The main occupation of the inhabitants of the forest, in whom nothing of the wildness which Mr. von Brinken describes them as having can be noticed, is reliable cattle breeding. This is because for the cultivation of grain they lack the fields and the necessary sunshine, because the tall, thick forest trees give too much shade. Sheep are kept by peasants in small numbers, as they hate swampy areas. The most common stock kept here are cows and oxen, whereas pigs are scarce, since they are devoured by wolves. Even cows are sometimes devoured by wolves, so that every peasant loses one each year. In fact, several head of the bison are also devoured by wolves every year. Since (1825) the hunting of wild animals, including wolves, has been generally forbidden, wolves have killed 54 bison in two years. Finally, because of a new order by the forest warden, hunting wolves was not only allowed, but even ordered. From July 1829 to September, about 36 wolves were slain. Sometimes, the wolves chase the bison until the latter are completely tired and fall, unable to defend themselves with their horns. Then the wolves attack with greater ferocity, tearing huge chunks from the bison's sides until the animal completely surrenders and dies.

In the forest, honey is collected in large amounts, most of it being the yellow type, but also white linden honey is collected, although this was lacking this year.

In the north, the Białowieża Forest borders a part of the Wołkowysk Poviat, separated from it by the Narew River, and specifically the forests of Count Tyszkiewicz, in which bison also live, although they are not bred there on purpose. Although no heaps of hay are prepared for them in the winter, the bison do not starve as they are able to locate the hay stockpiled by the peasants. Further west, the Grodno Poviat forms the northern border of the forest. Towards the east, in the Prużana Poviat, the forest borders the properties of various landowners; partly with the Starościński and Szereszów Crown forest; partly with the forests of Count Siewers, a landowner in the Brześć Poviat. In the east, there is also the former thirteenth forest subdistrict, currently owned by Count Rumiancow, from which the bison have withdrawn completely since the felling of trees commenced in the area. Towards the south, in the Brześć Poviat, the forest borders with the woodless plains that belong to numerous landowners, partly also with the forests of Count Ożarowski and the landowner Wilczewski. Finally, towards the west, the forest borders the Białystok governorate; partly also other Crown forests, and partly the agricultural land of local Crown peasants.

The bison are most abundant in the Augustów Forest Subdistrict. This year, there were over 120 head there, because they say that the most aromatic herbs grow in the area. The animals are completely missing from the Dziadowlański Subdistrict, as the area abounds in too little grass and too many swamps. Owing to the number of swamps and grassless places, the bison are also rare in the Kurukowskie forest subdistrict. However, numerous head of moose, bear, roe deer and wild boar are present here, which may have driven the bison out. It is in the area that most oaks grow, whose acorns are liked by wild boars so much. For this reason, hay is prepared only in eleven forest subdistricts, except for Dziadowlański, as no bison are seen there.

Every year, 30 to 40 more carts of hay must be harvested in the other forest subdistricts, as the number of bison increases year by year.

The bison counting is conducted as follows: each forest subdistrict is divided into several parts, depending on the number of shooters; the larger ones into 16 parts, while the smaller ones into 5 or more. The division of each forest subdistrict into parts is achieved thanks to the small roads accidentally found by the shooters. On the third day following the first snowfall, the counting is conducted within one hour, usually between 10 and 11 a.m. Because of hunger, the bison must certainly go to the haystacks, and therefore, they are forced to leave the resting places that they had been forced to seek by the cold. Each shooter carries two sticks, one longer and one shorter. The latter is notched if a bison leaves the shooter's area for another one, which can be recognized by tracks left in the snow. The longer stick is notched to mark each bison that stayed in the shooter's area, rather than going further. Such a bison is counted as actually present, while the one that has left is only counted by the next shooter, in whose area the shooter stopped at 11 a.m. At 12 a.m., the shooters report to their subdistrict forest managers the number of bison that were found and that have left. The managers, on the other hand, gather together to check the quantity again, as it might also happen that a bison has moved from one forest subdistrict to another and that, therefore, it should be counted in the second area rather than the first one. Only then can the total sum be calculated. The number, said to be very accurate, is reported to the district forest manager.

So much is written by Eichwald about the forest.

Another interesting issue is the life story of Eugeniusz Ronka, mentioned in this work. As Ronko's merits in terms of the forestry of the Wielkopolska region are great, it is worth recalling his turns of fate here again. Above all, the question arises how to write his name, 'Ronko' as Eichwald writes, or 'Ronka', as J. Łukowski says in *Krótki zarys historyi leśnictwa W. Ks. Poznańskiem* [Brief Outline of the History of Forestry in The Grand Duchy of Posen] and F. Skoraczewski in *Rozwój polskiego leśnictwa w XIX w. w W. Ks. Poznańskiem* [Development of Polish Forestry in The Grand Duchy of Posen in the 19th Century].

Since Skoraczewski knew Ronka in person and worked under his command for some time, which he always proudly mentioned, it should be supposed that he also knew the name correctly. On the other hand, Eichwald distorts names in general, writing, for example, Tinkkiewitsch instead of Tyszkiewicz, Wilnhewski instead of Wilczewski, Rumancow instead of Rumiancow. This fact encourages me to accept the spelling of Ronka.

In fact, Eugeniusz Ronka came from a Swiss family, as his father was appointed from Switzerland by Tsarina Catherine II as a professor at the Moscow University. Eugeniusz was born in Vladikavkaz during his parents' trip to the Caucasus and grew up in Moscow. Having completed a university education there, however, he joined the army and became an officer in advanced weapons (artillery) in the newly created corps of engineers with its headquarters in Tula, when Napoleon I entered Moscow. Following the Napoleonic Wars, Ronka was stationed in St Petersburg, where, in his time free from military service, he devoted himself to university studies on natural sciences, mainly forestry. In 1820, with a captain's rank, he was sent to be a district forest manager in the Białowieża Forest. Here he learned Polish and married a Polish woman, born Kasprowiczówna. Ronke's attitude to Polishness is proved by all his further life, and above all, the year of 1831. Together with his subordinate Szreter, undoubtedly a descendant of those German shooters whom Eichwald mentions, he organised a unit of Białowieża shooters with whom he joined the corps of General Chłapowski on its march to Vilnius.

Following the unfortunate campaign, Ronka, together with the remaining shooters and the whole corps of Chłapowski and Giełgud, left for Prussia, from where, having completed quarantine, he emigrated to France. Not wanting to live on French military pay, provided of mercy, Ronka went to Switzerland to earn a living among engineers and foresters.

A few years later, because he missed Poland and his family, from whom he had no news, Ronka went on foot through Bavaria and the Czech Republic to the Poznań Region, to see his friend from the camp, Count Seweryn Wielżyński, at that time the owner of the Miłosław estate. Ronka then used a Swiss passport, to avoid being turned in by the Prussians to the Russian authorities, the latter having determined a price for his head of 6,000 roubles.

In Miłosław, however, Ronka led no idle existence and started to work immediately. First he organised meadow irrigation in Miłosław, Łabiszyn, Samostrzel, Pudliszki in the Krobia Poviat and in several other places.

However, the Prussian police authorities investigated his past, and, despite the French passports, he was expelled to France again. Then Ronka sought a Baden passport and returned to the Duchy of Poznań, taking a walking route through central Germany. He worked again for several years as a gauger and forester, establishing forest enterprises in larger private forests, according to the best models available at the time. Maps of the Miłosław forests have apparently survived, and if I am not mistaken, I also saw in Łabiszyn photos taken by Ronka. Moreover, he was trying to encourage Polish, scientifically skilled youth to assume forest professions. When commencing the management of a forest unit, he would often put forward the condition that a Pole should be assigned to him as a technical assistant and thoroughly familiarised this person with forestry and surveying science. He obliged foresters of Polish nationality who were already employed, as well as his helpers, to attract young people to the forest profession. On the other hand, he would convince landowners about the need to sustain the forest and establish a forest enterprise. He succeeded quite frequently, because he was supported by contemporary influential circles.

Despite this, Ronka was once again expelled by the Prussian authorities to France and for the third time he returned again on foot by other routes to Grand Duchy of Poznań, and then, during the humanitarian rule of Frederick Wilhelm, he was granted by the police authority a residence permit, thanks to the efforts of the local influential personalities.

Having lived an extremely active life, whose influence on the forestry in the Grand Duchy of Poznań is beyond doubt, Ronka moved around 1868 from Miłosław to his daughter with the married name Breańska, to Zagórzany near Gdów in Galicia, where he died in 1875.

A. K.

The Białowieża Forest in the time of war

Since the summer of 1915, Polish foresters have turned their thoughts to a far corner of Lithuania, and until recently precious monuments of Polish forests, hunting grounds of kings and the only stronghold of bison, a place described and praised many a time – the Białowieża Forest!

What is the condition of its forests nowadays? What tribute did it have to pay to the devastating war? Will any of its remains survive? These are the questions we ask ourselves whenever a distant echo brings the rumour of large-scale exploitation of the forest.

A little more light on the issues concerning the Białowieża Forest is shed by the official **Report from the meeting of forest administration officials of Ober-Ost** [editor's note: an administrative unit established by the German Empire on part of the territory of the Russian Empire occupied between 1915 and 1918] **held on 12th and 13th October 1916 in Białowieża,** published in issue 1 of the *Forstwissenschaftliches Centralblatt* as of 1917. A literal translation of this report is provided below.

The author of the report, Lieutenant Dr. K. Rubner, second adjutant to the military forest board in Białowieża, provides no information concerning the present utilisation of the forest. An attentive reader, however, will be able to make some guesses based on the general remarks provided every now and then.

Finally, it should be noted that the meeting was held a year ago, and since that time the exploitation has certainly seen a significant increase.

The forest meeting in Białowieża was organised to discuss basic questions related to forest management in the Ober-Ost area and to supply the army with forest-based raw materials. The meeting was also aimed at giving participants the opportunity to visit the famous forest and to learn about the current exploitation.

On 11 October, 44 officers, forest professionals, arrived in Białowieża. A common room was prepared in the rooms of the former imperial hunting castle. Captain and forestry counsellor Dr. Escherich, currently the head of the military forest board in Białowieża, welcomed the guests in the officers' mess on behalf of Lieutenant General Seckendorf, district inspector. The head of the Ober-Ost forest department thanked him on behalf of the guests for the welcome.

The next day, at 8 a.m., the scientific collections were viewed, while Captain Dr. Voit gave brief explanations. These collections provide an overview of the entire fauna and flora of the area, ranging from the skeleton of a bison to a bark beetle, from forest oak slices to moss and swamp seaweed. The rich collection of taxidermied birds should especially be mentioned.

At half past 9 a.m., the visitors were taken by cars to the timber yard of the Białowieża forest district (Head Capt. Hornung). At the newly built sawmill in Białowieża, Captain Escherich briefly explained the direction for the forest utilisation in the area. The timber reserves available here being almost inexhaustible, the extent of exploitation can therefore be quite discretionary, limited only by the availability of workers and horses, as well as the efficiency of the technical means. Therefore, the extensive basis on which the entire exploitation of forest areas was based should be unconditionally justified, regardless of the temporary financial result.

The selection cutting, conducted in the first year, led to the construction of long field and supply railroads. They currently have the advantage that tree felling can be carried out simultaneously in many places in the forest. In this way it is possible to avoid transport congestion, which would undoubtedly occur in case of such huge (*gewaltigen*) quantities of timber. For now, 42 km of steam-powered railroads and 120 km of horse-drawn railroads have been laid. Subsequently, a huge fuelwood timber yard was visited, which is only used to meet the needs of the Białowieża forest district. According to the experience gained in the last year, this district consumes 12,000 to 15,000 stere of fuelwood a year. A portable electric machine for cutting and splitting the fuelwood will be installed for chopping.

Having left the timber yard, the group went to the old Białowieża sawmill, whose size and location do not match its purpose. Then they went through Podolany, passing vast spaces of potatoes and vegetables grown to satisfy the needs of the military board, to the prisoners' camp in Grudki.

This camp is sized for 800 prisoners, together with an appropriate number of guards. The individual barracks originally housed 120 people, which were extended and improved later. In the newest type, up to 200 people can be lodged. The barracks are built of double wooden walls, between which the cotton grass is placed. Brick stoves provide the necessary heat. There are kitchens with a dining room there, as well as pumps and a water tower for supplying germ-free, decent quality water from wells drilled for that purpose. The places in which to drill for the water wells were indicated by a dowser.

At the Grudki timber yard of the Podolany forest district (Captain von Axthalb), where the tour stopped again, the division of the cut material into round timber and stacked wood was conducted as early as at the logging and stacking stages. At the Gajnówka [Hajnówka] – Białowieża railway line, a junction for loading and a siding have been built, so that the total length of the loading line is 400 m. At each of the three timber yards, a separate access track for the field railway exists. Thanks to the exact levelling, access over the last 2 km is possible by natural descent. Based on the levelling, the yard for the roundwood, is flattened in such a manner that the trunks can easily be rolled over the sleepers onto the prepared railway carts. The surface of both the carts and the yard lie on the same level. If the necessary number of carts and workers is provided, up to 25–30 carts ready for transport can be loaded daily in this yard.

While traveling south, on the highroad to Prużana, the participants were able to observe stands consisting of pine and spruce, stunted pine growing on peat and pine of first quality grade with average height of 36 metres and growing stock of 750 m^3 per hectare.

At 2 o'clock p.m., the participants were taken in carriages and lorries to the headquarters of the Czerlanka forest district (headed by Captain Schamberg), picturesquely hidden among the trees. A horse-drawn train was waiting here, which quickly reached the station and the prisoner-of-war camp in Czerlanka.

This is the largest one of the camps built by the military administration, with over 1100 places. The arrangement is mostly identical to the one found in Grudki. On a small hill, there are barracks for guards and a water tower. From the camp, the participants were taken to the station, where Russian prisoners of war were occupied with loading heavy oak logs. A newly built sawmill is connected to the railroad by a loading track, has two vertical and one horizontal gang saws, the latter for hardwood. One vertical gang saw is currently working. From the sawmill, the participants were transported by the field railway back to the Czerlanka forest district, from where a distance over twelve kilometres was covered at high speed through the deciduous forest stands of the district.

Among the seven districts of the Białowieża Forest, Czerlanka has its own distinct character, which it owes precisely to these deciduous tree stands. Three fifths of the total area of 22,000 ha is occupied by deciduous tree species, whereas the rest is mostly covered with pine and, to a lesser degree, spruce. Throughout the district, formed in the shape of a quadrangle, there stretch two broad strips of land overgrown with deciduous tree species, genuine primeval tree stands.

The economy in the district is aimed at the production of deciduous tree species. In the course of free, natural succession, the trees have chosen suitable habitats in the wilderness, raising their wonderful trunks there. The continuous, variable mixture consists of oak, ash, aspen, birch, hornbeam, linden, elm, sycamore maple and alder trees. Beech trees are not present anywhere in the forest.

Under the conditions of full canopy closure, the pedunculate oak is characterised with a full, clean trunk. Given its relatively slow growth, the tree requires 300 to 600 years to produce smooth logs of 80 to 100 cm in middle diameter and 15 m in length. In terms of the narrowness of growth rings, the colour and gentleness of the best trunks are not inferior to the most valuable of oaks grown in the Spessart, they provide an excellent material for veneers and for the furniture industry, and are particularly suitable for the construction of railway wagons.

Ash grows on peaty soils to develop exceptionally beautiful specimens. The trunks, prepared for export, of up to 8 cubic meters in volume and completely free of defects are not exceptional.

The small share of alder (about 1,000 m^3) became a vital issue among military suppliers and cigar box manufacturers. The quality of the produced materials matched the opinion enjoyed by the Russian alder in the trade in timber.

Having reached the end of the field railway, the tour participants returned because of the nearing dusk to Czerlanka, and from there by cars to Białowieża.

At half past 6 p.m. the participants gathered in the dining room of the tsarist castle to hear a lecture given by Captain Lautenschlagier, on the silvicultural situation in the forest, the utilisation of the forest during the Russian reign as well as the method and results of the 7-month long stock inventory work. Captain Lautenschlager described the issue as follows:

The actual forest covers 128,000 hectares, it is located 140 to 202 metres above sea level, on diluvial sands and marlstone. About ⅕ to ⅙ of its area is covered by marshes, so the forest acts as a major reservoir that supplies streams and rivers.

Along the north-west edge is a railway line from Brześć Litewski to Wołkowysk, with a line from Gajnówka [Hajnówka] to Białowieża branching away from it. As far as roads are concerned, the forest only features a well-kept highroad from Bielsk to Prużana, whereas many compartment boundary lines are suitable for transport.

During the Russian reign, Białowieża served as a headquarters for the forest general who had 5 forest district managers under his command. The entire forest was divided into 1,147 square compartments of 1 square verst each. The only approach to the forest use at that time comprised removal of snag, to which the lack of insect damage should be attributed. Proper use of the forest in the form of an edge or clearcutting silvicultural system, established in the shape of squares located in the middle of the compartments, seemed to serve mostly hunting purposes. To say the least, nothing was done in favour of regeneration.

The Białowieża Forest comprises deciduous species, namely, oak, hornbeam, ash, birch, linden, sycamore maple, aspen, alder, and elm; all of them marked by a good level of height growth. Another group of species includes conifers, such as pine and spruce. The following types of forest stands can be distinguished in the forest:

1. Deciduous trees, solely or with an admixture of spruce, common type in the forest, trees of 2 to 400 years old, with an average height of 30 metres. Such stands cover 24% of the total area.
2. Mixed stands, composed of deciduous species and conifers, 10%.
3. Pure pine stands, or with the admixture of birch, 41%.
4. Pure spruce stands, 7%.
5. Spruce mixed with pine, 17%.

The lack of undergrowth in the tree stands undoubtedly results from the robust fauna.

Primary stands seem to have been formed from seed stand forests of the combined type (? R.), because individual specimens are strikingly diverse in terms of age. Indeed, these zones deserve to be called primeval forest, not only due to being intact, but mainly because individual species are located here strictly according to their individual needs, in the smallest spaces required.

An estimate of abundance and value, superfluous as it may seem, may prove to be a source of great advantage in peace negotiations. In this respect, the following data can be provided:

Stand type 1. Full canopy cover of over 500 m^3

Stand type 3. Over 700 m^3

Stand type 5. Up to 800 m^3.

The total value of the forest (soil together with forest stands and assets) ranges from 700 to 800,000.000 M. [editor's note: probably German marks], depending on whether a peacetime or wartime price for 1 m^3 is assumed.

In this respect, Captain Escherich offered some explanations on the hunting conditions.

The Białowieża Forest should be seen as a unique area in this regard. The area serves as the last asylum for bison in Europe (except for the Caucasus); in the marshlands and wetland alders elk has been spotted, whereas the red deer used to be distinguished by its great antlers.

Certain degradation occurred after Newely, a Czech, was appointed gamekeeper, as his main goal was the mass reproduction of animals. As a result of excessive feeding, the bison became almost a domestic animal and its degeneracy is currently manifested in its low fertility. Once the forest passed under German military management, a change took place. Due to the general lack of fodder, artificial feeding of the bison was deemed impossible, while in the winter months soft trees, mainly aspens, were felled to provide natural feed for the bison. In this way, the animals had to look for food themselves. Contrary to various predictions, no decline was noted, apart from one emaciated bison female. Several animals fell victim to poachers. The number of bison can certainly be assumed to be 120, but it might be as high as 150 to 180.

As a result of excessive nurturing, the number of red deer increased to 10,000 head in 1911. At the same time, the animals' sex ratio was completely incorrect; one mature stag to three hinds. For this reason, as a result of the surfeit of red deer and fallow deer in the area, the elk, with the exception of a few specimens, left the forest, whereas various diseases occurred in the animal population. In 1911, several thousand animals fell victim to disease. It is possible that by means of radical hunting of fallow deer and a strong reduction in the number of red deer, the elk will return, provided the animal is still present nearby.

The condition of the wild boar is good. The damage the animals do in the fields, despite fencing, proves quite considerable. Moreover, the small numbers of capercaillie, black grouse and hazel grouse result from the destruction of their hatching sites by wild boar.

On behalf of the assembly, Captain Kirchner thanked the speaker for the effort and interest.

The guests spent the evening in the officer's quarters.

The next day at half past 8 a.m. the participants took a special train to Gajnówka [Hajnówka], located on the Brześć Litewski–Wołkowysk line. First, the 100-metre long ramp was inspected, which is the end point of the Gajnówka [Hajnówka]–Nowy Most and Gajnówka [Hajnówka]–Czerlanka line. On this ramp, thick sawmill logs were being loaded to be sent to Schulitz, pilots to Königsberg and birch for gun beds to be transported to Erfurt. Then the guests visited a wood wool factory with ten machines, working partly with fourfold and partly with twofold mode, two automatic packing presses and one automatic knife grinding machine.

In two mechanical workshops, the construction of which is in progress, namely an iron processing workshop (for all repairs for the Białowieża military government and for division 12), as well as a woodworking workshops (production of sleds, carts and furniture, etc.) and some machines could be observed. Then the tour participants visited a camp for 1,000 civilian workers. Special attention was given to the canteen of substantial size, which ensures uniform nutrition for all workers employed on the site.

Dr. Escherich's Sawmill, surrounded on three sides by railway tracks, with a 350-horsepower locomotive and 10 gang saws, the largest of which is 1 metre wide. In the log yard, whose entire surface is lined with sleepers and where at least 6000 m^3 of round timber material can be stored, the thick pine trunks provoked general admiration.

Following that visit, a ride by field railway to Nowy Most (8 km from Gajnówka [Hajnówka] took place, during which the guests saw the north-western part of the forest, which boasts old pine and spruce trees. In Nowy Most, the turpentine and tar furnaces were inspected, where Captain Parst, the head of the Mała Narewka forest office, gave a short lecture on these facilities and the income they generate. One furnace can hold up to 100 m^3 and after the 16 day burning period, yields 1700 kg of turpentine oil, 1260 kg of tar and 4000 kg of charcoal.

The lack of time urged the visitors to return to Gajówka [Hajnówka], from where they returned to Białowieża on a special train.

In the afternoon the agenda was changed. So strong was the desire to see the famous bison that it was decided to devote an afternoon to this purpose.

A meeting scheduled for half past 3 p.m. was postponed by a few hours.

In 10 carriages and on 25 horses, the participants went north to the Białowieża stands, which fully deserve to be called primeval forest. An irregular stand with numerous swamps and wetlands, an ideal place for wild boar and red deer emerged before the eyes of the visitors. The carriages stopped at the most beautiful parts of the forest to give the opportunity to walk through the stands. The riders on horseback went further into the wilderness, led by the infantry squadron leader, and were indeed lucky to spot bison. When the riders approached, some specimens of the bison fled, but two or three of them stayed and could be observed from about 100 steps. Highly satisfied, the participants returned while the full moon illuminated the magnificent forest, creating an unforgettable impression.

At half past 6 p.m., Captain Kirchner opened the evening meeting, greeted the guests, notifying them that General von Eisenhart, Senior Quartermaster, could not attend the meeting due to lack of time. Then, Kirchner gave the floor to Mr. Schüttem, the forestry counsellor, who gave the reading **'On the objectives of forest economy in the Ober-Ost area'.** In connection with this very clear and engaging lecture, which, for easily understandable reasons, cannot be quoted here, the following questions were discussed:

1. Support for the forest management board by the district captains in order to recruit local workers.
2. Achieving the highest output of individual sawmills beyond doubt.
3. Creation of worker companies and the influence of forest clerks on the gendarmerie.
4. Piecework and daily pay work.
5. Bonus for military sawyers and its transformation into piecework allowance.
6. The recruitment of workers should not reach into areas of other forest inspectorates.
7. Including private forests to cover the wood demand.
8. Tariff issues.

The official part of the meeting ended at this point; the rest of the evening was spent in the officers' quarters. The next day at 9 o'clock a.m. the visitors departed by train.

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From the Białowieża Forest

Impression from a trip taken in April this year

The vague and fragmentary news that have reached Warsaw and Cracow since mid-February this year on the state of destruction of the Białowieża Forest by the Germans, especially the uncertainty concerning the situation of the truly royal animal population inhabiting this unique, giant primeval forest, as well as the concern for the endangered bison, prompted the Ministry of Education in Warsaw, in consultation with the Ministry of State Treasury, to send to the forest an environmental delegation whose task was to examine on site the level of destruction done to the forest and, if possible, to give protective orders. Equipped with military documents that allowed us to benefit from the transport available within an area of operations of the Polish Army, which were in action against the Bolsheviks not far beyond the forest, we set off on the road, passing through Siedlce, Czeremcha and Hajnówka, to Białowieża, located in the heart of the forest, from where we were supposed to take a series of hiking trips into the forest, to become more acquainted with the face of the war-torn forest of today.

Hajnówka, which lies on the south-western edge of the forest and has a major railway line passing through it, forms the entry to the forest and has provided us with a series of first 'war' impressions. These, somehow, were intended to prepare us for the images which the forest itself was to reveal to us. Throughout the entire period of the German management of the forest, Hajnówka, connected by a single track railway line to Białowieża, served as a concentration point for all kinds of materials that the industrious and greedy German hand had extracted from the forest. Here the first sawmills and other German industrial plants were built, and moved partly deeper into the forests at a later stage. Moreover, it is here that the large German war industry settled on a permanent basis, as its location within the forest would pose a risk of fire, especially concerning the huge wood spirit factories.

Hajnówka, situated at the entrance to the forest was a place of steady industrial activity from the very first moment of the German occupation. In August 1915, when the Germans finally garrisoned the forest, which was weakly defended by Cossack troops retreating northwards through the forest trails, the first portable sawmill was brought by the Germans to Hajnówka, assembled hastily and then sawed wood day and night, so as to produce lumber on a mass scale. This first German sawmill must have begun its destructive activity among the tree stands under an unlucky star, as in 1916 it suffered a mysterious fire, in which it burned down completely and was never rebuilt. When I visited the huge depots of wooden blocks, deposited within the huge Escherich's Plant, I was shown a destroyed gang saw standing in desolation. It was the gang saw originating from that first German sawmill. The wood processing industry in Hajnówka was developed by the Germans with unbelievable rapidity. Undeterred by the sawmill fire, in 1916 they commenced the construction of a huge sawmill with ten gang saws, which together with the industrial facilities erected in its immediate vicinity formed a complex known as the Escherich's Plant. It was named after one of the bravest forestry scientists in Germany, a Professor of Forestry in Munich, who, at the order of the army of the Successor to the Bavarian Throne, headed the organisation of the German exploitation of the forest.

The Escherich's Sawmill in Hajnówka is, according to the opinions of the Polish foresters whom I met in the forest, a state-of-art construction and is equipped with all the latest machinery in which the German wood processing industry excels. As a non-professional, at the Escherich's Plant I was, above all, stuck by its amazing ability to use in the most economical way all sorts and waste of wood. For instance, at the outlet of a huge conveyor that forwards from the sawmill the sawdust that were not used for heating the boilers, a plant was built for processing the sawdust to manufacture the walls for folding wooden houses. The wood wool factory is also impressive, with its huge warehouses to which a railway line was connected. The wooden clog factory, located next to it, aroused my interest as well. In its vicinity, there were large halls with incompletely assembled boilers: these were intended for uncompleted turpentine and tar factories. In addition to these completely new woodworking plants, either just completed or partly constructed, there is a wood material depot, intersected by narrow-gauge railway lines and filled with about 5,600 well selected logs of oak, ash, linden, pine and other species, arranged there in the best possible order. Some of these logs, impressive due to their powerful dimensions, often lie set aside, as if a different fate was awaiting them than for the other 'average' ones, although even these are materials of quality so high that it is rarely seen in such quantities.

The Germans abandoned the Escherich's Plant hastily, abruptly even, in the winter of 1918, when the decaying condition of their country included not only the German homeland but also its army at the front and other locations. The highly disciplined German soldiers, French and Russian prisoners of war and a number of local people previously employed for the dirty job, who were hitherto working according to schemes prepared by Professor Escherich and his staff, found themselves in a new and unexpected reality, when their masters began to leave their positions abruptly and return to their homeland. The work in the plants stopped immediately, the saws cutting logs in the sawmill literally coming to a stop in the middle of a trunk. Shreds of wood mulch remained in the teeth of a sophisticated machine used to tear wood to manufacture wood wool. In wooden footwear production plants, clogs remained stuck in a lathe, whereas assembly tools with which a new tar plant was being installed lay scattered around the pitch… Indeed, strong must have been the wind by which the German workers were driven away, as they say, to the four corners of the world!

The Escherich's Plant existed for only a short period (and only partly), of about 2 years. How much material was processed during this time and how much Polish wood was converted into Prussian gold is hard to determine. The life pace here must have been energetic. This is evidenced not only by the impressive number of machines, whose power is estimated at 400 horses, but also by the workers' colony of substantial size, which, in the form of rows formed by new wooden lodges adheres to the industrial centre of the Escherich's Plant.

Apparently, over 700 workers were constantly occupied with their jobs, not to mention the number of prisoners of war and workers occupied at material depots. I heard that Hajnówka alone brought Germany an income of 32 million marks a year. Obviously, I am not able to state how much this amount is exaggerated or if it is perhaps undervalued.

In Hajnówka, near the Escherich's Plant, whose equipment suffered only a slight damage, there exists another industrial complex that deserves attention. It is a huge wood spirit factory, located at a certain distance from the village, according to the Germans themselves, the largest plant of its kind on the European continent. Surrounded by multi-row barbed wire, it strictly separated all workers employed in the factory. On the one hand, such seclusion should be attributed to the fact that a large number of French prisoners of war worked there, due to their special qualifications to perform this job, and on the other hand to the fact that explosive materials were manufactured by German soldiers from wood potash in a certain division of the plant. The factory itself comprises four identical divisions. Each of them includes a spirit distillery and huge wood drying installations belonging to it. The number of huge (3 m^3 each) distillation retorts, 128 of which were in operation there, with another 200 held in stock, gives some idea about the size of the plant. The plant was established and technically managed by an engineer, Zeiss, who also lived permanently in a neat and quaintly furnished house located in the plant area. It should be added that the construction of the wood spirit factory by the Germans begun in 1916, continued through 1917 and began operating in 1918, when, in addition to wood spirit, whereof two large tanks were left, also other distillation products, mostly potash and tar, stored in pits, were manufactured.

The military and political disaster of Germany exerted a negative impact on the spirit factory. Once the officers and engineers left, the factory was taken over by the Bolshevik Soviet military, who partly destroyed the costly installations.

At that time, a German soldier by the name of Lenz sold 28 electric motors to Jews from Białystok for next to nothing. Others traded in a similar way, exchanging precious machines from Hajnówka industrial facilities for next to nothing, for about a dozen kilos of fatback. Fortunately, the rule of the soldier bands did not last long. In mid-February of the same year the Polish army took possession of this unfortunate land, devastated by fire and sword, as well as of those masterless and deserted German factories in Hajnówka.

Having visited Hajnówka, two days ago I travelled along the newly opened local railway to Białowieża. The ride took half an hour on a track running straight as an arrow through the area of the lower Hajnówka Guard District. Along the way, we saw a deplorable picture of the German robber forest economy, in the form of the most cluttered clear felling areas that stretched in an unbroken lane on the both sides of the railway line, about 2 km deep into the forest. Only the wetter parts of the forest with prevailing spruce remained in this most easily accessible strip of land. These clear felling areas depict a regrettable image, not only because they were left with numerous rickety and broken trees, but also due to the fact that almost everywhere they are packed with left-over tops and branches, which the Polish management has only gradually begun to remove. The destructive German hand did not spare young pine stands in the area. If unsuitable for felling, the trees were all subjected to resin extraction, conducted on young trees mostly, in an outright barbaric manner, on four sides of each trunk. On behalf of the Germans, the resin extraction was carried out here and elsewhere in the forest by Jewish girls, whose advantages were expressed by German foresters with the highest appreciation. On the way from Hajnówka to Białowieża, we passed by two large sawmills and numerous wooden barracks belonging to them in which workers, mostly Russian prisoners of war, lived. I did not have, however, a closer look at these sawmills. I was told that they were exquisitely organised and, except for the stolen transmission belts, ready to be put into operation immediately. I suppose that the Polish authorities started up the sawmills in order to process and remove the huge quantities of wood stored in the depots, as its presence posed a great threat of pest eclosion and a huge danger of fire, which, had it began, would have been almost impossible to be suppressed inside the forest.

Upon my arrival in Białowieża, surrounded on all four sides by the walls of the forest at a distance of several kilometres, in rainy and foggy conditions, I was unable to see much more than another German industrial plant, proudly called here the 'Hindenburg Plant' as well as a high wooden tower shooting toward the sky at the forest edge and named after this same Prussian marshal. Allegedly, high-born German commanders came here to see the views from this tower with the winner's look on their faces, over the huge forest areas belonging to the Białowieża Forest, as well as the neighbouring Świsłocz and Lacka Forests. Whether they did so to the very end with the same feeling of Prussian confidence, it cannot be stated for certain.

The Hindenburg's Sawmill lies at the edge of the village of Stoczek which was almost burnt to the ground during the war. In the vicinity of the sawmill, which is still in very good condition apart from the lack of transmission belts and slight damage to the machines, with nothing missing, within the area of the Hindenburg's Plants is a large and modern planing facility, with numerous, not fully assembled machines and lathes, only partly unpacked, bearing French inscriptions: *Leon Dukuroir Bruxelles*, a sign that they were brought to the forest from Belgium, plundered by the Germans. Alongside the prisoners of war and German soldiers, Polish workers from Żyrardów worked in the industrial plants in Stoczek. A terrifying quantity of wood lies accumulated in the extensive timber depots that surround the factories. I was told that this material would be enough for six years of operation of the Hindenburg's Plants, assuming a lively activity as under German rule.

The above, though superficial remarks, about the organisation of the wood industry by the Germans in Hajnówka and Białowieża, to some extent offer the reader the opportunity to evaluate this remarkable amount of energy with which the Germans embarked on exploiting the enormous wood reserves of the forest. To complete the picture, it would be worth presenting here in detail the exemplary organisation of transport means necessary to extract the best quality material from distant, often soggy and inaccessible parts of the forest. It would be necessary to introduce the reader to the network of narrow-gauge railways, hundreds of kilometres in length, reaching into the deepest areas of the forest, as well as the large-scale rafting of logs on the Narew and the Narewka, organized in a perfect manner. Finally, it would be necessary to indicate the numerous tar, turpentine and extensive wood coal plants scattered throughout the forest area. All the above permanent factories and places of temporary work, though spread across the vast area of the forest, were connected with each other by telephone wires, like nerves, converging at the main directorate headquarters in Białowieża, the all-powerful *Militarforstverwaltung Bialowies* [Military Forest Directorate Białowieża].

To conclude the results of my collateral observations on the exploitation of wood materials in the forest during the German occupation, it must be said that the result of this enormous amount of work, probably best expressed by the 23 gang saws operated day and night in 5 large sawmills, was the processing and removal of more than one million cubic metres of selected material from the forest and the about half a million cubic metres of timber left in the depots, either as logs or sawn boards. This was made possible by running at least 23 saws without cease. Most importantly, the large and most easily accessible forest areas, namely those of the Hajnowska and Starzyńska Guard District, and partly also Browska and the Lacka Forest, all fell victim to the German axe and saw. The Royal Guard District and the Świsłocz Forest, however, remained almost intact. From a forest area of roughly 160,000 hectares, the Germans completely felled 3.6%, or 5,760 hectares. This data, extracted from detailed German reports, was checked by Polish foresters and thus is quoted here on their responsibility. Numerous places of intentional plundering of the forest should added hereto, from where particularly beautiful, searched out specimens of ash, oak, linden, pine and sycamore maple were extracted. Perhaps, therefore, the entire amount of the war loss to the area of the Białowieża Forest, calculated together with the Wisłocka and Lacka Forests, reaches up to 4%, that is 6,400 hectares. It can, therefore, be said that despite severe and heavy loss, the Białowieża Forest left German hands in good condition and the vast majority thereof did not change the pre-war appearance of its ancient woodlands.

The Białowieża Forest, together with the adjacent Ladzka, Świsłocz, Szereszewo and Jałówka forests, is the largest forest range in the lowlands of Central Europe, with an area of about 40 square miles, located between latitudes 52°30' and 53° north and between longitudes 41°10' and 42° east of the Ferro meridiam. This enormous forest has retained in many of its parts a purely unspoiled character, due to the unique conditions of its existence dating back long ago. For many centuries under Polish rule it was reserved for royal game (aurochs, bison, elk, red deer), which lived perfectly in this peaceful, remote refuge under the custodianship of royal forest wardens. This is not to say that it was a completely untouched forest in Polish times. On the contrary, a primitive wood industry existed here from time immemorial, which consisted in the removal of snags from the stands and using them to produce potash, tar and turpentine locally in the forest. In addition, since its origins, the forest has supplied construction material for the villages scattered in its vicinity. In most recent times of Polish rule, the forest was exploited in a planned manner, to obtain mast pines and other precious wood, highly valued on the western commercial markets. The Polish Treasury was enriched by about 100,000 guilders from this source every year. Except for timber harvested in the forest for a long time, though on a small scale, the forest provided the most favourable area for breeding wild bees and game, its extensive glades and meadows located by the streams were constantly mowed and provided huge amounts of hay.

Once the forest passed under Russian rule, the entire area of the proper Białowieża Forest was recognized as state property, whereas the area of the Świsłocz Forest, located east of the Narew, remained for several decades the property of Counts Tyszkiewicz. In 1888, the Białowieża Forest itself was proclaimed tsarist property (about 128,000 ha), while the neighbouring Ladzka Forest still remained state property. The forest was kept in good condition under Russian rule. The Russian Empire, having an excess of forests, had no need to raise its hand to the wilderness sacred by royal hunting tradition and which still provided convenient shelter for the bison and other noble game. In 1802, Tsar Alexander I issued a decree on the protection of bison for all time, whereas in 1820, the area of the forest was declared inviolable for all time. Since that point, the axe was not to be seen in the forest for many decades. Only dry and wind felled trees were removed from more easily accessible places.

During Polish times, the forest had been divided into 12 guard districts. This division was perpetuated by the Russians in the early nineteenth century, whereas the area of each guard district ranged from 3,000 to 15,000 *dessiatines*. In the years 1843–1847, the forest was divided into 541 so-called quarters, each with an area of 2 square versts. After 1910, the existing quarters were again divided, so that the entire area of the forest was split into 1,147 quarters, rectangular in shape whose shorter side equalled 1 verst.

Apart from removing dry and wind felled trees, the forest was not used in any other way. It was not until the last decades before the war that planned clear felling areas were established in some areas of the forest, though they were meticulously cleaned and immediately afforested, and, following the afforestation, surrounded by a strong fence to protect the sapling stand against game. However, only a small amount of such clearcutting areas is found in the forest, so that the primeval character of the whole is not much affected. Only once the Germans, after taking over the Białowieża Forest in 1915, did a violent upheaval take place in it. Having unscrupulously broken the inviolability of the forest sanctified by centuries-old tradition, they immediately recognized Białowieża as valuable war booty, which had to be taken advantage of as soon as possible and as actively as possible for their own benefit. The magnitude of the scale on which the conquerors exploited the respectable, enormous wood reserves in the forest is proved by the colossal contributions they made in the form of numerous industrial plants built to the greatest possible extent, of which I have already informed the readers above. The radical changes made in the forest during the short period of German reign are forcing the Polish Government to make hasty decisions as to the future of this huge forest area, since it is too obvious that in view of the industrial facilities left by the Germans in the forest, as well as considering the wood depots piled with blocks of timber, any delay would be dangerous.

Given that Poland, recovering from the conflagration of war, necessarily needs large amounts of timber for construction purposes and, also taking into consideration the catastrophic exhaustion of Polish forests during the war, it seems to be an inevitable necessity for the State to reach into the Białowieża Forest for part of its material treasures. The scope and pace of this necessary exploitation must, however, be decided by our Government assuming full responsibility towards the nation for whom the Białowieża Forest will continue to present, as has been the case so far, not only a material asset, but also one of immeasurable value of a moral nature. A rational economic plan, which shall gradually cover the unspoilt areas of the forest, must permanently secure an absolute untouchability of a certain part of it, which will be maintained forever as a 'nature park' and constitute by this a natural refuge for primeval fauna and flora, being so much specific to this area, but also a site for scientific research.

There is no need to convince a forester, all the less so a nature scientist, about the need to convert the certain most primeval part of the Białowieża Forest into a reserve. However, as the exclusion of some larger complexes of the forest from exploitation (in my opinion, it would be necessary to allocate to the reserve about a quarter of the current area of the forest, i.e. about 40,000 ha) may be opposed by factors and spheres of society that fail to comprehend sufficiently the necessity and usefulness of such a reserve, thus a need exists to mention this topic as often as possible now, in the daily newspapers and professional magazines, as well as during the congresses of Polish foresters, and thus pave the way for this, so much desired, project.

Since it is not my intention to embark on a more detailed description of the nature park planned in the Białowieża Forest, I promise to return to this issue in *Sylwan* soon.

My remarks on the current condition of the Białowieża Forest would be incomplete without mention of the bison. Since this animal currently belongs rather to the past than to the present, I allow myself to present its history in the Białowieża Forest as a brief, historical outline. I will say a few words about its current status in the afterword. Reports about the bison being for centuries the king of this famous population of animals can be obtained the descriptions of the royal hunts in the Białowieża Forest that date back to various periods, forest service registers, and the numerous descriptions made by national and foreign writers of the fauna inhabiting the forest. So as not to repeat the well-established facts here, I will limit myself to quoting some positive data regarding the history of the bison.

During a hunt of the Polish Royal Court, held on 25 September 1725, 42 bison, 13 elk and 2 roe deer were killed in Białowieża, and therefore it can be concluded that the total number of bison living in the forest at that time must have been several hundred. Such a number more or less persisted throughout the entire 19th century. In 1888, there were 400 head of bison in the forest, and another 11 in the animal preserve. In 1893, 400 to 500 bison were recorded. Since approximately that year, a 'modernization' of the fauna of the forest took place. This consisted, on the one hand, in declaring a ruthless war against the wolf and the lynx, and on the other, on the artificial introduction of red deer and fallow deer to the forest. Installations intended to facilitate the breeding of the bison, such as placing haystacks in the forest, draining marshes and the like date back to that time. At first, these changes affected the animal population of the forest in a favourable way, but unfortunately, over the years, they exerted a catastrophic effect. The tsarist hunts show a different distribution since then. In 1897, a total of 37 bison, 36 elks, and 25 red deer were killed. In 1900, 45 bison, 38 elks, 55 red deer, 326 roe deer, and 138 wild boars. In 1901, around 15,000 head of game was considered to be living in the Białowieża Forest, that is around a dozen per 100 hectares! Before 1910, in the entire forest, which had already become the most irrational animal reserve in the world, there were about 30,000 head of game. The severe hand of nature put an end to this walk towards absurdity, when in 1910 a terrible plague broke out in the Białowieża Forest and decimated the excessively reproduced animal population. In 1914, just before the outbreak of war, there were about 16,000 animals in the forest, including about 500 bison.

What was happening in the forest during the war? I find it difficult to provide a comprehensive answer to this question, as the witnesses to the occurrences of war that happening in the forest were mostly dispersed and, with the exception of the Belarusian peasants who were indifferent to everything, apparently no one followed the military history of this area on the spot. The following picture of the wartime fate of the game in the Białowieża Forest can be reconstructed on the basis of reports by the local forest service, stories told by former officers of the Russian directorate who remained in Białowieża, and finally, from the printed German reports.

As I mentioned above, on the day of the outbreak of the war about 16,000 animals inhabited the forest. During the first months of the war the animal population led the same, peaceful existence. Then in the summer of 1915, when the Germans, pushing against the retreating Russian army, brought the bloody front line nearer to the vicinity of the forest, the retreating Russian soldiers used the formerly respected wild game for their own means. However, the rapid pace of the retreat together with not fully disorganized Russian forest service, however, made it impossible to inflict a greater destruction. The Russian forest management, leaving Białowieża to escape the Germans wanted to save the bison that, partly tamed, lived in woods partially enclosed by fences. In order to do so, the Russians ordered that these barriers should be demolished to allow the animals to spread across the forest, or to at least make it possible for the bison to move to other woodlands adjacent to the forest.

At this moment, the Bavarian army appeared in the forest, pushing at the Cossacks, who were covering the Russians as they retreated.

In order to present fairly the behaviour of German soldiers towards the animal population of the forest, I will allow myself to quote here a few sentences taken from a report by Captain Gruber, the adjutant of the Bavarian division (*Die Eroberung des Urwaldes* in the publication entitled *Bialowies in deutscher Verwaltung*, Berlin 1917).

When the first troops entered the Białowieża Forest, not only did wild boar and red deer, but also several large bison, fall prey to them and end up in the soldiers' cauldron. It was difficult at the time to refuse the soldiers such invigorating food. It had to change, however, when the soldiers stopped killing the animals out of hunger and began to enjoy themselves by obtaining easy hunting trophies. As soon as this situation was reported, orders to prohibit the soldiers from shooting the bison immediately appeared. However, according to the proverb that 'where there is no prosecutor there is no judge either', several heads of bison were still to fall victim to soldier-hunters.

On 25 September 1915, on the order of the army, a hunting bill was issued for the Białowieża Forest. The regulation was essentially in favour of protecting the bison, the shooting of which was only allowed from then onwards by permission of General von Seckendorff, military base inspector.

From this point onwards, a separate, well-trained forest and hunting guard took the bison under its protection to save the remaining specimens from extermination.

In all fairness, it must be admitted that once the Germans settled in the forest and established their administration there, they surrounded the animal population, already significantly damaged, with effective protection. Admittedly, there were cases of individual bison being killed by a bullet shot from the hand of high-born people, to whom General Seckendorff gave permission for hunting, or from a poacher's hand. In principle, however, the bison found protection and vigilant care. In 1915, the Bavarian government sent a scientific expedition to study the bison in its homeland and to gather a collection of its hides, skulls and bones, whereas numerous professionals began to search the wilderness urgently to seek dead bison or their skeletons. To put it briefly, German science took a keen interest in the European bison, and this probably exerted a significant impact on the fact that its last remnants still living in the forest were successfully protected.

This state of affairs lasted until February 1919. According to a credible account provided by a former Russian gamekeeper, who, being a German, survived the entire period of German invasion in Białowieża, 180 bison were said to be still alive in the forest in mid-February of that year, namely when the German administrative machine began and when the German authorities left Białowieża.

Once Białowieża had been abandoned by the organised German military authorities, the final act in the tragedy of the bison began. Now marauders and stray bands of soldiers in cooperation with the local peasants, each of whom, naturally, was equipped with a rifle, began the systematic slaughter of game. I was told that in the second half of February and in March of that year, such wild, constant and noisy shooting engulfed the forest that it was dangerous to enter the paths leading into the woods, as it was easy to be hit by one of the wandering bullets. The royal animal, half tamed, was unable to save its life by escaping to the nearby woodlands. Thus, it wandered around the familiar wild woods which it grew accustomed to and died from a brigand's bullet.

Unfortunately, the Polish military authorities, having to deal constantly with bands of Bolsheviks, could not control the situation in time. Finally, it became known that armed peasant groups roaming the forest were killing animals in order to satisfy the terrible hunger that overtook all villages in the vicinity of the forest…

In the first days of April, as I was walking in the forest, no poachers were to be seen anymore. Nor did I find any living game. For the three days of my visit to the forest, I spotted three red deer, one hare and common cranes once in the wilderness! The forest looked as if it were extinct. Throughout the Białowieża Forest, there are supposed to be several dozen more red deer, fallow deer, roe deer and a large number of wild boar. Individual wolves and lynxes appeared as well.

The King of the Forest, the bison, seems to have gone completely extinct. I am writing this with some hesitation, as according to a relation of the forest service, there were still three or four animals straying in the Hajnowska, Browska and Starzyńska Guard Districts in April. I was told a detailed story by an old forester in Hajnówka about a one-year-old bison calf, apparently still alive at that time, spotted in compartment 546 of the Hajnowska Guard District.

From a former Russian gamekeeper, I heard the opinion as well, that ten to twelve head of bison are still believed to be living in the forest; however, this opinion, though being the most optimistic of all I heard here, is probably not based on anything. Nevertheless, it cannot be excluded that some bison head moved away from the Białowieża Forest into the distant forests that stretch across the vast spaces towards the Polesie Basin, and that individual specimens would still return to Białowieża. It should be openly admitted, however, that all these predictions, assumptions and hopes are unlikely to ever change the sad fact that the bison has ceased to exist in the Białowieża Forest in the wild. Even if the several head that might be left could still be kept alive in the wilderness, a healthy generation of this animal will never be re-established from these few specimens.

Thus, among the turmoil of the largest war that ever shook the face of the world, among clashing foreign weapons, among the blows of the German axe that felled the giants trees worshiped for generations, the bison, the King of the Polish forests, vanished from the backwoods and stocks of the Białowieża Forest.

In Cracow, in June 1919.

Władysław Szafer, PhD
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Fir in the Białowieża Forest

Among the greatest natural peculiarities of the Białowieża Forest, the occurrence of native fir (*Abies alba* Mill.) is worthy of mention. Since the naturalness of this fir site, despite its extremely inaccessible location, has been questioned on several occasions, I decided to finally clarify this issue, during a scientific trip I took to the forest in July of this year. In this paper, I will provide *Sylwan* readers with the results of my field research. So as to make the subject clear, I will precede the conclusions with a brief history of the discovery and gradual scientific study of this, by any measure interesting, fir oasis, completely detached from the geographical range and located 120 km away from the northern border of the latitudinal geographical range of the fir in Europe.

In 1823, Stanisław Gorski, a professor of the Medical and Surgical Academy in Vilnius, discovered fir in the Białowieża Forest. He made a mention of this tree species in the *Dziennik Wileński* (Vol. IV, 1829) in the work entitled 'About plants preferred by the bison and others of the Białowieża Forest', using the wording quoted below in extenso:

The tree grows only in one place in the Białowieża Forest, in the Okolnicka Guard District, in the Cisówka wilderness, which is surrounded by marsh and difficult to access in wet summers. The tree grows within a small area and fails to reach the heights that are observable in Galicia and the Kraków region, perhaps owing to the low elevation on which it is located. The largest trunk at the bottom was only 3 feet in diameter. The tree is commonly referred to as the white yew, for the white bark that covers the trunk, and for its truncated leaves located dually on branches, as in the ordinary yew (*Taxus baccata*). It cannot be assumed that this tree, limited by one area of occurrence, was to be intentionally planted here. The location in a low elevation does not correspond with the intention. It can rather be assumed that the origins of its creation should be sought in the primeval forest itself. At the time of Gilibert, who lived in Grodno in 1780, fir was felled and transported to Grodno intentionally. Thus, whether the above-mentioned naturalist saw the tree or not, this cannot be stated for certain. In the later edition of *Flora of Lithuania*, having left Vilnius, he made no mention of it.

It is clear from the above quote that Gorski was the discoverer of the fir in Cisówka and that he considered the originality of this fir site to be unquestionable.

In 1830, in a well-known compilation entitled *Naturhistorische Skizze von Lithauen, Volhynien und Podolien* (Józef Zawadzki, Vilnius 1830), E. Eichwald reproduced Gorski's comments about the site of native fir in the Białowieża Forest (p. 128), without indicating (as was his custom) the source from where it was summoned. Also Fr. Th. Köppen, not familiar enough with Polish floristic literature, wrongly attributed the merit of this discovery to Eichwald (in the work *Geographische Verbreitung der Holzgewächse des Europaeischen Russland*, Petersburg 1889, Vol. II, p. 546).

In 1850, Trauwetter (*Die pflanzengeographischen Verhältnisse des europaeischen Russlands*, Heft, 2, p. 79) expressed his view, based on no evidence, that the firs in Cisówka were introduced artificially.

In the 1950s, Brzozowski informed Köppen (chapter 1, p. 548) that the fir in the Białowieża Forest grows in the wild.

In 1884, the forester Bretschneider confirmed the presence of a small number of fir trees in Cisówka (Köppen, chapter 1, p. 540).

In 1888, in a joint work entitled 'Report from a botanical field trip to the Białowieża Forest in the summer of 1887', (*Pamiętnik fizjograficzny* [Physiographic Diary], Vol. VIII, Warsaw), Fr. Błoński, K. Drymmer and A. Eismond described in detail their field trip to Cisówka aimed at finding the fir described by Gorski. They stated that 'the tree occurs there in a number not exceeding several hundred specimens, in the form of trees or small trees at the height of a man, 5–6 inches thick'. These researchers did not observe any larger specimens. On page 64 of their report, in the afterword to the above information, the authors expressed the assumption that the 'fir in Cisówka numbers about 200 specimens, not older than 40 years old, judging by the thickness of the trees.'

In this way, three Polish botanists basically confirmed Gorski's information on the presence of fir in Cisówka. It remains a mystery why they found specimens not older than 'presumably 40 years old', since the Gorski's expedition to Cisówka took place in 1823, that is 64 years earlier and thus specimens much older than 40 years were to be expected. It is also to no avail to search the report mentioned above for information on the natural seeding of the fir. It seems that our florists failed to notice either cones on the firs, nor young self-sown plants.

By a twist of fate, consecutive information on the fir in the Białowieża Forest was provided by the temporary 'owners' of the forest, the Germans, in their war publication entitled *Białowies in deutscher Verwaltung* in issue 224 (1917 to 1918). It could have been expected that German foresters and botanists would become interested in the fir exclave in Cisówka and that they would pay close attention to it. However, this was not the case. None of the German botanists who visited the forest in 1917 and 1918 (Conwentz, Graebner and others) bothered to make the arduous trip through the marshes surrounding the Cisówka wilderness to reach the fir site. P. Graebner, in his rather superficial work entitled *Die pflanzengeographischen Verhaltnisse von Bialowies* (4th issue, the publication quoted above, Paul Parey, Berlin 1918), based on the account given by Captain Voit, who was supposed to have personally visited Cisówka, states that fir is found in the form of young trees of approximately the same age and therefore, 'it should be assumed that this small fir stand was artificially planted several decades earlier.' In another magazine by the above-mentioned publisher, one of German foresters even made attempts to prove (founding his claims on no evidence) that fir was brought to Cisówka on the event of some Russian celebration or party.

This latest information on the Białowieża fir, introduced to the scientific literature by Germans, who are normally considered diligent and meticulous researchers, is in stark contradiction to the earlier data provided by Polish naturalists.

In view of such contradictions in the information on the fir site in Cisówka, a need appeared to investigate the entire issue once again at its very source. In July of this year, I made a trip to the Cisówka wilderness, where I arrived from the direction of Chwojnik, following the guide from the forest wall for over one kilometre through a peatbog, jumping from sedge tuft to sedge tuft and sinking knee-deep into the water.[1] Approaching strenuously the wooded island of Cisówka, we understood in depth the nonsense of the German inanities about parties and meetings that were allegedly supposed to take place in this backcountry and assessed accordingly the value of fairy tales about fir planting in this lost corner.

The attached photograph (Fig. 1) presents a view of several forest eyots located in between large marshy areas: Głęboki Kąt and Wielki Nikor, which lie on the European water divide between the catchment areas of the Baltic Sea and the Black Sea. The Cisówka wilderness is one such eyot.

Fig. 1. A view from the Głęboki kąt peatbog to the wooded islands with the fir site *(Abies alba* Mill.)

The peatbog through which we had to wade on our way to Cisówka was of a low moor nature, with a predominance of the following sedge species: *Carex stricta, paniculata, elongata, pseudocyperus, vesicaria, lasiocarpa* and *chordorrhiza*. Willow and birch thickets mark

[1] I took this trip in the company of Professor B. Hryniewiecki, PhD, St. Kulczyński, PhD, and Mr. J. Lilpop. Its main goal was to select and determine a location for a larger forest reserve in the Białowieża Forest, about what I will inform readers more accurately in one of the forthcoming issues of *Sylwan*.

the transition area between the peatbog and the wooded island. The most significant willow species were: *Salix cinerea, aurita, nigricans, rosmarinifolia* and *livida*.

The forest overgrowing Cisówka, here and there artificially thinned, turns in many places into muddy clearings. The forest at the edge of which the first firs were shown to us by the guide consisted of spruce, birch, aspen, hornbeam, linden, ash and elm (*Ulmus effusa* and *scabra*).

Fig. 2. The oldest borderland fir (about 200 years old), 33.5 m high, in the Cisówka wilderness in the Białowieża Forest. On the top, distorted by the impact of a harsh climate, cones pointing upwards can be seen

Even after a first brief look at the stand, with its scattered fir trees, we became convinced that the dates provided by the Germans were completely false. The measurements of the diameter of the firs, with heights and thicknesses that visibly differed, proved that the concept of an even age of the entire stand could not be true. I wrote down in my notebook the following diameters of several fir specimens scattered across a small space: 12.5 cm, 16 cm, 12.5 cm, 26.5 cm, 18 cm, 34 cm, 12 cm, 17 cm, and 30 cm. We were delighted to see a huge specimen of fir growing at the very edge of the forest, whose photo is attached below (Fig. 2). Its circumference at breast height was 3 m 64 cm (i.e. 1 m 20 cm in diameter) and its height was 33.5 m. At the top of this borderland giant, distorted by climatic factors, green cones pointing upwards could be seen clearly. We collected a number of shapely cones from another specimen of fir, 26.5 cm in diameter and 18 m in height. We found two specimens of fir freshly cut by people from the Babinice settlement. One of them, with a diameter of 18 cm at 1 m height, had 57 growth rings. The other one, 30 cm in diameter, was 47 years old and was characterised by fairly even growth rings, whereas in case of the first, the rings between the 14th and 35th years were of extreme density. After a short search, we managed to find completely young fir specimens (2–5 years old) among the ground cover.

It is difficult to indicate the exact number of fir specimens growing in this wilderness, especially since it is impossible to count very young specimens. The local foresters who accompanied us claimed that there were about 100 older fir specimens growing in the part of Cisówka visited by us, whereas the others reported that they were only 74. Apparently, several dozen fir specimens grow in another part of Cisówka, at a slight distance from the one described by us, but we did not check this.

Our observations indicate that the fir agglomeration in Cisówka bears all the features of a primary agglomeration, settled on the site for hundreds of years. The thickest specimen we mentioned, displayed 19 growth rings in the sapwood of a depth of up to 6 cm. Assuming this growth rate as average, the tree would be at least 190–200 years old, but it might be much older. The foresters accompanying us assessed the age of this specimen at 350 years. Both the uneven ages[2] of the firs growing in Cisówka, as well as their seeding ability, in our opinion provide enough evidence, contrary to what the Germans claimed, that fir growing in the Cisówka wilderness in the Białowieża Forest is indigenous, long settled here. In this way, we fully confirm the initial comments about fir growing wild in the Białowieża Forest, as provided less than a century ago by Stanisław Gorski, a researcher of Lithuanian flora of outstanding merit, but so often forgotten, who was the first to discover the fir in the

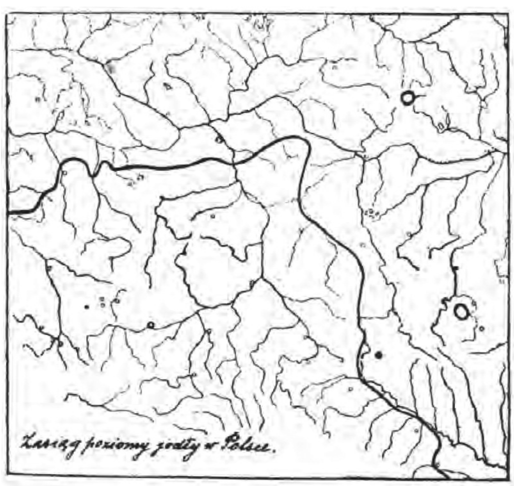
[2] The fact, seemingly difficult to explain, that in the described fir stand there are currently no specimens constituting an understory with a height of 0.5 to 5m can be explained, by the fact, that the game reproduced excessively before the war (especially red deer) grazed the young generation of fir completely, as this was the case with the second-growth of almost all tree species in the forest, except for spruce, whose self-seeded specimens were least destroyed by the game.

Białowieża Forest and to express the claim that 'the beginnings of fir in the Białowieża Forest lies in the genesis of the forest itself'.

The flower flora of the forest where the fir grows is quite abundant. Tree species found here include spruce, hornbeam, maple, aspen, pedunculate oak, small-leaved linden, elm (*Ulmus effusa* and *scabra*) and rowan. Shrubs: hazel, raspberry, viburnum, alder buckthorn, stone bramble (*Rubus saxalilis*) and European euonymus. From herbaceous plants, I noticed the following as being particularly characteristic:

Galium schultesii, Oxalis acetosella, Majanthemum bifolium, Fragaria vesca, Stellaria holostea, Convallaria majalis, Melampyrum nemorosum, Athyrium filix femina, Phegopteris dryopteris, Asperula odorata, Poa nemoralis, Milium effusum, Dentaria bulbifera, Asarum europaeum, Equisetum silvaticum, Aegopodium podagraria, Angelica silvestris, Orobus vernus, Galeobdolon luteum, Urtica·dioica, Pulmonaria obscura, Geranium Robertianum Geum urbanum, G. strictum, Polygonatum multiflorum, Viola mirabilis, Anthriscus silvestris, Actaea spicata, Stachys silvestris, Hepatica nobilis, Impatiens noli me tangere, Circaea lutetiana, Ranunculus lanuginosus, Campanula trachelium, Paris quadrifolia and *Cimicifuga foetida.*

Both the abundance of the forest flora and the presence of species with low self-sowing ability (e.g. *Dentaria bulbifera*) prove the primeval and ancient nature of the flora that overgrows Cisówka. It seems that it was since long a dry, wooded island, located among the muddy bogs that surround it nowadays. The seclusion of the fir site on an island was certainly an advantageous circumstance that contributed to the preservation of this tree species: away from continuous changes to the flora of the forest, the fir could remain protected against the destruction it underwent over the centuries in the forest. Fir was preserved only in the shelter of Cisówka and owing to this remoteness its remnants survived here from the destruction which this tree species was touched throughout the entire Białowieża Forest in the process of a natural forest crop rotation.



As can be seen from the attached map presenting the latitudinal geographic range of fir in Poland, the fir in the Białowieża Forest is the north-easternmost site of this tree in Europe. A similar fir exclave, detached from the main geographic range, occurs in the proximity of Dubno. In the paper quoted by us in the beginning, treating the topic of the flora of the Białowieża Forest, Stanisław Gorski mentioned on page 211 that 'P. Witzell, director of the botanical garden in Vilnius, saw it (probably around 1820) in the forests towards Volhynia Polesie.' Today, the nearest sites of native fir are located approximately 120 km south of the Białowieża Forest in the Łuków–Siedlce Uplands, where they demand the most immediate scientific examination.

These interesting fir exclaves, located on the perimeter of the geographic range limit, the Białowieża site being one of them, prove (along with other facts from the field of contemporary geographical distribution of plants in Poland, not to be discussed here) that **fir is a tree species that withdraws in the contemporary climatic period towards the southwest**, whereas its isolated exclaves are remnants from a past climatic period that was more favourable for the life of this tree. It is likely that the Białowieża fir oasis is a remnant and relic of a wave of vegetation of the south-western type, which in the phase of **climatic optimum**, after the retreat of the diluvial continental glacier, temporarily reached far into north-eastern Europe.

The exclave of native fir in the Cisówka wilderness in the Białowieża Forest, considered in the context of general geo-botanical relations in Poland, belongs undoubtedly to the most interesting natural phenomena in our country. As a peculiarity of nature and a monument of a past climate, it should be preserved here, as a permanent monument to the continuing changes caused to the flora of our forests by **Time,** changing all and mighty.

In Cracow, in August 1920.

Władysław Szafer

A plan to establish a forest nature reserve in the Białowieża Forest

The example of the United States of North America, where in order to preserve a part of the unspoilt nature of their beautiful homeland for future generations, a series of giant national parks have been established, including most importantly, the famous Yellowstone Park (established in 1872, with an area of 8,700 km^2), followed by all culturally developed countries in the five continents. In Europe, however, greater challenges in establishing larger nature reserves have to be faced, as on this continent ancient human culture and population densities have turned almost all the surface into an area of human economic activity and thus completely changed its original picture. Despite these difficulties, thanks to a general understanding of cultural needs by the nations and to the usefulness of the protection of the remnants of primitive nature in Europe, it has become possible to overcome all obstacles and to establish major 'Nature Parks' in almost every country.

The first country in Europe to join the path towards protecting the natural beauty and uniqueness of its nature by establishing major reserves was Denmark. In 1903, the government purchased 1875 hectares of moorland, located in western Jutland, in order to preserve it for the generations to come and transferred it to the administration of the Ministry of Agriculture and the Ministry of War (for the purpose of conducting military manoeuvres there), as well as to the University of Copenhagen. The example from Denmark was followed soon by Sweden, where pursuant to the State Act on Natural Reserves of 1 January 1910, two areas, one of 15 and the other of 19 km^2 in the most beautiful parts of its homeland mountains and glaciers were permanently demarked and protected against any changes. The Norwegian government followed suit. In 1910, a national park covering an area of 200 km^2 was created in Switzerland, to which the beautiful and wild Val Cluosa alpine valley was allocated. In Germany, in a short period of time, between 1909 and 1914, a bold and costly plan to create three 'national parks' in the German lowlands near Hamburg, in the Harz and Styria was implemented almost fully. A total of 150 km^2 of mountain areas were acquired for this purpose. Even in Russia, which tends to be used as an example of backwardness, larger reserves have been established in recent years, either privately or at the expense of the public purse for the protection of the original nature of the steppes, forests and mountains.

In Poland, divided into three Partitions, ruled by foreign powers, there was no opportunity to establish Polish 'nature parks'. There were, however, opinions by naturalists and explorers about the need and necessity to protect the original flora and fauna, together with the disappearing beauty of the Polish landscape by establishing larger reserves. Yet, on 15 November 1910, the Sejm Galicyjski, the only Polish governing body, considered the issue of creating major reserves in the country, based on a speech given by the deputy, Juljan Brunicki. Having been deprived of the ability to govern in accordance with its own plans, Poland was not able to create a single larger protection area. This situation has not been changed by the already existing small private and state protection areas. Above all, such areas were left to Poland by the Prussian government, which, thanks to the operation of its government body, *Centralstelle fur Naturdenkinalpflege* in Berlin, protected from oblivion a number of smaller state and private areas in the areas of the former Prussian partition of Poland. The largest of these reserves was established in the state forests of Pustkowie Tucholskie to protect the dying out yew tree (*Taxus baccata*). It covers only 18.5 ha, and therefore cannot be called a 'Polish national park'. A number of private forest reserves were also established in Poland owing to the generosity of sensible citizens, such as the forest reserve in Pieniaki (40 morgen) founded by the late Włodzimierz Dzieduszycki, or similar conservation areas in Nawojowa, (Adam Stadnicki) and in Złoty Potok (Raczyński). Though of high value to science, their limited areas mean that they are unable to replace in any way the Polish 'nature parks' missing to this day.

Today, having regained political independence, we organise our life on new foundations, and it is time to start implementing the long-existing concept of establishing Polish nature parks to protect the remnants of the original beauty of Polish nature, to become a refuge for the remnants of Polish fauna that is slowly dying out, offer space for unhindered research by Polish scientists, naturalists and foresters, as well as provide a place of study for artists and young people undergoing their education.

In each country governed in accordance with the law, there are three ways to establish major nature reserves, or 'nature parks', desirable from the point of view of nature conservation. These are either a relevant ordinance issued by the authorities or a private person that owns a given area, the purchase of a given area, or finally acquiring a given area by means of legislation issued by the supreme legislative body, in case of Poland – by the Sejm.

The Ministry of State Treasury may separate by an ordinance certain areas from state-owned properties and establish 'nature parks' there, for which complete inviolability or certain limitations in their economic use can be ensured by separate provisions. Undoubtedly, this way to obtain larger areas for 'nature parks' is the easiest one, as it requires from the mentioned ministry only the good will and an understanding of the usefulness of such a designation of some part of the state property. In such way, by an administrative order of the Prussian Ministry of Agriculture and State Treasury, the above-mentioned reserve for the conservation of the native yew in Pustkowie Tucholskie was established a few years before the war. In the same way, in 1914, by an ordinance of the Directorate of State Domains and Treasury in L'viv, a yew site in Kniaźdwór near Kołomyja was supposed to be protected and a larger forest reserve, which would fully deserve being called a 'nature park', was to be established in state forests in the Eastern Carpathians at the source of the Prut River. Unfortunately, these intentions were hindered by the outbreak of the world.

Larger reserves may also be obtained by purchase or long-term lease, but this way is – it goes without saying – by its nature much harder than the previous one. To give an example of obtaining a larger reserve in Europe in this way, let me remind you that a beautiful plot on the right bank of the Isar River near Munich was purchased for 50,000 marks before the war with the purpose to establish there an inviolable reserve of primeval nature, which sum was paid fifty-fifty by the municipality of Munich and the Munich *Izartalverein* association of artists, naturalists and tourists. In the way of purchase from private owners, the Danish government created in 1903 the above-mentioned large nature park on the moors in western Jutland.

In several European countries, the issue of establishing larger reserves that is nature parks is determined directly by state law. In France, pursuant to the fourth article of the *organisant la protection des sites et monuments naturels de caractere artistic* act of 21 April 1906, it is possible to establish governmental commissions entitled to attribute to a given area the status of an inviolable reserve. A similar act has been valid in Sweden since 1 January 1910. Norway, Switzerland, Russia and some other European countries also have such an act.

In Poland, no 'nature parks' or acts concerning this matter established by the Sejm exist. The establishment of the State Commission for Nature Conservation by the government proves that the idea of nature conservation has been fully acknowledged by our government. We may also expect that by having an advisory body in form of the mentioned commission, the Ministry of Religious Affairs and Public Education, in agreement with other ministries, shall take energetic steps to rescue the last remnants of primeval nature from destruction. In pursuit of accomplishing these plans to conserve the Polish nature and landscape on larger areas, as already proposed by the communities of naturalists and artists, certainly not just one, but all of the three indicated methods must be applied. After all, there will be a different way to execute a plan to create larger reserves in state properties (e.g. in the Świętokrzyskie Mountains or in the Carpathian primeval-type stands), a different one for the areas belonging currently to a large number of private owners (e.g. the Pieniny or the Ojców valley), the striving for obtaining reserves located in wildernesses and wastelands (e.g. sand dunes by the sea or the cliffs on the Podolian walls) need to be considered differently, while plans for reserves located in areas used economically, thus valuable for the people, need another approach. Much consideration and reflection will be required from planners working in this field, as well as good will, civil dedication and reasonability shown by the decision makers. Only consistent cooperation between the government and the Commission for Nature Conservation, supported and understood by society, may lead to a solution for the current concepts of establishing 'nature parks' in Poland, favourable for future generations.

Fig. 1. Route from Hajnówka to Białowieża near Czerlanka

In this paper, we shall discuss one such project to establish a larger reserve, i.e. a nature park, namely a plan to save part of the Białowieża Forest, commonly known not only in Poland, but also renowned abroad, from being cut down. This project has been developed based on the works performed on site by two governmental commissions: the first one sent for guidance purposes in April 1919 by the Ministry of Religious Affairs and Public Education in consultation with the Ministry of Agriculture and State Treasury (participants: Professor E. Kiernik, PhD, Professor Kloske, and Professor W. Szafer, PhD), and the second one, organised in July 1920 by the State Commission for Nature Conservation with the help of the above-mentioned ministries and the former Commissariat for the Eastern Territories. That commission comprised Professor Władysław Szafer, PhD (as the President of the State Commission for Nature Conservation), Professor B. Hryniewiecki, PhD, Stanisław Kulczyński, J. Lilpop, and delegates of the ministries: Professor S. Kunzek, PhD (delegate of the Ministry of Culture and Art) and M. Orłowicz, PhD (delegate of the Ministry of Public Works). On site, the Forest Inspector, Włodzimierz Jagodzki, participated in the commission's works on behalf of the Regional Board of State Treasury.

The Białowieża Forest constitutes the largest forest area on the North European Plain. Together with the neighbouring Ladzka and Świsłocz Forests, of which the latter has especially maintained its primeval nature, it covers a huge area of approximately 32 square miles, most of which is covered by forests, while the rest by fen, peat bog and the glades formed by forest clearing, with only a few villages, partially burnt down and depopulated during the current war. This huge area belonging to the Bielsk, Prużana and Wołkowysk poviats, with usually fertile, sandy or loamy soils, with minor differences in elevation (140–202 m), is located on the European watershed, from where the Narew and Narewka Rivers flow towards the west, the Leśna River towards the south, while the Prypeć River feeder – the Jasiołda River with its sources located in the Wielki Nikor [Large Nikor] marshlands to the east. In the very centre of this compact forest complex is a large open area of around 2,000 ha may be found, where the village of Białowieża is located, along with the hamlets Stoczek, Podolany, and Zastawa destroyed during the war. It is surrounded by forest walls, up to 25 km deep, towards all four corners of the world. Apart from the Białowieża Glade, the homogeneity of the forest is interrupted also by three smaller open spaces, located towards the west, where old Masurian settlements were established: Pogorzelec, Czeremiszki and Budy. However, we will not deal here with the description of the forest itself. A reader who is interested in this subject can easily find extensive literature – older and newer – on the subject, a list of which is provided at the end. Here I would like to deal only with the forest as the place where a 'nature park' is to be established.

From this point of view, three circumstances are crucial: firstly, the value of the Białowieża Forest as an area necessary for scientific research; secondly, the landscape nature of the forest as the last area in Poland and one of last in Europe where the untainted beauty and charm of a virgin forest has been maintained; and thirdly, the economic value of the forest stands, which would have to be relinquished to create an inviolable 'nature park' from the forest.

Fig. 2. Side wall of the reserve seen from the Białowieża glade

Let us discuss these three issues in more depth. The significance of the Białowieża Forest as a unique and simply priceless area for scientific work almost does not need proving. It is enough to indicate here that the very geographical location of the Białowieża Forest on the edge of the European watershed makes it extremely interesting for geographers, foresters, botanists, and zoologists. Let me remind you that highly important geographical range limits of several forest species of the utmost importance pass through the Białowieża Forest. Here are the eastern limits of yew (*Taxus baccata*), sessile oak (*Quercus sessiliflora*), and ivy (*Hedera helix*). Here is a borderland site of native (*Abies alba*), which catches the interest of so many foresters and botanists. Here we can see the borderland sites of many flora and fauna species, which find a home in the dark and cold forests of northern and north-eastern Russia. And finally, its existence as a refuge of numerous Carpathian species, demonstrating the primeval closeness of the Białowieża Forest to the warmer south. How much of scientific interest and the curiosity of native and foreign foresters alike is caught by inadequately researched types of mixed stands of the forest? How many unsolved mysteries may be uncovered by the secret interior of forest wilderness, if we gain a scientific insight into it? It is impossible to answer this question. However, it is certain that in the Białowieża Forest, left in its natural condition, a nature scientist and a forester researching the forest life shall find a never-ending source of scientific research, which will bring not only solutions to purely theoretical questions in the area of biology, taxonomy and geography of flora and fauna, but also many results obtained by Polish foresters in the field of forest regeneration by natural seeding, the biology of trees and forests, which will stimulate the science of forestry and thus it may result in purely practical benefits with economic value that can hardly be assessed today. All these benefits for our science, for which the Białowieża 'nature park' will become a source, shall not be of a temporary but permanent nature, one that grows year by year, as the scientific research started here by our generation shall be handed down and continued by future generations, better prepared for carrying out this research than us and finding ever newer problems to solve. How important will this Polish 'nature park' be, nowadays and in the future, for young people studying research methods concerning nature? Is it possible today to at least approximately assess the entire educational and scientific value of school trips to the reserve in the forest? Is it possible to create a better museum of live nature to teach our students of vocational schools, first of all young foresters? In my opinion, these arguments are strong enough to convince every intelligent citizen that leaving part of the Białowieża Forest in its primeval form shall create a permanent and irreplaceable workshop for science, and for the Polish education system a place dynamically attractive to the young, freely and successfully teaching about the forms and principles of life.

It is not my role to assess the landscape value of the Białowieża Forest as a never-ending source of artistic experiences. Our poets and artists have already done that. Who may forget the power of feelings experienced while reading a description of the Lithuanian primeval forests in *Pan Tadeusz* [Master Thaddeus]? Who has not accompanied Mickiewicz in his longing for tree-giants felled with an axe or burnt down, inhabitants of ancient primeval forests, after which all we have are just their names? Is there a Pole who has not desired to enter those glooms that shaded the heads of Gediminas, Jagiełło and Batory in the Białowieża Forest?

Our artists should speak up on this matter, although I do not know if their words may be more meaningful and plausible than pieces of work of our literature and painting, that is works by Grottger, Fałat or Weyssenhof, originating from impressions these masters took from the mysterious depths of the primeval forests.

The material value presented by the stands respected for ages in the Białowieża Forest is huge, as in the context of a growing domestic demand for construction material and export opportunities this value shall not decrease, but just the opposite – it shall continuously increase. Therefore, while considering the plan to create an inviolable reserve from part of the Białowieża Forest, we must conscientiously consider also its economic aspect. According to the latest estimates of the value of the Białowieża Forest, which we partially repeat after Nawrocki BEng (*Roboty Publiczne* [Public Works], organ of the Ministry of Public Works as of September 1919), this matter is as follows:

The Białowieża Forest stands cover an area of 128,000 ha, including 8,000 ha of marshlands, farmland, roads, etc. According to a low estimation by the Germans who had managed the forest for some time during the war, the wooded land comprises 32,800,000 m^3 of growing stock of mostly mature timber suitable for felling, and partially already overmature. 8,800,000 m^3 of it is deciduous wood and 24,000,000 m^3 coniferous wood, while 15,200,000 is pinewood. In relation to the wooded land, approximately 80% of the area of the forest is covered by coniferous trees (pine and spruce) and around 20% by deciduous trees (oak, ash, hornbeam, black alder, aspen, birch, linden, elm, and maple).

In 1919, in accordance with an assessment carried out by Nawrocki BEng, the value of the entire forest including the facilities left behind by the Germans, i.e. industrial plants, light railways etc. was approximately as follows:

	Marks
Growing stock of timber, 31 million m^3 at 30 marks	930,000,000
Forest stands up to 20 years old 7,000 ha at 500 marks	3,500,000
Harvested logs in the forest and at depots, 50,000 m^3 at 60 marks	3,000,000
Sawn timber at depots	2,000,000
Forest land without marshlands 124,000 ha at 250 marks	31,000,000
Administration buildings, castle, forester's lodges, etc.	15,500,000
Value of industrial buildings, machinery, railways, left behind by the Germans	15,000,000
Total	1 billion marks

While converting this sum to the current value and taking into account that the Germans' calculations were certainly too modest, we may assume that the current value of the Białowieża Forest comes to the huge **amount of approx. 3 billion marks**. The economic value of the Białowieża Forest for the Polish State is largely increased by the ease of timber removal from it thanks to the railroads located close to the forest, with a spur to Białowieża itself; moreover, thanks to the narrow-gauge railways, approx. 200 km of which were left by Germans there, and thanks to the navigability of rivers flowing from the forest, mainly the Narew River. Modern industrial plants constructed here by the Germans, including sawmills in Hajnówka (6 gang saws), Narewka (2 gang saws), Czerlanka (2 gang saws), Gzówki (4 gang saws), and in Białowieża (4 gang saws), large factory for dry wood distillation, furniture and wood wool factory in Hajnówka, and large woodworking workshops in Białowieża allow material processing on site, which also substantially increases the forest's production value.

Considering such enormous values provided by the economic exploitation of the Białowieża Forest to the Polish State, impoverished by war, it is even impossible to consider maintaining the entire Białowieża Forest as an inviolable reserve. Leaving aside such a huge forest wealth and resigning voluntarily from it, when our state fights so hard for its existence and economic independence, leaving millions of cubic metres of growing timber just when we have no material to rebuild the ruins of war would constitute too heavy a sacrifice, or would even be simply reckless. Therefore, I do not intend to convince the readers that it is necessary to leave the entire Białowieża Forest in a primeval condition and to resign from deriving profits from it. However, I would like to introduce all readers to the concept of establishing a 'nature park' in a certain, relatively insignificant part of the Białowieża Forest.

To support the above arguments, I allow myself to quote the sentence expressed in 1919 by the above-mentioned Nawrocki BEng in that matter in the official organ of the Ministry of Public Works. I allege this citation with a strong emphasises, as this voice is objective and devoid of the 'sentimentalism' of which a naturalist or an artist speaking up in this matter might be accused.

'Thus, it is still necessary to answer,' Nawrocki writes, 'the question whether the forest is to stay useless for the population, or quite the opposite. If we were a rich country with a developed population, if we had endless volumes of timber, we should support, in the name of respect for the gifts of nature and their protection from destruction, the idea of the preservation of the forest in its primeval state and for the creation of an American-type reserve from it. However, a poor country that has to strive to exploit its gifts of nature, with little forest, largely destroyed by the war, with a homeless population needing the forest's treasures to satisfy their primal needs – which is the need for a house – cannot take the liberty of wasting the gifts of its nature. Nevertheless, the German plundering economy should not be continued, **just the opposite, part of the forest should be left in an intact condition, as an area of work for researchers into the nature of our lands.'**

We have no reason to doubt that this opinion is shared by all people on whom the final completion of our project shall depend.

We face the final question: how large a part of the Białowieża Forest should be designated as a forest reserve? This is not easy to answer. Considering the vast spaces covered by the Białowieża Forest, the almost uniform landscape nature of the area and highly dispersed picture of forest types in the forest, it is hard to make a decision, especially if you have not spent your life in the forest or personally explored its backwoods and wildernesses. The current literature on the forest does not provide directions in this regard, as all the past descriptions are too general and superficial to constitute the desired basis for this purpose. As well, the previous insufficient research concerning the forest flora and fauna cannot constitute a guideline for us.

Following the exclusion method, applied frequently in scientific research, large areas of the forest may be at once excluded from being taken into account in seeking the nature reserve. Therefore, all areas, even if slightly destroyed by the war, must undoubtedly become excluded, as the presence of felling or artificially regenerated areas within the 'nature park' is contrary to its basic concept. Since the Germans conducted very intense exploitation, or even a plundering of the forest (they removed from the forest during a short period approx. 1,800,000 m^3, i.e. approx. 6%, of the entire wood volume), covered large forest areas with a network of narrow-gauge railways and left huge, naked clear-cut spaces scattered over a very large area, therefore we may exclude at once from the permanent protection plan such huge areas belonging to almost all of the twelve guard districts, as only the Podbielska Guard District (XI), the Okolnicka Guard District (IX), and the inaccessible Świsłocz Forest, located behind the Narew River, were left intact. This does not mean, though, that other guard districts do not have vast spaces untouched by the axe and capable of becoming a suitable area for a nature reserve. After all, the Germans made the selection 'easier' for us by destroying the forest's primeval appearance in vast areas.

Let us now consider theoretically what properties an area should possess, to be classified as suitable for conversion to a 'nature park'. In my opinion, the following aspects should be included: 1) it should be a forest complex so far untouched by an axe, 2) it should not be too small to include as many forest types and primeval plant communities as possible, 3) with regard to landscape, it should constitute all components most specific for the Białowieża Forest, 4) if possible, it should have natural borders, well-distinguished in the field, and 5) it should not be hard-to-reach for researchers and excursions, but if possible it should be located far enough from the noise of human economic activities in the forest that it maintains its dignified silence and constitutes a peaceful animal refuge.

So if, by keeping the above theoretical requirements in mind, we take a look at the Białowieża Forest, the area marked on the attached map seems to be the best suitable for a reserve. It is an area of the forest belonging in its main part to the Augustów, i.e. Royal Guard District, directly adjacent to the Białowieża glade, constituting its north wall. Regarding the theoretical requirements, this area has the following advantages:

1. It is forest land, almost untouched by humans, apart from small new clearcutting areas in its south-eastern part and apart from a few old Russian clearcutting areas regenerated a long time ago, located centrally, and the area on the right bank of the Narewka River constitutes a primeval over-mature forest.
2. This area is sufficiently large as its main area covers 42 quarters, i.e. square compartments, each with an area of 113 ha. Regarding the forest's entirety, which comprises 1,147 such quarters, this area cannot be considered a large one.
3. It is characterised by an enormous diversity in forest types, thus has a high variability in its physiognomy. Apart from forest plant communities, it includes clusters of meadows and peat bogs, specific for the forest flora, and is located by the Narewka River and its tributaries, the Hwoźnia and Orłówka.
4. Its borders on three sides are very distinctive. They are constituted by the Białowieża glade to the south, the Narewka River with its wide overflow areas to the west, and Hwoźnia River to the north. Only on the east side the border is artificial, although sufficiently distinctive, as it is constituted by a highroad from Białowieża towards the Świsłocz Forest.
5. The area is easily accessible for researchers and for scientific field trips, as it can be entered directly from the Białowieża glade. The distance of the reserve's edge from the castle (a typical starting point for all trips from Białowieża) is approx. 1.5 km.
6. Due to its location separated on three sides from the rest of the forest by boundary rivers, and due to the fact that Germans did not install any branch of the forest railway deep into this area and due to the significant distance from the sawmills, this forest area is peaceful, ensuring the necessary tranquillity for animals. The rest of the only forest railway here need only be removed from a small area on the

side of the east wall, along the above-mentioned boundary highroad, and from this side the reserve should be protected by fencing.

A serious argument for selecting this part of the Białowieża Forest as a 'reserve' is the fact that German forest scientists and naturalist, under the leadership of Professor Conwentz, when deliberating in 1917 about selecting an area for a 'nature park' also considered this area as most suitable.

From the reports of the State Office of Nature Conservation in Prussia of 1919 (*Beitriige zur Naturdenkmalpflege* Bd. VI. H. 3. S. 337, Berlin, Gebr. Borntraeger) we can learn that in the beginning of 1918, the Białowieża Forest administration demarcated from the forest an area of 30 km^2 as an inviolable 'nature park', while in the original German map, which I owe to the kindness of the head of a section in the Ministry of Agriculture and State Treasury, Mr. Jan Miklaszewski, this area is clearly marked and described as *Naturschutzpark*.

So far, we only discussed the area of the main reserve, located on the eastern (right) bank of the Narewka River in the Royal Guard District. The enclosed map shows that the planned Białowieża reserve stretches over to the left bank of the Narewka River in two places, and in addition shall cover forest compartments 281, 282, 312 and 313 (partially) located on the north and a forest strip on the south, stretching out from the Czerlanka forest subdistrict (belonging to the former Zwierzyniec [menagerie]) on both sides of the highroad to the Białowieża glade. Grounds inclining us to such an extension of the area of the 'nature park' are as follows:

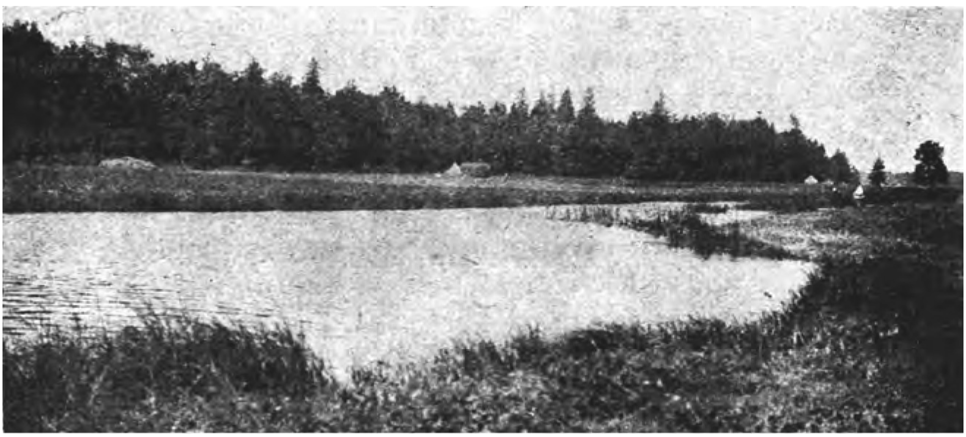


Fig. 3. By the Narewka River

We wish to include these four forest compartments mainly because in compartment 281 is the so-called Zamczysko [castle]. It constitutes the ancient ruins of a castle or a stronghold, the establishment of which is traditionally attributed to Gediminas. The beautiful forest wilderness where these ruins are located has been a preferred destination for groups visiting the Białowieża Forest since historical times. The vegetation here is also very abundant and rich in species rare in other places. Adding this forest fragment to the main reserve will have one more advantage – at the juncture of compartments 282, 283 and 313 are the very scenic and floristically interesting banks of the Narewka River, which will be protected once and for all.

We intend to include in our 'nature park' compartments 419, 420, 421, 422, 423, 421, 425, 426, 444, 445, 446, 447, 448, 449, 450 and 451, in order to maintain the primeval forest appearance along the main road leading into the forest, which will be very important for those riding or walking into the forest. The remaining part of the strip along the road in the western direction was completely devastated by Germans. In compartment 450 is Góra Batorego [Batory Mountain], famous in the forest history, which should be respected in memory of the king-hero and the overmature forest growing there should not be destroyed by the axe. In my opinion, this strip of the reserve alongside the road that I am talking about might be not a reserve on the strict protection level, but a partially protected reserve, which means that at some distance from the highroad regular forest logging with the selection method could be permitted.

In this way, according to our project, we would obtain in the Białowieża Forest a strict reserve, i.e. the proper 'nature park', covering an area of 42 forest compartments located on the right bank of the Narewka River and 4 compartments near Zamczysko on its left bank. A strip of partially protected reserve stretching from the Białowieża glade to the former Zwierzyniec and the Czerlanka forest subdistrict would stay connected with this strict reserve (through compartment 426).

This is how a project for a Polish 'nature park' in the Białowieża Forest could look. After obtaining the consent of the relevant authorities, it would be the responsibility of the Commission for Nature Conservation to develop, as soon as possible, together with the Administration of the forest, detailed provisions concerning the conservation of the primeval nature of this area. However, it would be prematurely to discuss now the details of these necessary provisions, modelled on analogous foreign regulations.

Our planned 'nature park' in the Białowieża Forest, although covering a significant area and housing almost all forest types specific for the forest, does not include tree species that constitute two of the largest singularities, i.e. fir (*Abies alba*) and yew (*Taxus baccata*).

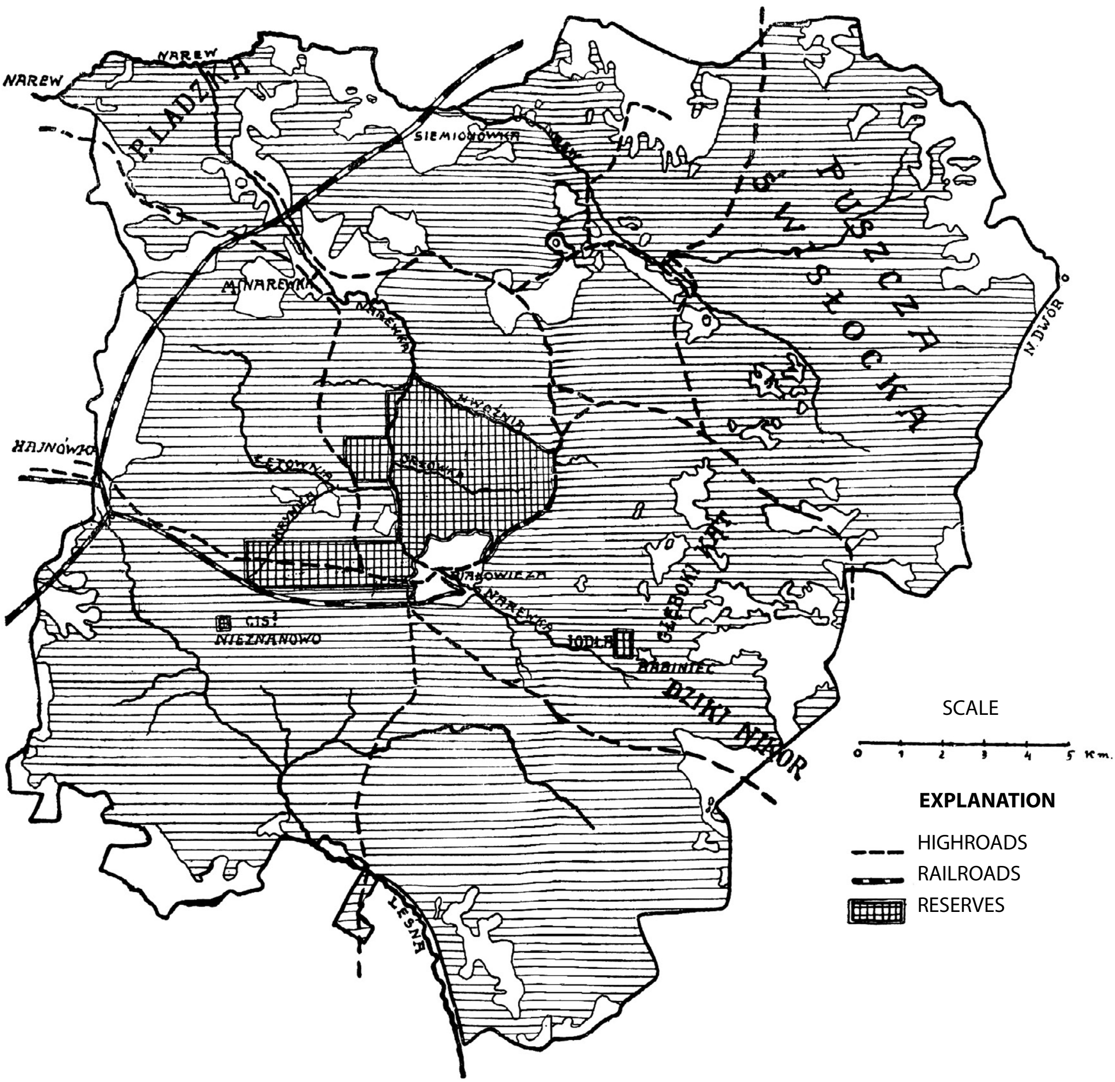
The fir grows in wild in the Białowieża Forest area in only one place, i.e. in the wilderness called Cisówka, is extremely hard to reach, where the huge Wielki Nikor peatbog moor meets its southern branch, known as Głęboki Kąt (compartment 561). Since I have already described in a separate paper, recently printed in *Sylwan,* that separate site of native fir, here I will just say that fir in the Białowieża Forest necessarily requires permanent protection, which may achieved only by excluding the part of Cisówka where the fir grows from commercial use. Since it only requires a very small reserve, so I think that its creation should not encounter any problems.

The situation for the native yew (*Taxus baccata)* looks less hopeful. As we know, here in the forest it has its easternmost sites. The yew was formerly quite a popular tree species in the Białowieża Forest, but, exterminated by humans and naturally poorly regenerating at the edge of its geographical range, became very rare with time. The last two specimens of yew were seen in 1887 in the Nieznanowo wilderness, in the Leśniańska Guard District by A. Eismond, K. Drymmer and Błoński, who were exploring the flora of the Białowieża Forest at that time. In 1917, the Germans attempted to find that yew site, with no success, so they assume in their forest-related papers that the yew has been completely lost here. Judging by the stories that I have heard from local foresters, it is possible that one specimen of native yew has yet survived in the same forest wilderness. It is obvious that in the case of finding this 'last of the family' it should be provided with utmost care, by leaving around it a small part of the forest in its primeval condition. Finally, one thing about the areas called in Russian *zakaźniki*. They constitute more than a dozen conservation areas scattered around the entire forest, created by the Russian forest administration. They were of non-equal sizes, between 400and 600 ha. These reserves were aimed mainly at game protection, in particular regarding the bison. Today, when bison in the Białowieża Forest has been completely exterminated, maintaining of these *zakaźniki* in the form of inviolable reserves would be pointless, especially if our plan of a larger 'nature park' could be quickly implemented.

Fig. 4. Deep into the reserve. Huge withered pine in the middle

Nevertheless, while developing a thorough management plan for the forest stands of the Białowieża Forest, which will certainly be soon commenced by the authorities appointed for this purpose, in my opinion at least some of these *zakaźniki* should be respected and if not excluded from use, then their use must at least be limited to a careful selection system with natural seeding as the only acceptable form of forest regeneration. Thus, a good dozen smaller conservation areas, apart from the main reserve, would be maintained in the forest to keep their natural imprint forever. In addition, they will be important for foresters studying forest regeneration methods by natural sowing.

We provide the present plan of establishing a forest reserve in the Białowieża Forest to all Polish naturalists and foresters for their consideration and evaluation. However, first of all we plead that our plan is taken into favourable account by our government, which in



W. SZAFER
A PROJECT OF A FOREST NATURE RESERVE
IN THE BIAŁOWIEŻA FOREST

its role as legal owner of the royal wilderness of the Białowieża Forest may create a historic monument for the benefit of Polish science by establishing the Białowieża 'nature park'.

More important works, scientific papers and descriptions referring to the Białowieża Forest.

The great and long enduring interest in the Białowieża Forest in Poland and abroad is measured by the very rich scientific, descriptive and belletrist literature referring to it. Our bibliography lists only the most significant works, and we omit a number of small essays and articles that may be found by an interested reader in annual and periodical journals of various content.

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Cyryl Kochanowski, BEng

The use of the Białowieża Forest

In the former Poland, the Białowieża Forest was Crown Land, while in Russian times it belonged to the appanage and for many years it was used only for the tsars' hunting purposes. Its management was limited to the removal of fallen trees, windfalls and snags.

Relations changed upon the German military occupation. The Germans built sawmills, with one huge sawmill in Hajnówka, a factory for dry wood distillation and a turpentine factory, while in order to facilitate the material forwarding from the forest to the sawmill they built forest railways 228 km long and started cutting. By the time of their retreat, the percentage of felling was not so high; however they have to face a serious charge because of the cutting sites they chose. Logging was carried out near railway lines, without consideration of the cutting sequence. They did not have enough time to cause a lot of damage, and if considered what they left (forest industry, 20 sawmills, forest railways), their fault diminishes. It must be explicitly admitted, giving voice to the truth.

However, the Germans did much more. They published the perfect forest monograph titled *Bialowies in deutscher Verwaltung* and conducted triangulation on which the current forest area calculation is based.

The Polish government, when taking over the rule of the forest, had to consider its regular use and firstly to look to converting the huge stock of roundwood left behind by the fleeing Germans into money. The Council of Lithuania was in charge of the forest for only six weeks, yet this was enough for the local population to exterminate the bison completely.

Before the war, there were about 750 bison living in the forest. When the Germans took control of the forest, the bison were put by order under highest level of protection and when the Germans were leaving, there were still 150 specimens. Today, there is no bison in the forest and we could hazard a guess that bison in the forest already belongs to history.

Approx. 90 smaller contracts concluded by the Ministry of Agriculture and State Treasury originate from the first years of Polish governance. Currently they are handled by the Ministry of Treasury, which in order to conduct normal utilisation, or rather provide the state with a higher income, organised a survey to consider this issue and appointed the undersigned as an expert.

On this occasion, I have stated that the timber rotation period was established at 120 years, which, in any case, is too conservative a number and could be reduced to 100 years.

Further, it was declared that a normal annual allowable cut taking into account the surplus of overmature forest comes to 300,000 m^3. If we add firewood to this, the overall figure for the annual use is 450,000 m^3. If we assume that the total wooded land comes to approximately approx. 110,000 ha, then the output of 1 ha of cutting surface is approx. 459 m^3 of the entire volume, while the mean annual increment to approx. 4 m^3. For the Białowieża Forest, with its image idealised by Polish society, these numbers are not excessively high. The mean canopy closure is 0.6, which points to a scarcity of these stands, comprising 65% of pine and spruce, 10% of oak, 18% of alder, while the rest includes ash, wych elm, birch, aspen, and linden.

However, the survey states one very important detail, i.e. that the forest faces a disaster. It was detected that thousands of spruce trees are infested by the European spruce bark beetle. The total wood volume infested by the European spruce bark beetle is calculated as 2,500,000 m^3. This number is truly terrifying. The gradation of this pest started a few years ago, but could not be radically stopped, for reasons not attributable to the forest administration. Therefore, the first duty is to remove these trees, starting from those currently with the presence of the beetle. However, due to level of beetle gradation, it has been decided that over the next five years to log 500,000 m^3 of timber infested by the beetle per year and to add to this 150,000 m^3 of timber from normal logging. After five years, the normal annual allowable cut for a period of fifteen years will be 350,000 m^3 of timber per year, provided that it is not obstructed by further gradation by the European spruce bark beetle. It should be expected that in 1922 further stands will be attacked and it remains to be seen whether it is possible to overcome this problem in the near future. The intention of the Ministry of Treasury is to assign the forest utilisation rights for 20 years.

Based on this, bidding will be announced, limited to a few financially wealthy companies. Billions are needed as an initial investment in order to get the business going. However, I think that enough capital will be found in Poland, so that this business can remain in Polish hands.

Although it would be more profitable to split the entire utilisation into several units, as it may be expected that more interested parties will be found and therefore the prices will be better, but the intention of the Ministry of Treasury is that a single company be entrusted with the entire business.

Currently, there are 20 gang saws in the forest, while the processing of the entire volume of timber requires at least 20 gang saws more, assuming a two work shifts.

Moreover, it appears that approx. 150 km of new forest railway lines must be constructed.

There is no doubt that from now onwards the Białowieża Forest shall be reasonably managed and shall become an important factor in the State budget. The value of annual income may be estimated at one billion Polish marks.

Zygmunt Czubiński

The role of national parks and nature reserves on the background of the current situation and the needs of national culture

We should welcome the initiative of the Polish Scientific Forest Society, which has organised this conference in order to discuss the concept of organisation and the issues of scientific research in national parks and nature reserves in detail. It has its purpose of indicating the vivid interest of the Polish Scientific Forest Society in the reasonable use of the most valuable elements of Poland's natural environment for scientific, teaching and educational activities. Society and the Government of the People's Republic of Poland have entrusted the Ministry of Forestry and the Polish foresters with nature conservation issues. Here it is worth quoting Lenin: 'The state of nature conservation in a given country is the best criterion of its cultural level'.

Other scientific societies and institutions, in particular the departments and institutes of the Polish Academy of Sciences, will certainly also commence a discussion about these issues, as national parks and reserves belong to the whole of society and constitute irreplaceable, almost priceless sites for research work, so the decisions on them must be taken by all who care about science and culture. Let us remember that they constitute living museums of nature and workshops for long-term activities, for current and future generations.

By creating national parks and reserves, we protect the most valuable jewels of Polish nature and the country's natural resources; we maintain the characteristic features of the land, the regional diversity of the natural landscapes, the richness of its plant and animal world. Thus we establish the necessary framework for the scientific development, protecting from destruction the undiscovered secrets of the nature, the knowing of which shall bring benefit to theory and practice. Reserves constitute an amazing and reliable educational tool. They open one's eyes to pristine beauty, the diversity of forms, colours, shapes and sounds, and they stimulate imagination and creativity. National parks, with their primeval nature, are a source of health, a tourist destination and a place of rest after the travails of work.

The conference today aims to indicate the most significant tasks facing national parks and reserves, and the methods of their adjustment to long-term, stationary and more time-limited research concerning narrower topics.

It sets out to consider issues that are interesting mainly to foresters, to outline possible contributions of the society's members to research related to national parks and reserves. Certainly, it aims also to arouse enthusiasm for further work and animation efforts.

That is why this conference is taking place in Białowieża – in our prototype national parks and reserves, where scientific, educational and organisational achievements, in particular of foresters and many other biologists, pedologists and climatologists, are the most significant and worthy of replicating.

This does not mean that in other national parks or reserves, even the ones still only being designed, legally not recognised yet, there are no such works or that they are conducted in a poorer way. Maybe we do not provide enough information and hence sometimes we hear the accusation that we do not fully take advantage of the opportunities for research afforded by the nature reserves. Every year, the situation improves regarding this. The number of new research staff is growing, although still there are no people particularly trained for the purposes of national parks and reserves. Research in reserves has also obtained its due position in the academic plans of universities and the Polish Academy of Sciences.

Scientific works within the national parks and reserves have a long tradition, at least as old as the efforts to establish the parks themselves. In the case of the Tatra National Park, this tradition goes back to the second half of the last century, while in the Wielkopolska National Park the planned works began more than 30 years ago by researchers of many taxonomic categories of plants and animals, and recently these have also been conducted collectively.

It is enough to realise that the bibliography of publications concerning the Białowieża Forest listed by Professor J. J. Karpiński, PhD, by the year 1947 already had 478 items. In case of the Wielkopolska National Park, the bibliography covers approx.170 items, including many works being published in a separate series of publications of the Poznań Society of Friends of Science, in the *Monographic Works on the Nature of the Wielkopolska National Park*. For ten years now mainly the scientific centre in Poznań has been conducting extensive collective research works in the territory of the future national park on Wolin Island, which has resulted in several dozen scientific publications being published. Many other examples of planned collective or comprehensive works conducted in other national parks or reserves could be presented.

The significance of the Tatra Mountains for Polish society and its role in Polish culture is shown by the comprehensively composed bibliography of the Tatras, which now includes more than 3,300 pages.

The topic I am describing now has been repeatedly and comprehensively discussed. Foresters have often participated in these discussions in professional and conservation-related journals and in popular publications. That is why I will present only general issues –

detailed questions will certainly be considered in subsequent papers and developed through discussion. Admittedly, I will speak about generally known matters, but I want to place special emphasis on less visible areas, especially within the scope of establishing a reasonable network of reserves. Gross deficiencies can be perceived here, and the conservation of certain types of reserves or particular areas for research and teaching-educational activities is a question of high priority and urgency.

As a preliminary point for the review of reserves and national parks and of the assessment of their role, I want to say that every protected object comprises a number of values that fully justify its protection. Groups or categories distinguished within the types of strict (full) and partial (non-full) nature reserves indicate usually only the main objective of the conservation. Here it should also be mentioned that surrounding reserves or national parks with a relevant protective zone is a requirement for their permanent protection. The fulfilment of this postulate is extremely important, in particular during the establishment of national parks.

The reserves of non-living nature constitute the group of natural areas with the weakest protection, thus they require urgent legal protection.

Despite the numerous opinions of our geologists (Professor J. Czarnocki, Professor S. Małkowski, Professor W. Goetl, and others), despite the exhaustive papers in the publication *Monuments of Non-Living Nature*, the volumes of *The Environmental Protection* and, *Let us Protect Polish Nature* and events organised by the Museum of Earth, valuable objects of non-living nature are to a large extent, or even almost completely, not legally considered as reserves. As industry is in rapid development, there is the most urgent need to protect important documents of the history of the Earth in the form of typical geological profiles, karst objects, caves, traces of volcanic phenomena, concentrations of erratic blocks, etc. For the benefit of science and society in general, we must establish reserves of non-living nature as soon as possible, mainly within the strip of old mountains, were these objects may be exterminated due to the small scale of the phenomena and very quickly progressing industrial works.

On the verge between the monuments of non-living nature and culture, sites of former mining works exist, such as Neolithic flint mines, old adits and traces of ancient metallurgy. They also should be protected, as they are fundamental for the history of the national culture.

Among the Polish natural resources, spring areas, running waters and standing waters are of key importance for economic, living and health purposes. Due to a continuous decrease in water resources, the dangerous consequences of drainage and, in connection with ever larger sections of the water network being dedicated to industrial purposes and which leads to their harmful contamination, greater attention should be paid to the protection of spring areas and waters. This issue of key importance often remains underestimated. An unreasonable attitude to these fundamental issues will burden the future. Unfortunately, spring areas and the upper sections of river courses are the rarest in reserve registers.

A network of water reserves must be developed very carefully by the best experts in this area, after due consideration of a number of questions, but quickly enough so that it is ensured before the implementation of great nationwide water management plans.

Waters belong to the group of very under-explored biotopes in Poland. A multi-annual research project should be started on a small number of selected lakes, which represent all possible limnologic types in Poland, by conducting serial analyses in order to describe them thoroughly, as well as to understand the basic processes of overgrowing and ageing of water reservoirs. Organisationally, such research might be based on hydrological and fishing stations. Apart from lakes classified as strict reserves, in similar partial reserves simultaneous research with mainly an economic focus should be conducted.

Only recently one has paid attention to the necessity and urgency of protection of natural spawning and wintering grounds of valuable fish, while securing as partial reserves those reservoirs or sections of running water that determine the condition of the fishing economy in entire drainage basins or in their parts. The determination of protective spawning grounds by the fishing authority constitutes a half measure that usually does not exclude the exploitation of some fish participating in spawning and does not prevent the catching of fish flowing down after spawning. So far merely single reserves for the conservation of spawning grounds of rare fish species exist in the Masurian Lake District and in the Wielkopolska region (at the mouth of the Wełna River to the Warta River), while they should be established on rivers in piedmont areas and in Pomerania, especially on the Drawa River.

In the current situation, lakes are protected almost exclusively as bird reserves, more seldom as flora reserves. Some fragments of old riverbeds with concentrations of relict plants such as water caltrop or water fern – *Salvinia*, are subject to protection. Relict lobelia lakes in the Pomerania and shallow water reservoirs with relict Atlantic flora located in the coastal zone of the Pomerania are particularly worthy of protection. Sometimes only landscape protection is applied to lakes.

Due to the maintenance of numerous relicts from the ice age, certain raised bogs, poor fens and, in exceptional cases, fens should be protected, as long as they constitute a refuge for rare northern forms or present dealpine meadows. There are relatively many peat bog reserves, in particular those designed, but they require a review from the position of the reasonable network of reserves. This network must consider all plant associations existing in the territory of Poland and the entire scale of diversity of peat bog types, as well as distinguishing objects to trace back specific stages of succession and regeneration. The so-called wild, unordered and unreasonable exploitation of peat bogs, which leaves extensive areas as complete wasteland after peat exploitation, must be definitely stopped.

On the areas covered by the operations of the newly created peat industry, areas remaining after peat cutting must be properly managed. It should be kept in mind that peat bogs located on watersheds constitute important water retention reservoirs, which should be protected for this reason, just like water protection forests. Special attention should be paid to this type of object in Wielkopolska, Lubusz Land [Ziemia Lubuska] and Pomerania.

So far the reserve network has also not properly covered salt pan communities, developed near the sea as halophilic communities and littoral vegetation of water reservoirs, permanent or temporary, and inland as the closest neighbourhood of karst springs or runoffs of salty springs, e.g. in Kujawy or near Busko and Stopnica. In Poland, these communities, although permanently becoming ever poorer in rare species of plants and animals, have yet to be researched sufficiently, in particularly no one has viewed them from such an interesting ecological view.

Patches of steppe and forest steppe vegetation, typically growing on the steep slopes of river valleys and dry limestone crags, in particular gypsum crags, are of an exceptionally relict nature in Poland. The recent years of detailed floristic and faunistic research in the crag area in the Nida Basin and in Miechów rendzinas have provided simply sensational results. It appears that a series of relict flora and fauna species, specific for the Pontic or Mediterranean areas, has remained there on northernmost, detached borderland sites. The number of steppe reserves is definitely insufficient. The current reserves do not reflect the entire richness of forms and typical grass, thicket and forest steppe communities. Among them, a few protected objects constitute partial reserves due to the necessity of performing maintenance, such as cutting down trees and shrubs casting much shade, which deteriorates the environmental conditions or even makes it impossible for light-loving and xerothermic steppe species to vegetate.

Floristic peculiarities are subject to conservation in separate floristic reserves or in other, water, peat bog, steppe or forest reserves, similarly to the dying forms of domestic fauna. To maintain them, the entire biocoenosis together with specific systems of environmental conditions needs protection. In this way, those sites of extremely interesting endemic species, i.e. species limited in their occurrence to certain geographical areas, as well as the last sites of rare and endangered species or borderland sites near or beyond their natural geographical range limits, as well as important phyto- or zoogeographical elements revealing the nature and history of flora and fauna are preserved for science and future generations. The scientific research conducted in these reserves shall undoubtedly improve the knowledge about the biology of protected forms. In order to maintain and reproduce native species of animals disappearing from Poland, we protect lairs, breeding sites of animals, and resting places of migrating birds.

Special reserves are dedicated for the regenerative breeding of dying-out animals: bison, elk and beaver.

The most numerous and most important group of reserves in Poland are the forest reserves. This area of environmental protection has been provided fairly with the greatest attention. The currently existing and planned forest reserves must be fully analysed in terms of maintaining a reasonable network, which must be conceptualised in the most comprehensive way, based on an extensive investigation by many experts from various areas.

Professor Adam Wodziczko, PhD, an indefatigable fighter for and pioneer of the modern concept of nature conservation, once said these words about forests:

'The forests constitute an inherent robe for our homeland, the most important component of the native, natural landscape. In the whole economy, nature is an irreplaceable factor, maintaining a balance for the successful development of the human economy. The moderate the odds of the climate are making our land rich and productive. They constitute the best barrier against destructive floods of mountain streams and rivers, they stabilise coastal dunes and drain swamps. They are a source of health for the body and soul, a priceless workshop for scientific research, without which modern societies cannot successfully develop (…). This research establishes a basis for rational forest economy, based on patterns from nature. The primeval forest is a prototype of beauty, a kind of eternal art museum inspiring poets and artists. Humanity will always return to this source of pristine beauty, each time when art wanders off course. The forest must be conserved, protected and tended, because the successful development of our life and our culture is associated with its existence.'

The multifunctional role of forests is fully valued in our Nature Conservation Act, as well as in further regulations and ordinances of the Minister of Forestry on forest management. Everywhere there, the care for the due protection of any blessings provided to us by forests can be observed. Let's hope that this will have practical consequences for the delimitation of protective forests and for the establishment of the forest reserve network (the analysis of existing or planned reserves requires some adjustment).

The following elements must be considered while developing the network of reserves:

1. examples of all forest communities in Poland within the entire scope of their diversity,
2. examples of all forest habitat types and subtypes in respective natural-forest regions,
3. fragments of primeval forests with refuges of old historical trees that should be particularly protected for many rightful reasons,
4. particularly valuable, isolated tree and shrub sites in borderland locations, out of their geographical range limits,
5. selected sites of native ecotypes and varieties of commercially valuable tree species, which require a long-term research projects,
6. model areas for tracing the natural succession in communities, which will shed light on the possibilities of its acceleration in managed areas, or respectively help to redirect it purposefully to other development paths.

Sometimes, all these motives for conservation can be applied at the regional level, even to the establishment of just one reserve, as in the Bukowa Forest near Szczecin, where the reserve covers both the differentiation of forest communities and habitat types specific for the Pomerania, as well as groups of monument trees, beech ecotype sites and an area for tracing the natural successions.

The network of forest reserves interpreted in this way shall enable the commencement of planned and long-term works on the individual forest typical species in their ecological aspect and generally on the entire forest biocenosis.

In addition, the forest economy must also have appropriate sample plots available where various types of research shall be conducted on, for example, a) the stages of regeneration of areas affected by natural disasters, b) the assimilation of alien tree species that can be usefully included in the forest economy, and c) the consequences of commercial and maintenance treatments in forest stands. These sample plots should, however, be treated separately, apart from the reserves.

The beauty of the natural landscape, the richness of the landforms and the characteristic elements of regional landscapes are protected from destruction by landscape reserves, referred to also as scenery reserves. These are partial reserves where human commercial treatments are subject only to some limitations, aimed at the maintenance of picturesqueness, mainly of specific landscape features. Their present network leaves much to be desired from the geographical and touristic standpoints.

The educational reserves present a separate group of conservation areas. Actually, every national park or reserve or nature moment performs an educational role and can be used for this purpose. However, it seems that if within a radius of 25 km from larger concentrations of schools and students there are no easily accessible reserves, they should be established. If we assume that in Poland towns with a population of more than 20,000 constitute such school centres and if we assess the location of the closest reserves, we will conclude that approx. 20 educational reserves should be considered in the general network of reserves. Their area does not have to be large, but they should illustrate the largest possible number of natural phenomena and concentrate natural monuments. The care of these reserves would be taken over voluntarily by young people or the management personnel of the educational centres. Undoubtedly, it will have high educational value and form appropriate attitudes to nature. In these suburban reserves, nature trails should be established and described, so that young people may get to know by themselves the lives of plants and animals in their natural environment. They will learn how to perceive an organism in close interdependence with the environment, observe the rhythms of the phenological stages, etc. This contact with nature shall waken high-minded emotions in youths, its attachment to the homeland and many aesthetic experiences and cognitive interests. The issue of establishing educational reserves in areas with no nature reserves existing in the neighbourhood should still be re-discussed.

As the review of reserves demonstrates, the conservation purposes and motives are very diverse. Now we have 88 legally assured reserves, with a total area of 17,200 ha. The number of planned reserves is estimated at 430 with a total area of 20,800 ha. When speaking about a rational network of reserves and the necessity of a repeated analysis thereof, I meant each time not only the scientific, but also the economic prerequisites. I have discussed the general needs with regard to the scope of supplementing the reserve network only indicatively. It is the task of nature parks to conserve and maintain for future generations the most beautiful and the most typical parts of the Polish landscape in, as much as possible, a primeval condition. Besides, the national parks constitute a work object for scientific research, approached more broadly than in the reserves. As areas usually clearly distinguished in physiographical terms, with usually typical features of a given region, also abound in a number of animal and plant peculiarities, sometimes connected with the history of human beings and the country – they represent a part of the homeland precious to the heart of every Pole.

That is why society acknowledged so happily and proudly the news about the conferring of legal status to the national parks in the Tatra Mountains, the Pieniny Mountains and on Babia Góra. Together with two formerly recognised parks in Białowieża and the Świętokrzyskie Mountains, we now have five recognised national parks in Poland, while still six more are planned: the Kampinos National Park, the Wielkopolska National Park near Poznań, the Ojców National Park, the Wolin National Park near Łeba and the Karkonosze National Park.

Each of them represents certain typical physiographical features of the country. In the coastal parks on Wolin and near the Łeba coast, sections with various landform configurations were put under protection – from a steep cliff to a wide sandy beach, then shifting dunes, tottering peat bogs and forests with beech, oak, pine and nests of white-tailed eagle, not mentioning other peculiarities of the plant and animal world. The mountain parks in the Tatra Mountains, on Babia Góra [Old Wives' or Witches' Mountain] and in the Pieniny Mountains protect the most precious jewels of domestic nature, which are constituted by the isolated group of Babia Góra and the famous all over Europe Dunajec River Gorge in the Pieniny Mountains. Primeval forests with bison, representative of the lowlands, are protected in the Białowieża National Park, while the Capital National Park in the former Kampinos Forest and the Wielkopolska National Park near Poznań shall be of slightly different character. The latter two parks represent perhaps lesser natural values, but the hygiene and social values are most important here. The establishment of these parks is less determined by primeval nature, as their close proximity to large urban areas such as Warsaw and Poznań has already transformed them long ago. However, the rich topographic texture, the abundance of standing and running waters and a number of peculiarities from the world of plants and animals have so far remained unchanged. A highly diversified rocky forest landscape will be protected by the Ojców National Park, which is famous for the accumulation of many rare plants and relict animals. The Świętokrzyski National Park with its Silver Fir Forest, lastingly associated with the name Stefan Żeromski, and specific stone runs, represents the landscape of old low mountains with an accumulation of mountain forms of flora and fauna.

Within all national parks there exist strict reserves, with which long-term scientific research has been associated. Unfortunately, due to the lack of permanent research positions and suitably qualified staff for the purposes of the parks, these studies are one-sided and often show no continuity. The research work in national parks should become comprehensive, with the larger participation of experts and based on long-term scientific plans.

Apart from the questions to be simultaneously solved in all national parks, each should feature research works focused on a special topic. Uniform work methods must be applied to enable the comparison of results.

Scientific collections need to be created at the museums which will undoubtedly be established at every national park. However, the main museum activity should be oriented towards the facilitation of visitors, allowing them to become familiar with natural phenomena and plants and animals in the territory of parks. National parks and maybe some reserves shall perform an important role in the education of young biologists and foresters through summer internships. Already experience has demonstrated that students' contact with the primary nature of the park and participation in field works under the direction of mature specialists, who simultaneously conduct lectures, arouses scientific interest, introduces the methodology of field research (especially ecological) and very much opens up the scientific horizons of students. Such internships may result in the formation staff properly educated for research in national parks. National parks in mountains, by the sea and in the lowland's primeval forests enable young naturalists to get to know typical Polish biotopes and characteristic flora and fauna, as well as the diversity of work methods and the specificity of questions related to particular National Parks.

National Parks, as paradigms of the natural functioning of the environment, deliver valuable guidelines for forest practice. Foresters in two lowland national parks, near Poznań and Warsaw and partially on Wolin Island, play a special role as the forest complexes there require habitat-compliant restitution.

The role of national parks is not limited to scientific research. Apart from strict reserves, partial reserves exist in the territory of parks, covering the greater part of the conserved area. They are enjoyed by a large number of working people, visiting for trips and leisure purposes. Specially trained guides should give tours, drawing the participants' attention to natural and landscape peculiarities of the area. In this way, together with information provided while visiting the museums in the national parks, society will expand and improve its knowledge about nature, which will undoubtedly affect its proper attitude to the homeland's natural resources.

Recently, a number of legal acts and regulations concerning the establishment of national parks and reserves have been issued. In addition, there was an announcement about establishing protective forests and an initiative to develop a network of reserves for the whole of Poland. All these actions provide us with the right hope that the questions of nature conservation are entering a new stage. One may assume that the existence of legally recognised National Parks and reserves shall facilitate the fulfilment of the laudable foresters' obligation to protect the native nature for the country's benefit and future generations.

Paper abstracts

Professor A. Dehnel, PhD:

Specificity of the research on the Białowieża National Park within the nationwide network of national parks and nature reserves

As a preliminary remark, Professor Dehnel has pointed out that he developed his paper mainly from the point of view of his specialisation, i.e. the anatomy of small mammals, and he has emphasised therein mainly two issues: the specificity and the conditions of the research in the Białowieża National Park.

In his opinion, the conditions created by the Białowieża National Park constitute one of its most important and greatest specificities, while further strict protection of this exceptionally valuable site is necessary.

The Białowieża National Park consists of a forest complex, the size of which is extensive in European terms, preserved in a condition close to natural. It is also the only area of its kind where numerous studies have been carried out on a European lowland forest. The important feature of the Białowieża National Park is the almost 40-year long continuous series of research works, mainly on the regeneration of the forest environment and its succession.

However, that the conditions here are average and typical is a great advantage of the Białowieża National Park. Here one may find typically represented forest communities and plant species mainly characteristic of the Polish lowland, in particular for its northeast part. In addition, almost all mammal species typical for the European lowland can be found here. Some animal species discovered for the first time in the park, such as the shrew (*Sorex macropigmeus*) or little birch mouse (*Sicista betulina*), are present also beyond the Białowieża Forest, albeit in much smaller numbers.

The existence of the Białowieża National Park allows not only the identification of the presence of rare species, but most importantly – the exploration of them and their biology and forms in specific natural environments, in an appropriately large area. The last mentioned basic condition is inevitable to adjudicate a number of significant and interesting scientific questions. The occurrence of similar and distorted plant communities in close proximity to the Białowieża National Park, in the managed part of the forest, allows the undertaking of interesting comparative research, which is of huge scientific and economic significance.

The exceptional scientific values of the Białowieża National Park are demonstrated partly by the fact that the material (small mammals) collected on small experimental plots, which together cover an area of 25 ares, often exceeds in terms of quality and quantity everything gathered in the scientific collections of European or maybe even global centres. The Białowieża collection has a huge advantage over other foreign collections in that it covers materials from all months of the year, thus allowing for the thorough study of the variability of collected species. In this way, it has been possible to identify the phenomenon of seasonal variability in the skulls of individuals of the same species. This discovery is of huge importance, not only for systematics, but also for research into such diseases as rickets, osteoporosis, etc. A significant number of small mammals caught during the last eight years (approx. 25,000) does not decrease their total number and allows further intensive research. The richness in fauna in the Białowieża National Park is amazing and, in many ways, not seen elsewhere in Poland.

During the nine years of continuous research, never has the phenomenon of a mass appearance of small mammals or a rapid decrease in their number been observed in the Białowieża National Park. Previous observations indicate that small mammals, thanks to their availability, have played an important role as food for predators, e.g. lynx. This fact explains why a large number of deer-type game was sustained despite a simultaneously existing and relatively significant population of predators. These phenomena confirm the view that such exceptionally convenient conditions for development, in particular of small mammals, were principally able to develop in the Białowieża National Park due to the strict protection of its entire area.

The Białowieża Park now provides the best (compared to other national parks) conditions for conducting environmental research due to its accessibility (railway station), appropriate accommodation premises, possibility of board, existence of relatively well-equipped scientific institutions and systematic, long-term meteorological observations. The scientific work conducted in the Białowieża National Park is of huge value and contributes to an even larger increase in the importance of Polish science abroad.

Then the lecturer briefly discussed the history of establishing, developing and the scope of the activities of the Mammal Research Department of the Polish Academy of Sciences in Białowieża. At the end of his speech, Professor Dehnel called on the people assembled to adopt a resolution on the reconstruction of the ruined palace. In this way additional premises for new scientific units could be obtained and the accommodation difficulties of already existing ones could be solved.

Associate Professor T. Trampler, PhD:

The importance of the Białowieża National Park for forestry

At the beginning of his paper, Associate Professor Trampler emphasised the huge significance of national parks and reserves in the socialist system for the scientific, economic and cultural development of society. Then the speaker described the role performed by the Białowieża National Park for forestry.

'Foresters' interest in the Białowieża Forest as a research object dates from the beginning of this century.' After a period of introduction of single-species tree stands, having an adverse impact on the productivity of habitats and the resistance of these tree stands to natural disasters, the foresters started to look for paradigms in natural forests and came to see the primeval forest as an ideal to be blindly followed. 'Only a few progressive foresters, with Jedliński among them, indicated the possibility of modifying the tree species composition depending on economic need. The research conducted by Paczoski and Karpiński in the Białowieża National Park helped to prove that modern concept.' Paczoski, while observing processes in the Białowieża Forest, developed the theory of 'dynamic sustainability' for forest complexes. That theory debunked the mistaken theory of 'static sustainability'.

In the area of the Białowieża National Park, the first theories of classification of forest communities were also established. The basis for Paczoski's phytosociological classification was the vegetation, mainly the tree species composition of stands. According to Paczoski, the vegetation constituted an external manifestation of the relations between plants and between vegetation and the environment. On that basis, Paczoski distinguished 58 types of forest community in the Białowieża Forest.

In opposition to that concept, Karpiński adopts as the typological unit the 'type of biocenosis, type of forest whose leading element is not a tree stand, but a biotope (environment), as an expression of the comprehensive impacts of all those factors that together determine the productivity and define the general direction of ecological succession'. On that basis, 'Karpiński distinguished in the Białowieża Forest the biocenoses of seven forest types: pine forest, coniferous forest, mixed coniferous forest, deciduous bog forest, deciduous forest, mixed deciduous forest, and alder carr'. 'Karpiński's concept, developed as a result of the analysis of natural forest communities of the Białowieża National Park, established a theoretical basis for the modern typological classification of Central European forests. The typological classification of forest habitats developed by Mroczkiewicz basically draws on the scientific basis of Karpiński's biotopes.'

The research conducted by Karpiński in the Białowieża National Park on avifauna, arachnids, ants, etc. also sheds light on the problem of the biological fight with pests and is of huge practical significance. However, Trampler emphasises that although scientific studies conducted in the Białowieża National Park do not provide forestry with any ready-to-use recipes, they are of key significance for the development of natural foundations of forest economics. Identifying some of the regularities in biological processes of the Białowieża Forests allows an understanding of the laws that exist and apply also to managed forests.

Finally, the speaker expressed his opinion that for foresters the Białowieża National Park forests have constituted not only a valuable object of scientific research, but also an educational facility, which should be used more rationally, especially within the scope of staff training.

St. Graniczny, PhD:

The scope and directions of the former research within the area of the Białowieża National Park

Firstly, Graniczny pointed out that 'research in the Białowieża Forest, and in particular in the area of the strict reserve – the Białowieża National Park – encompasses very extensive branches of science. The research activity is expressed not only in a strictly scientific or popular scientific bibliography, but often also in the form of documentation, reports, manuscripts and decisions made on conventions and conferences…'

The speaker distinguished three periods in the historical development of research in the Białowieża area:

first period – up to the end of 1928, i.e. to the date of establishment of the strict reserve called the State Forest District Reserve;

second period – 1929–1943;

third period – since 1944, i.e. since the beginning of research in the People's Republic of Poland to the present day.

Graniczny expressed his view that 'the picture of the research activity and permanent interest of society in the forest and in the Białowieża National Park may be obtained by reviewing the Białowieża bibliography'.

List of publications concerning the Białowieża Forest

Periods	General and historical issues	Zoological papers	Botanical papers	Hunting issues	Forest protection	Silviculture	Forest management planning	Total no. of publications
I	103	80	30	7	5	2	2	229
II	110	87	12	18	6	1	1	234
III	46	59	17	3	8	1	2	136
Total	259	226	59	28	19	4	5	600

The bibliographical review shows that the direction of interest in the forest changed gradually. The focal point moved slowly from literary publications to scientific papers, the share of which in the first period was 30%, in the second period to 40%, and in the third period to 60%.

Zoological papers, particularly in the first and second periods, were dominated by papers dedicated to the bison, elk and tarpan, mainly due to their breeding in the wild conducted in reserves within the park.

In the first period, the individual activities of scientists of various nationalities, mainly historians, botanists, zoologists and partially foresters, prevailed.

The second period was characterised mainly by an increased amount of research and a significant number of papers popularising the forest. The following objects were established in that period: the Primeval Forest Museum with Paczoski's valuable botanical collections and Zawadzki's and Karpiński's zoological collections and in 1932 (pursuant to the regulation of the Minister of Agriculture and Agrarian Reforms) the special organisational unit named 'National Park in Białowieża'. The establishment and launch in 1938 of the first under-canopy multistorey meteorological station was a great achievement of that period.

The third period, despite serious damage to the Białowieża National Park during World War II, meant the beginning of a series of intensive research studies in the Białowieża Forest. A new system of social relations and the strong attention of the Government of the People's Republic of Poland established a basis for long-term work through the establishment of the Białowieża National Park in 1947, the funding of scientific research, the provision of technical equipment and staff training. In this period, research in the Białowieża National Park is usually conducted collectively with more and more scientific institutions beginning field work here. The well-equipped, publicly accessible, local library and its rich collections are a great help in research work. In the last period, Białowieża has also become a venue for numerous conventions and scientific conferences.

Finally, Graniczny emphasised the great practical benefits that were achieved thanks to research conducted in the Białowieża National Park, in particular in the area of silviculture (forest [habitat] typology, structure and dynamics of development of forest communities, renewal methods), pedology (classification and nomenclature of soils), forest protection (biological pest control), climatology, ecology, botany, zoology, microbiology and other branches of science, and above all within the scope of training of new staff comprising young biologists.

Against the background of the general review of the scope and directions of previous research work, the role and significance of the Białowieża National Park for science and practice are becoming understandable for everybody, while the need to preserve the entire park as a strict reserve is beyond doubt.

Associate Professor Z. Obmiński:

A concept for the organisation and scope of forest and nature related research in national parks and nature reserves

At the beginning of his paper, Associate Professor Obmiński pointed out that the 'issue of research organisation in our national parks and nature reserves is closely related to the issue of the role that should be performed by these objects in the development of science and the national economy. There is no doubt that improvement in our natural sciences, thus progress in the area of the planned management of natural resources, depends to a large extent on the rational use of parks and reserves for research purposes.' Therefore, the necessity of conducting complex collective research with the participation of experts from various branches of science is faced by all sciences, in particular the natural sciences. The most important of the numerous problems are the questions of forest economics within the scope of forest [habitat] typology, silviculture, forest protection and use and others, which require an increasingly complete environmental foundation.

Our natural-forest research begun by Rivoli, Jedliński, Paczoski, Karpiński, Sokołowski, Niedziałkowski and others is insufficient in comparison to the accomplishments of other countries and our current needs. Therefore, we should make strong efforts to make quick and rational changes, especially in the most important and the most neglected sections of research work.

According to Associate Professor Obmiński, the field basis for research work should be mainly constituted by our network of national parks and reserves, as these objects, due to the appropriate protection of the natural system of natural-forest conditions, are an exceptionally valuable resource, in particular for long-term research.' The nature reserve network comprising all of our natural forest regions requires an appropriate location for the research work and reveals wide-ranging general and regional issues. However, national parks and reserves require proper adjustment to make research work possible. They should include, above all, detailed inventories, the establishment of properly equipped meteorological stations and properly equipped field laboratories.

Objectives should be pursued in stages. Initially, a start-up network should be organised, represented by objects with conditions typical for our most characteristic natural forest regions. In the next steps, this network should be gradually extended and supplemented. During the first stage, also the planned natural parks and nature reserves, which will constitute a kind of back-up area, should be properly protected and made available for works that do not require any special preparation of the area.

According to Associate Professor Obmiński, the initial basis might be created by two mountain parks (Babia Góra National Park and Tatra National Park) and three lowland parks (Białowieża National Park, Wielkopolska National Park, Kampinos National Park), together with a regional network of relevant nature reserves. The speaker emphasises 'that research work outside the parks and nature reserves must be continued, e.g. because many current issues of direct significance for forest practice may be solved only based on appropriate research in forests where normal commercial treatment is conducted' and due to the necessity of comparing research in reserve forests and normally managed forests.

The research subject should follow from a detailed analysis of the condition and needs of forest science on the general and regional levels. The overall research objective 'should be to thoroughly investigate forest nature under physiographic condition systems typical for our country and to explain objective laws concerning both the nature of interdependence between the components and the specificity of the processes of its development.'

According to Associate Professor Obmiński, with such an approach to the assigned tasks, a prospective plan for the research in our national parks and reserves should include the following:

1) Physiographic forest research constituting the general environmental foundation for detailed floristic, faunistic, pedological, climatological, hydrological or similar research;
2) Typological-comparative research oriented towards an isolation of regional forest types present in Poland and a better understanding of their features;
3) Research on the ecology of forest communities within particular forest types, having regard to the genetic relationship between these communities;
4) Comparative research on the impact of forests and other plant formations on local climatic-hydrological and edaphic conditions;
5) Research on the biology and especially on the ecology of plant and animal components of forest biocenoses under conditions not formed by human economy.

All the research directions mentioned are strictly related to each other and, since they are equivalent, provide us altogether with a perspective to explain the essence of many natural phenomena, on which the theoretical underpinning of the principles of rational forest economy broadly depends.'

'The scientific research programme, apart from problems resulting from the current needs of economy, should also include issues that go beyond the present interests of practice, but which are deserving of attention due to their theoretical significance, for example. In the research issues related to our national park and reserves, such problems include mainly the questions of the biology of protected plants and animals, as peculiarities of the natural environment in Poland, and issues of the biology of newly discovered species and species generally little-known to science.'

According to the speaker, appropriate coordination of the work is needed in order to carry out the planned collective research with the largest possible benefit for science. Associate Professor Obmiński regards the Polish Academy of Sciences as an institution best suited for this purpose.

At the end of his paper, the speaker expressed his opinion that 'with a programme and organisational assumptions thus designed, our national parks and reserves should over time become an active centre for field research work, ensuring the permanent intensive development of forest and environmental sciences, and simultaneously strengthening the forest economy in the country with an effective weapon to fight for the most efficient implementation of its production plans.'

Ryszard Zaręba

Traces of human activity in the stands of the Białowieża National Park

The Białowieża National Park was selected and established from among the least destroyed parts of the Białowieża Forest. Białowieża Forest was too large (approx. 1,250 km^2) to be entirely put under conservation without detriment to the national economy. As it constituted one of the largest forest complexes in the Central European lowland, with natural habitats and stands similar to the primeval ones, our task was to conduct the forest management in a way allowing to maintain this condition for the future. This task was not easy and was impossible to be performed with use of common methods of forest management, through constant shortage of funds for appropriate renewing and maintenance methods, and mainly because of the lack of developed, concrete management methods and of an appropriate professional level of the forest staff entrusted with the field work.

Solid pine stands established artificially on clear cut areas not only in coniferous habitats, but also in mixed and deciduous forest habitats gradually blur the primeval nature of this forest complex, becoming similar to the average appearance of our managed forests in the lowlands generally. In consequence of the irreversible changes ensued in habitats and stands due to such forest management methods, the necessity arouse to establish a protected area that could represent the appearance of truly primeval stands, not only of the Białowieża Forest itself but also of the entire lowland of Poland and – without exaggeration – of the Central Europe.

The Białowieża National Park, as a unique forest research object, where natural processes occurring in forest biocenosis may be observed, has already passed its exam during its short existence. The sense of its selection and its value do not require any justification, it is enough to point at the scientific studies carried out, as proof thereof.

At the beginning of the description of the distorting impact of the forest economy in the Białowieża National Park, I would like to make the reservation that I do not intend to diminish its value. I would only like to present some data from former eras of forest economy and its consequences manifested in the current status of the stands. I suppose that these data will be needed for the further management of the park's nature reserve, in particular for the establishment of research areas.

It was impossible to select from the entire forest such a huge area (4,675 ha) as is covered by the park, and to avoid at same time that certain areas with traces of forest economy are included. The recently conducted nature and forest inventory has delivered a significant amount of materials concerning clear and selective cutting in the park; however, more accurate data should be obtained when the inventory is revised. In the future, not only should clear traces of clear and selective cutting of stands be considered, but also former burnt areas and the contamination of stands after the logging of certain tree species, after fires or as a result of grazing (3).

The skill in the accurate recognition of the kind of contaminated stands and solving a series of other forest economy and management planning-related problems is not too easily acquired, so the future inventory works should not be based on the organisation of student groups for field work, but on the creation of a group of experts in the field of development of national parks and reserves.

It should be emphasised that forest regeneration on clear-cut areas in all cases occurred naturally – by natural seeding. Planting or seeding was not performed on any clear-cut areas, only on pasture glades were alien tree and shrub species introduced, the soil was ploughed, and fodder plants were grown.

In the pre-Partition period, the forest was never intensively exploited. It was used for extensive royal hunts, while the stands were used by the plundering method, only in the vicinity of navigable waterways and rivers, where more beautiful mast pines, oak or construction material and firewood of other tree species were selected. In that time, the *budnicy* [colliers] produced tar, wood tar, and potash, while beekeepers managed wild beehives. Meadows were mowed. Temporary crop production was often practiced on the so-called *wchody*,[1] usually located at the forest edges. They consisted mainly in farming on cleared forest areas, which were left after some time to once again become forested.

One encounters all these traces of use of the primeval forest, while in the territory of the park, traces of a former settlement by the Orłówka River may be found in compartment 314 sub-compartment 18 in the Orłów Stok wilderness. Although an old stand of the deciduous forest type has grown here, small traces of once ploughed beds and occasionally even a brick can be found. Still nearby is a place not overgrown with a stand, featuring only nitrophilous herbaceous perennial plants, with dominant raspberry and nettle. This is a former charcoal pile, meaning that this was most likely a small settlement of *budnicy* from the 18th century. Another trace of a charcoal pile can be seen in compartment 343 sub-compartment 14.

When **Antoni Tyzenhaus**, Treasurer of Lithuania, managed that land (in 1780), the Narewka River was engineered. The embankments which were raised in that period can be seen by the Narewka River at the western border of the park. While straightening the riverbed, a number of bights were left, which are now at the stage of overgrowing or have

[1] Cleared forest area, used temporarily for farming and then turned into forest again [translator's note].

been entirely overgrown with meadow vegetation, depending on the former depth of the riverbed.

In the same period, a *binduga*[2] was built by the Narewka River between compartments 369 and 398, from where the timber was floated down the Narewka River to the Narew River.

Opposite these same compartments (369, 398) lies the village of Pogorzelce, the population of which comprised of *budnicy* who burned forests in the nearby wildernesses. The name of the Paharelec wilderness, located in compartment 398, attests to the fact that initially a *budnicy* settlement was located there, which was then moved to its current site on the other side of the Narewka River. *Budnicy* and the established *binduga* probably affected the logging of stands in these parts of the park. Clear traces of selective cutting can be seen in compartment 398 near the Jagiełło Oak and in compartment 369 on both sides of the 'palace road', especially by the 'tourist walkway'. In compartment 398, in a deciduous forest community, there can be seen an excessively large admixture of birch, and even of pine, which happens extremely rarely, while in compartment 369, an almost solid spruce forest (pseudo *Piceetum Karp*.) occurred in a mixed coniferous forest habitat and is currently in the final stage of stem exclusion.

In the Białowieża glade, in an inventory dated 1696, a 25-morgen centre was listed, which only 100 years later was surrounded with other settlements, achieving its current area of approx. 2,000 ha. In the normal course of events, the compartments located at the edge of the glade were usually felled for firewood and construction material, but mainly they were used for livestock grazing.

At the source of the Jelanka (Orłówka) River, there are still such wilderness names as Wielka Kletnia (Wielkie Kletno – compartments 374, 375) and Małe Kletno (compartment 402). Here there was the first menagerie in the forest, established during the reign of King Stefan Bathory. At the time of Augustus III, the former menagerie was renewed and extended and received the name Augustus Orchard. For the hunting organised on 31 August 1784, during the reign of King Stanisław August, a two-storey pavilion (2) was erected in the Augustus Orchard for the king's arrival. Currently, there are no traces of the menagerie and the pavilion no longer exists, but it would make sense to search to see if more detailed evidences could be found somewhere.

The Russian historian of the Białowieża Forest, **Karcew,** indicates that 'gratitude should be owed to the Polish kings for their care of the forest and its animal population'. Unfortunately, the same cannot be said of the Russian management of the forest and the short but extremely damaging management by the Germans during World War I.

[2] Timber yard located on the bank of a river or waterway, where logs brought from the forest were stored and prepared for water transport i.e. driving or rafting [translator's note].

The largest distortion of the primary nature of stands took place during the period of the Russian Partition. The then National Park covered the Browsk Forest Subdistrict, from which trees were removed for ship building (oak, ash, pine for masts and faulty ones), and broken trees, woody debris and snag were removed. In that time, the grazing by livestock was officially permitted by the authorities in compartments 398, 399, 400, 401, 402, 370, and 371. Initially, that economy did not harm the stands in the forest and only when the Białowieża Forest became the possession of the tsarist court (in 1888) did the period of disasters began.

Despite the ban on any felling, the game management was developed to an astonishing degree, senselessly turning the forest into one large menagerie. The accumulation of a huge number of herbivorous game resulted in the impoverishment of the bottom strata and the undergrowth, as well as the herbaceous vegetation, which made natural regeneration impossible for several decades.

This abnormal condition extremely strongly affected the structure of the forest stands, where almost no intermediate age classes can be found between the strongly infected by fungi, old-growth storey in the stem exclusion process, and the second-growth forest. Only after World War I, when almost all game was killed by the occupying German army and the massacre was finished by local poachers, did the lush layers of undergrowth and second-growth forest begin to be replenished. Apart from animals completely consuming the bottom stand layers, they also directly harmed the older stands by bark gnawing (bison), bark stripping and rubbing (red deer). These marks are particularly noticeable in spruce forests, which in some parts are strongly injured and covered with tumours and resin leaks. Nowadays, red deer and roe deer also cause damage by bark stripping of deciduous second-growth, in particular of linden, ash, and of the young pines, but this kind of damage is incomparably less than formerly.

The most apparent and difficult to be erased traces of the former game management are visible in the form of large pasture glades for game. Formerly, these glades were fenced. Currently, in some parts they are covered with brushwood with loosely scattered old trees, birch stands and various meadow synanthropic communities, untypical for the forest. Trees and common for deciduous forest herbaceous vegetation regenerates with great difficulty. Probably this may be explained with the fact that as a result of over a dozen years of long-term root crop cultivation, with deeper ploughing and a reversal of soil layers, a turf creation process began in the soil. For a very long time, this process has been making the forest regeneration impossible, in spite of apparently most beneficial conditions for sowing from the surrounding stands, on soil often rooted up by boars.

On these glades, in the form of regular rectangles, there still can be found traces of the structures made from thick scorched pine poles more than 2 m high, with densely nailed transverse perches. There were the so-called *oborogi*, i.e. roofed hayracks supported on four piles, with rungs behind on which the hay was placed. There were also cellars built for storage of root crops, deer licks and shooting stands for game watching. Traces of these constructions can still be found in the glades.

The pasture glades were cut out in the richest deciduous forest habitats, whereby old oaks that provided food for game while fruiting were left. Usually, linden trees were also left.

Within the park are three large glades:

Łagiery	– subcompartment 370.11	13.02 ha
Kobyła	– subcompartments 315.8 and 12	11.44 ha
	– subcompartment 257.2	7.39 ha
Łuki	– subcompartment 256.25	

The glade in compartment 370, in the Łagiery wilderness, is the closest one. Many apple trees were planted and still survive, bearing small and sour fruit. It is overgrown mainly with raspberry, with numerous circles of linden root suckers around fallen, old, moss-grown stumps of the parent trees. In some places there are birch sapling groves with grass vegetation underneath. One huge oak – a seed-tree, has a diameter at breast height exceeding 180 cm.

The forest glade in the Kobyła wilderness is regenerating relatively better than in the previously mentioned place. There are groups of saplings with a prevailing share of birch, aspen or goat willow, with undergrowth composed of plants typical for deciduous forest habitats. In some parts, there are small ‘naked' glades, with grass and meadow vegetation. The glade was planted out with various willow species and grey alder (*Alnus incana* Moench.). Here and there, groves of saplings of grey alder may be found, or even sporadically horse chestnut (*Aesculus hippocastanum* L.) and jasmine (*Philadelphus coronarius* L.). This glade was cleared in 1909.

The Łuki glade is located on the border of compartment 256/257. Traces of fencing and the former feeding rack were poorly maintained. Here and there it is grown over with birch wood with scattered sites of meadow vegetation. Traces of ploughed beds are clearly visible there.

Small glades, in which game feeders were placed, are located in compartment 255, sub-compartment 42 (overgrown with extremely lush bracken), in compartment 318, sub-compartment 16; in compartment 297, sub-compartment 47 and in compartment 317, sub-compartment 4, named Niedźwiedziówka, where a guardhouse was constructed in 1929 near the cages with bears in connection with an action to return bears to the forest. Today, only a wall base made of concrete and bricks exists as a reminder.

Despite the orientation of forest economy only towards hunting in the times of the Russian Partition, clear cuts in the forest stands were made in order to increase the forest's pasture acreage. Strip cutting was conducted on fertile deciduous forest habitats.

Based on the notes of Jurgenson, a long-time forest district manager in the forest, Paczoski quotes that in compartment 372 some clear cuts were made in 1910 and 1912. In the period of Paczoski's research, on the clear cut from 1910 the following seed trees were growing: oaks, maples, one ash, scattered on the clear-cut area overgrown with young dense birch wood. Among the birch groves were blanks with meadow vegetation located, here and there weeds and raspberry. On the banks were single willows and small groups of second growth hornbeam and birch, with a small admixture of aspen. Since the time of the Paczoski's description, almost nothing has changed and the regenerations on the former clear cuts are everywhere uniformly composed of pioneer tree species. The other total clear cuts in deciduous forest communities were carried out in compartments 370, 345, 285.

Some dates of clear or selective cutting of stands are known, e.g. compartment 401 – intense felling took place in most parts of the compartment. About half of the stand was felled. Medium size hornbeams, old spruce, linden, rarely oak were left. This selective cutting was conducted at the same time as the neighbouring stripes in compartment 372 were cut;

compartment 345 – a clear cut area of 1908 exists there. Its width is 100 fathoms (i.e. 213 m), the birch coverage slightly larger than in compartment 372;

compartment 370 – a narrow clear cut area of 20 fathoms (42.6 m) width, dated 1898, exists there; it branches off from the pasture glade to the east to the compartment line;

compartment 285 – in several places clear cut areas dated 1910; here and there birch sapling stands, in terrain depressions going over into alder ones; on the stripe many huge oaks left on the clear cut area; many second-growth linden, partially originating from root suckers, together with second-growth hornbeam;

compartment 346 – a clear-cut area connected with a clear-cut in compartment 345 dated 1908 overgrown with birchwood; oak residual trees, single maple and hornbeam were left there;

compartment 402 – post-German clear-cuts from the period of World War I.

In some compartments of the park, small selective cutting areas can be found, which have their origin in the removal of a few up to over a dozen of trees, traces of which remained in form of stumps. The stumps are usually located near the roads or in compartments adjacent to the Białowieża glade or located close to it. Pine in coniferous forest habitats was particularly strongly subjected to selective cutting in the entire park area. The large number of left pine stumps results the most probably not only from a number of cut specimens, but also from their longevity. Stumps of other species usually decay earlier and disappear.

In the Białowieża National Park, in the beginning of its existence, until 1929, snag, broken and fallen trees were prepared as firewood and partially for timber. In the entire park, firewood piles formed in that time and not logged can be still found, decaying, overgrown with herbaceous vegetation, even with small trees grown on the top. Since the beginning of the tenure of Professor J. J. Karpiński, any utilisation in the park has been stopped.

Traces of strong selective and clear cuts and other destructive factors generated by human activities in the territory of the Białowieża National Park

Compartment / sub-compartment	Clear cut or strong selective cutting	Traces of stumps of felled trees	Pasture glades	Traces of former roads	Piles of firewood	Fires	Ditches	Remarks
224/52		+						
53		+						
57				+				
58				+				
254/ 9		+						
28								bunker
41				+				
255/31						+		
36		+						
41		+						
42			+					
47		+						
48		+						
56		+						
58				+				
256/25			+					
257/ 2			+					
284/ 6		+						
28		+						
285/15	+							
17		+						
18		+						
25		+						
34	+							
40	+							
42		+						
286/ 4					+			
17	+	+						
19	+							
29	+							
39	+							

Compartment / sub-compartment	Clear cut or strong selective cutting	Traces of stumps of felled trees	Pasture glades	Traces of former roads	Piles of firewood	Fires	Ditches	Remarks
40	+							
44	+							
287/20		+						
34		+						
35				+				
36		+						
47			+					
49		+						
53						+		
54						+		
56						+		
288/28		+						
34	+							
289/48	+							
314/ 2					+			
14					+			
13								settlement
19							+	
315/ 3					+			
4		+			+			
8			+					
12			+					
317/ 4			+					
8				+				
18				+				
318/10	+							
12	+							
16			+					
17		+						
319/ 1		+						
2				+				
12					+			
340/ 7		+						
9		+						

Compartment / sub-compartment	Clear cut or strong selective cutting	Traces of stumps of felled trees	Pasture glades	Traces of former roads	Piles of firewood	Fires	Ditches	Remarks
10		+						
341/ 6				+				
7				+				
8				+				
18	+							
22				+				
30				+				
31		+						
343/ 7	+							
14								remnants of charcoal
344/ 8				+				
22		+						
24		+						
245/11	+							
9	+							
10	+							
11	+							
12	+							
370/11			+					
17	+							
23							+	
24							+	
25							+	
26		+						
371/ 8	+							
13		+						
372/ 8	+							
12	+							
16	+							
17	+							
22				+				
23					+			
27	+							

Compartment / sub-compartment	Clear cut or strong selective cutting	Traces of stumps of felled trees	Pasture glades	Traces of former roads	Piles of firewood	Fires	Ditches	Remarks
28	+							
29	+							
33	+							
34	+							
35	+							
36	+							
37	+							
38	+							
39	+							
376/ 9				+				
23				+				
24				+				
31	+							
34		+						
38		+						
374/22		+						
23		+						
35		+						
36	+							
39		+						
42		+						
398/ 5	+							v. old
9							+	
32	+							v. old
400/ 1				+				
5		+						
8		+						
9		+						
10		+						
13		+						
15		+						
401/ 6	+							
7	+							
8		+						

Compartment / sub-compartment	Clear cut or strong selective cutting	Traces of stumps of felled trees	Pasture glades	Traces of former roads	Piles of firewood	Fires	Ditches	Remarks
11		+						
15	+							
17	+							
22		+						
24		+						
402/ 2				+				
6		+						
8		+						
10	+							
12	+							
14		+		+				
15				+				
16	+							
20	+							
21	+							

In that time, the use of some hunting and logging roads and paths ceased. These roads are now grown into the forest, but drainage ditches, collapsed wooden bridges and undestroyed road crowns are still noticeable. The view of these unkempt roads is quite incredible and impresses everyone who observes how the lush primary forest nature encroaches upon the deeds of human hands. Traces of paths that were poorly marked in the terrain are almost completely blurred and only with the help of a map and the trained eye of a forester may their search be attempted.

Not many drainage ditches were dug in the park, primarily in compartments near the Białowieża glade or along roads (they drained water from them).

During the last World War, in the occupation period, embezzlements took place in the park, but usually these incidents happened sporadically over its entire area and concerned single trees, so they can hardly be noticed.

In the past, fires occurred constantly in the forest. The largest ones known happened in 1811 and 1831. Usually, they broke out in coniferous forest habitats in pine and spruce stands, where it was relatively the driest and the potential for a fire outbreak among resinous species of coniferous trees was the highest. In the Białowieża National Park, fresh coniferous forests are poorly represented, so the stands are not at a too high exposure to fire. Despite that, traces of fires that happened in the past and nowadays can still be noticed. Older fire traces may be found in compartments with coniferous forest habitats in the northern part of the park. They should be inventoried more carefully at the next forest management planning or researched as a separate issue related to the development of coniferous stands.

The latest fires broke out in 1946 in compartment 255 sub-compartment 31, and in 1953 in compartment 287 sub-compartments 53–54. In both compartments they were ground fires, covering mainly the ground layer and the undergrowth, not damaging the main stand.

During the environmental-forest inventory, observations and notes were taken in sub-compartments with stands touched by selective cutting, but very briefly and not in all compartments. However, plenty of material was collected that should be considered basic for future more detailed observations. A table (p. 14, 15, 16, and 17) and a map (flyleaf) have been prepared from data obtained in the current inventory.

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1st Scientific Session of the Forest Sciences Committee of the Polish Academy of Sciences on the regeneration of the Białowieża Forest

15–18 October 1958, Białowieża

The session was opened by Professor **Leon Mroczkiewicz**, PhD, Vice-President of the Forest Sciences Committee of the Polish Academy of Sciences,[1] welcoming the guests, particularly the representatives of the central and local authorities. Then he read the telegrams and letters with wishes for fruitful discussions received from Professor **Szafer**, Professor **Krzysik**, Professor **Suchecki** and **Więcko**, PhD.

The following people were appointed to the session presidium: Professor **Tadeusz Włoczewski**, PhD, Professor **Jan Jerzy Karpiński**, PhD, and Associate Professor **Maksymilian Kreutzinger**. Professor **J. J. Karpiński** was appointed as the chairman of the Requests Committee, while the following were appointed as its members: Professor **Edward Chodzicki**, PhD, Professor **Witold Koehler**, PhD, Associate Professor **Zygmunt Obmiński**, and director **Reindl**. Then Professor **Karpiński** and Professor **Włoczewski** delivered their lectures.

In his lecture titled 'The significance of the Białowieża Forest for science, culture and the national economy', Professor **Karpiński** described the role performed by the Białowieża Forest in the development of natural sciences, in particular forestry. The author describes the huge academic achievement in the field of zoology, botany and phytopathology, and recently forest ecology, origins of which trace back to 1523, i.e. the time of publication of the work by **Hussovianus** on the bison.

While discussing the economic significance of the forest, the author states that the first larger commercial felling started in the second half of the seventeenth century and since that time the forest has been continuously utilised, while the economy in the period of Partitions and huge forest fires in 1807 and 1811–1812 caused great damage to the stands. Adding to this the German management in the years 1915–1919 and The Century[2]

[1] Currently, Professor **Leon Mroczkiewicz**, PhD, is the president of the Forest Sciences Committee of the Polish Academy of Sciences.

[2] In the period 1929–1934, on the base of a concession, The Century European Timber Corporation carried out massive clear-cuts (approx. 2.5 million m^3 of timber was logged within the given period) in the Białowieża Forest, which led to the devastation of its large areas [translator's note].

corporation in the years 1923–1929 and the overexploitation in the recent period, it should be stated that the economic condition of the forest is unsatisfactory. The growing stock of merchantable timber per ha has decreased significantly, recently amounting to 189 m^3 according to the 1950 inventory data, while the optimum stock under primeval forest conditions should be approx. 400 m^3 per ha. This state of affairs requires necessary improvement, as restoration of all positive values to the Białowieża Forest, providing it with the features of a forest being close to a primeval one, lies in the interest of Polish forestry.

Referring to the development of natural and forest sciences in the post-war period, experiments have found their anchor in the Białowieża National Park. The locally developed framework for the organisation of collective scientific work has become the model to be applied in other research centres. In the lifetime of the People's Republic of Poland, approx. 150 scientific publications related to the forest have been published. The first in Poland bioecological-forest and climatological-forest works have been commenced, and scientific conferences and conventions organised here.

The significance of the Białowieża Forest for environmental protection, in particular for the Białowieża National Park, the first in Poland and which began the process of creating national parks in this country should also be emphasised.

The significance of the Białowieża Forest for national culture, science and the economics has been exceptional, so care must be taken that the forest is capable of performing this role in future too.

The next lecture, 'Principles of the Białowieża Forest Regeneration', was delivered by Professor **Włoczewski**.

The author first presented the history of the Białowieża Forest and its exploitation and emphasised that 'currently the forest is brought to the last moment at which its regeneration is still possible'. In turn, when discussing forest regeneration, he discussed the forest environment factors that should be properly formed to allow biocenosis regeneration in the forest. As for hydrological relationships, the author thinks that, generally speaking, the forest has no excess water. Bogs occurring in some places are only of local significance, while in the overall water balance they are useful. Therefore, the outflow from the forest should not be increased, nor should the groundwater level be lowered, as this would violate hydrological relationships and their balance with the forest biocenosis. Then the author discussed soil and forest stand factors, as well as their impact on the forest regeneration processes and indicated forest regeneration methods.

Firstly, commercial and forest activities in the forest should be performed by people with appropriate professional skills.

Secondly, hydrological relationships in the forest's catchments and nearby catchments should be left without technical changes. The basis for the design of commercial operations should be the forest's division into biotopes, which should be characterised with regard to the relevant group of species of groundcover, forest stand, soil and moisture relations. The forest stands should include diverse species within the framework of possibilities of the particular biotope and be of different ages.

The application of an appropriate cutting system will be one of the most appropriate technical measures. It should be shelterwood cutting with a long regeneration period, patch cutting based on Bavarian cutting models (by **Gayer**) and group selection cutting. Strip felling only under special conditions.

The regeneration needs, decreasing growth, size of trees and their health may determine the cutting age under the conditions of the proposed cutting. The cutting age may be approximately determined for pine and spruce as 120 years, oak and ash at approx. 140 years, and alder and birch at approx. 80 years. The author finished his lecture with remarks on forest work techniques.

After a break, the session participants visited the local scientific research centres. The visit began with the IBL (Forest Research Institute) meteorological station, where Associate Professor **Zygmunt Obmiński** presented some theoretical assumptions of the research conducted by the Department of Ecology on the ecology of forest communities of the Białowieża National Park. Comprehensive environmental-forest research was started by the former branch of the IBL [Forestry Research Institute] in Białowieża under the tutelage of Professor **J. J. Karpiński**. The results of these studies were published in numerous papers and provide a view on the diversity of phytosociological, zoocenotic, ecoclimatic, pedological and hydrological relationships within the strict reserve. Associate Professor **Obmiński** discussed in detail some results of the forest-hydrological research, illustrating them with tables and charts. The speaker provided a short description of examined forest hydrotopes, showing that, depending on hydrometeorological conditions, the hydrological relationships in non-bog biotopes may change year by year on a very large scale.

In turn, Associate Professor **Tomanek** presented a programme of meteorological-forest research in the Białowieża National Park. The speaker emphasised that the research had been positively assessed by the Agrometeorological Commission of the International Meteorological Organisation of the UN, which had visited Białowieża in October 1958. Associate Professor Tomanek claimed that previous meteorological-forest research conducted by the IBL and other institutions in the Białowieża National Park contributes to the explanation of specific properties of the habitual climate in various forest habitat types, thus constituting an important basis for forest sciences.

Then a discussion followed, in which Professor **Karpiński** emphasised that the ecoclimatic and hydrological research conducted in the Białowieża National Park may be of high importance for the performance of tasks related to the Białowieża Forest regeneration.

Afterwards, the session participants visited the Laboratory of Primeval Forest Research of the Department of Forest Ecology of the IBL. The Laboratory Manager, **Roman**

Pachlewski, PhD, DSc, introduced the visitors to the results of his research on the development of mycorrhiza of specific forest tree species in various ecological conditions. This research, as stated during the debate, contributes to the explanation of the impact of various environmental conditions on the formation of symbiosis between forest stand components and specific mycorrhizal fungi. These works are closely related to phytosociological, meteorological and hydrological research, they contribute to the explanation of many so far unknown issues concerning symbiotrophic relations in forest communities of the Białowieża National Park.

Obmiński, DSc, and **Borowski**, MSc, recounted theoretical assumptions, methodology and previous results of the research on the impact of meteorological and soil conditions on the course and intensity of disease processes in various forest communities of the Białowieża National Park. The research is conducted by station methods in the biocenotic aspect and strives for the detection of irregularities in the dynamics of so-called chain diseases in the forest against specific ecological conditions.

Borowski, MSc, then presented the results of his research on the occurrence of bark beetle in the stands of the forest. The research showed that the bark beetle gradation was caused by a precipitation shortage in 1951. Many details were explained concerning the biology of the European spruce bark beetle and the validity of the promoted opinion that the Białowieża National Park constituted the focus for the propagation of this pest in the managed part of the forest was contested.

Then the session participants visited the Department of Mammal Research of the Polish Academy of Sciences. The head of the Institute, Professor A. **Dehnel**, PhD, introduced the guests in detail to the work programme and the equipment of the unit. The Institute conducts research on small mammals, and recently also on bison and boar. There are five principal research directions: 1) morphology of mammals, 2) microbiology, 3) histology and anatomy, 4) parasitology, and 5) bioclimatology.

On the second day of the session, the participants visited meteorological-forest stations of the Department of Forest Ecology in compartment 317 (mixed coniferous forest) and 340 (moist oak hornbeam forest) of the Białowieża National Park. The works were recounted by Associate Professor **Tomanek**.

At the stations, the measurements are made with regard to air temperature (extreme and typical), ground temperature in two series (with and without soil cover), precipitation passing through the stand canopy, evaporation, fluctuations in the groundwater level, snow depth and ground freezing temperature. The research of this type is conducted simultaneously in five forest communities of the Białowieża National Park. The meteorological station in the Białowieża glade is used as a point of reference.

Associate Professor **Obmiński** addressed the issue of fluctuations in the groundwater level in the biotopes of moist and fresh oak-hornbeam forest, as an example of the nature of hydrological relationships in the forest.

Then the sample plots (ecological series) used by Professor **Włoczewski** in compartments 316 and 317 of the Białowieża National Park were visited. The works conducted on these areas were recounted by Professor **Włoczewski**, who referred to the subject of melioration in the forest, previously mentioned in the paper.

Then a discussion developed. The debaters expressed that the matter of forest melioration should be pursued very carefully. It is necessary to first conduct very detailed studies and research into hydrological relationships in the forest, which would make it possible to figure out if a need really exists to carry out melioration works. The regularising of hydrological relationships may be obtained through a limitation of the cutting volume and this is rather the route to follow. The discussion was continued in the meeting room. Professor **Włoczewski** continued recounting his studies conducted in ecological series, gave detailed explanations as to the species composition of stands, soil conditions and regeneration spots, by illustrating his statements with boards and charts. After the lecture, the research assumptions and methodologies, as well as preliminarily developed research results, were discussed.

On 17 October 1958, the session participants visited the managed part of the forest, with the purpose of acquainting themselves on site about the economic problems recounted by Jurkowski, MSc, the director of the State Forests Board in Białystok and Reindl, head of the Forest Management Bureau. The trip route included the forest types most representative for the forest, the proper management of which and the associated regeneration method for the major species representing the most important regeneration problem.

The following objects were visited:

Forest District Zwierzyniec, compartment 474 – mixed deciduous forest type. In 1950, patches were cut in the stand for regeneration of oak and pine. After the last war, everywhere in the forest except for the bog forest type, initially the group selection and later the patch cutting system were applied. The patch size fluctuated most frequently from 10 to 30 a. Initially, the overstorey was left with a stocking index of 0.2–0.3, while from 1953 it was omitted. In 1956, the patch cutting system was changed to clear cutting, while in some deciduous forest habitats – to the strip selection cutting system.

Compartment 548 – fresh deciduous forest (fresh oak-hornbeam forest), clear cut dated 1957, regenerated with oak. Single oaks, maples and ashes 60–100-years-old were left. The adjacent surface of hornbeam sapling stand with scattered oaks on a clear-cut of 1935. Due to missing maintenance, the oak was suppressed by the hornbeam and small-seeded species. In the oak-hornbeam forests and alder-ash carrs, the shelterwood cutting method was applied just before the war. Based on this example, there was a discussion on the application of cutting systems, the issue of special research and the need for establishing a model forest district in the forest.

Compartment 425 – fresh deciduous forest, patches elongated in the East-West direction, regenerated with oak in 1954. The oak was partially destroyed by the game and then was suppressed by an admixture of hornbeam of natural origin. The discussion in the aftermath focused on the issues of cutting systems, liquidation of trees remaining in the cutting areas and maintenance of plantations.

Compartment 420 – fresh deciduous forest, spruce-oak-hornbeam stand, stocking 0.6, growing stock 250 m^3/ha. This area, excluded from normal utilisation as a partial, so called 'along-the-road' reserve, was showed only as an example. Here the treatment was limited only to sanitation cutting.

Compartment 335 – moist deciduous forest, alder carr established on the so-called strip cutting area, exploited by The Century company. The 100 m wide clear-cut goes through the entire length of the compartment. In the forest, there are 2,000 ha of similar stands, for a total area of clearcutting areas by The Century company amounting to 8,000 ha. The discussion touched on the appropriate species composition and the appropriate stand structure in this habitat, the methods of transformation of the present composition and the use of cutting methods in undistorted stands.

Compartment 334 – moist deciduous forest, sample plot of the Department of Silviculture of IBL. The research works were recounted by Associate Professor E. **Ilmurzyński**. The natural regeneration process and the impact of human interference in the species composition and the stand structure were the research subjects here. The discussion concerned the issue of the forest structure on this type of habitat and the use of commercial treatment.

Compartment 497 – mixed coniferous forest, cutting area regenerated with pine with admixture of oak, self-sown birch and spruce. The discussion touched on the questions of conversion of distorted pine-spruce stands by means of maintenance or by removal and afforestation of these areas.

When visiting the mentioned objects, a discussion was conducted with the multiple contribution of the local hosts **Jurkowski**, MSc, and **Reindl**, MSc, and the visitors participating in the session – representatives of the science and practice: Associate Professor **Kreutzinger**, Professor **Karpiński**, Professor **Włoczewski**, Professor **Szymkiewicz**, Professor **Chodzicki**, Professor **Królikowski**, **Kucharek**, MSc, Associate Professor **Ilmurzyński**, Associate Professor **Graniczny**, Associate Professor **Trampler**, Associate Professor **Krajski** and others.

The cutting systems and regeneration methods relevant for various habitats were discussed. All discussants spoke in favour of the possible extensive use of natural regeneration and the adaptation of the species composition of future stands to the conditions and requirements of a given habitat, emphasising the need to maintain the natural character of the forests as much as possible. The principal concordance of opinions was also expressed in the view of maintaining in the forest as old cutting age as possible for valuable deciduous species, which continue to have for a long time an equal increment and produce technically valuable timber grades.

The differentiation of the cutting age of some species due to their different development properties sometimes imposes the need for cutting systems with a long regeneration period. One should not hurry with the liquidation of some young stands by cutting them, if they protect proper soil structure and do not contribute to its degradation. It was pointed out that greater emphasis should be put on the intermediate cutting. Due to the existence, on the one hand, of large areas of stands that require their liquidation, and on the other hand of forest stands being subject to gradual conversion and exemplary fragments suitable for ordinary management, the differentiation of applied cutting systems must be large. Clear cuts with high cutting intervals, narrow and advantageously located, can be acceptable for the liquidation of low stocked stands and rests of stands. However, it should be emphasised that the balance of water and ecoclimatic relations is not disturbed and that the land does not become weed-grown. Ash, oak, elm, linden, which need an upper or a side shelter, thus require a more complicated cutting system. In order to maintain or create an uneven-aged structure, it is necessary to apply the patch-selection or group-selection system. The cutting and the forest regeneration in the forest must be accompanied by forest maintenance treatment, which were rarely ever carried out.

The debaters emphasised that the forest should perform not only a role of timber producer, but it should also constitute an object maintaining its physiognomic specificity, performing a general social role. While discussing the forest management issues, the administrative and economic matters were also addressed.

On 18 October 1958, the last session meeting took place and then, after a debate summary by Professor Leon Mroczkiewicz, PhD, and a discussion, a resolution was adopted. Its content is provided in issue 12 of *Sylwan* of 1959.

Based on the protocol drawn up by W. Mierzejewski and St. Dunikowski

edited by

St. Dunikowski

The paper was received by the Editorial Committee of *Sylwan* on 28 July 1959.

Chronicle

Report from the field conference held in Białowieża on 5–6 April 1968 on the 'Management of the Białowieża Forest'

At the initiative of the Forest Management Commission of the Polish Forest Society and with the organisational support of the OZLP [Regional Board of the State Forests] in Białystok, a field conference on the management of the Białowieża Forest took place on 5 and 6 April 1968 in Białowieża. It belonged to a series of debates organised by the Forest Management Commission of the Polish Forest Society concerning the regionalisation of the silvicultural principles in Poland.

In all, the conference involved 45 participants from the Regional Board of the State Forests in Białystok, from universities in Warsaw, Poznań and Kraków, from the Forest Research Institute, from local research centres and the State Forest Vocational School, the General Directorate of the State Forests, the Forest Management and Forestry Project Offices in Warsaw, Białystok, Łódź and Radom, and from local forest districts.

The conference was opened and its participants welcomed by the host of the area, the director of OZLP in Białystok – Roman **Filipowicz**, MSc, BEng He expressed among other things his belief that the discussion and conclusions drawn at the conference would contribute to the proper solution of the many problems faced by the local administration of the State Forests.

The conference sessions were chaired by Professor E. **Ilmurzyński**, PhD.

The Chairman of the General Board of the Polish Forest Society – Professor F. **Krzysik**, PhD, expressed his appreciation for the Forest Management Commission for dealing with issues that matter to foresters – both scientist and practitioner. However, he stated that the conclusions and desiderata concerning the improvement of the forest management organisation in the forest are brought forward many times, but the matter of introducing those desiderata to forestry practice was very difficult. He wished that the implementation of the current conclusions were possible.

Then the four papers described below were discussed.

1. S. **Graniczny**, W. **Mierzejewski** – 'Former directions of the economic utilisation of natural forest resources and the first attempts for a planned economy in the Białowieża Forest by the year 1939'.

2. S. **Graniczny**, W. **Mierzejewski** – 'The modern pursuit of the management of the Białowieża Forest with consideration of the socio-economic and scientific postulates'.

The authors presented the history of the Białowieża Forest from ancient times to the present. Against its background, they emphasised the pursuit of enlightened foresters in maintaining the unique, primeval nature of the forest. The authors, personally occupied with the forest's problems for a long time, based on the research and experience of other scientists and practitioners, presented many important assumptions and conclusions aimed at the further improvement of the organisation of the management of the Białowieża Forest and '… maintaining the timeless natural environmental and scientific values of the forest'.

The content of the papers focused on the historical depletion of the growing stock together with the increasing logging volume, variability of the management methods, damaging impact of the overabundance of game in the 19th and 20th centuries, the need for leaning the management toward the expert report and guidelines developed in 1960, the necessity of distinguishing various functional groups of stands, and the need for developing experimental forestry and further comprehensive forest research.

3. A. **Reindl** – 'Economic problems of the Białowieża Forest'.

The author presented the history of forest management planning in the territory of the forest, simultaneously citing more important numerical data for the various periods of its existence. He stated that there had been a reduction in the share of oak in the area of the forest. He proposed subjecting the possible increase in final cutting volume, mainly in respect of oak timber, to an improvement in the condition of plantations. As with the authors of previously presented papers, he stated the very frequent introduction of significant changes in the management and management planning methods in the past. He emphasised the necessity to improve the relations in the area of management and the conversion of stands, as well as regarding the improvement in working conditions of the employees.

4. S. **Wroczyński** – 'The issue of damage from the game and bison in the Białowieża Forest with consideration of the population adjustment, game management, protection of stands and plantations'.

The author discussed the game population and damage caused by it in the respective forest districts over the past ten years. He spoke about the inaccuracy of previous game inventory methods and about the lack of appropriate competences of the State Forests' administration in making decisions on the game population adjustment. In particular, he gave weight to the significant damage caused in the forest by the excessive population of bison living freely. The severe damage to the forest results from decisions being taken in the above-mentioned matters without any coordination with the local Regional Board of the State Forests.

After the lectures and a short discussion, the participants went to the Zwierzyniec, Leśna and the Białowieża Forest districts to view the fragments of stands illustrating the most significant organisational and economic problems affecting the forest. The conference participants were guided around the area by W. **Sosnowski**, MSc, BEng, deputy director of the Regional Board of the State Forests.

1. Formation, protection and maintenance of plantations and sapling stands. These issues were illustrated by examples shown in compartments 450A, 425A and 422B. In the discussion, one emphasised the very large difference in the quality of plantations and sapling stands not damaged by game (mainly bison) and plantations being since a certain point of time permanently damaged by the game in the entire forest. This damage nullifies twenty years of silvicultural achievements by local foresters.
2. The problem of late thinning and conversion of aspen-birch stands of the third age class,

established mainly as a result of large clear cuts performed by The Century company and during World War I on a total area exceeding 10,000 thousand ha of forests was illustrated in compartment 392C.

3. The issue of conversion of mixed forest stands with a prematurely formed, as a result of incorrect application of the shelterwood cutting system, regeneration of alder and ash under the canopy of ash, alder, spruce and oak aged 100–120 years, was demonstrated in compartment 464B. As the discussion proved, an individual, diversified approach to particular components of the stands is inevitable. The uncovering of the bottom storey and the second-growth forest should not be conducted after just one general pattern.
4. The use of natural regeneration under the canopy of older stands – compartment 488D. It was stated that those regenerations usually differed from the composition determined by the target stand composition type and often required a long period of regeneration to maintain the beneficial, forest-specific mixed-species and uneven-aged structure.
5. Stands from the oldest age classes in the Białowieża Forest planned for cutting in the 1969–1979 period (illustrated by compartment 488D) were the final stage of the field discussion. One argued for the maintaining a high rotation age for those stands, disputing the concept of so-called overmature stands in uneven-aged stands.

A particularly negative and disturbing effect during the field trip was exerted by the huge damage caused to the plantations and sapling stands by game, mainly bison, as well as the wide divergence between the species compositions of plantations and sapling stands in richer habitats and the species compositions relevant to the target stand composition types.

The discussion was attended by a total of 22 conference participants: A. **Czerwiński**, J. **Dalmaczyński**, J. **Faliński**, R. **Filipowicz**, T. **Gierliński**, S. **Graniczny**, S. **Gunia**, M. **Hajduk**, E. **Ilmurzyński**, J. **Jarecki**, K. **Korzeniowski**, F. **Krzysik**, L. **Kulig**, T. **Mokrzycki**, A. **Reindl**, T. **Szczęsny**, A. **Sokołowski**, W. **Sosnowski**, T. **Włoczewski**, E. **Więcko**, B. **Zabielski**, T. **Zieliński**. The majority of the above-mentioned participated in the discussions several times.

Prior to the discussion of the results of the debate, which out of necessity will be provided in a generalised form, slightly more attention should be paid to the extensive contribution of the director of the Nature Conservation Board, Associate Professor T. **Szczęsny**, PhD. His point of view concerning the discussed topics often differed significantly from the statements of the authors of the papers and from opinions of the other debaters. He stated that we had boasted internationally of our achievements in the restitutional breeding of the bison, and in saving this species from extinction. In the opinion of Associate Professor Szczęsny, the Białowieża Forest, as a forest area of unique value, is associated mainly with the presence of bison, which should be kept as an inseparable resident of the forest. He emphasised that it is impossible to simultaneously conduct suitable forest management oriented towards accomplishing economic and production objectives as well as the breeding bison. He suggested classifying the entire forest as a Group I forest.[1] In addition, he informed the audience that its part on the Soviet side is managed according to principles that take into account the breeding bison and other game. In the opinion of Associate Professor **Szczęsny**, when determining the hunting ground capacity, priority should be given to the bison, for the existence of which the forest is the only forestal area. He proposed modifying the forest management system by considering the breeding needs of the bison, for which an appropriate target population should be determined. Two countries perform the main role in the restitutional breeding of bison: Poland and the Soviet Union. One should also aim to involve other countries in the performance of this task. In the case of the Białowieża Forest, 200 free-roaming bison is considered the target number. Currently, steps are being taken to spread bison across the entire area of the forest, as their existing concentration contributes to greater damage. Szczęsny also supported greater powers for the local administration in terms of reducing the excess game population.

During the discussion, many problems were mentioned, concerning both the issues contained in the papers and the observations made during the field trip to the stands, mainly within the scope of damage caused by bison and other game.

A lot of attention was paid to the forest's role, a worldwide unique, only one of this kind natural object, both with regard to bison breeding and to the conservation of rare forms of stands. It was underlined that the unique nature of the stands preserved there

[1] Protection forest [translator's note].

commits us to protecting it and maintaining for the benefit of next generations. In the interest of the forest as a whole, almost all the debaters highlighted the necessity of taking such steps in the management of forest holdings that would ensure the full protection of the phytocenosis and zoocenosis – two inextricable components of forest biocenosis. While discussing zoocenosis, a lot of attention was paid to its most attractive representative, i.e. the bison. As a counterweight, putting predators under conservation was also suggested. While discussing the conservation of phytocenosis and zoocenosis, the necessity of keeping the right balance between them was emphasised. Concerns regarding the excessive population of game, including the bison, were firmly expressed. Those statements were based on examples of mass damage to plantations and sapling stands caused by bison and other game. The questionability of the previously applied methods of determining habitat capacities was also underlined. The carrying out of relevant studies in that regard was deemed necessary.

In order to create more suitable conditions for forest management, the idea of classifying the Białowieża Forest as a Group I forest was strongly expressed. Such a move was justified mainly by the hope of creating first legal act for special approach to the forest (different from standard, managed forests) in form of an appropriate statute. Sporadically, voices questioning the effectiveness of such a move were expressed. Moreover, proposals for establishing a partial reserve on the entire area of the managed part of the forest were broached, with a properly developed production plan and a plan covering the other functions of that the forest must perform due to its character. Such a solution, apart from many negative aspects (i.e. the necessary change of administrator), would have as its positive aspect that the entirety of issues of phytocenosis and zoocenosis conservation would be decided in one place.

The general view among employees of the State Forests administration was that there a relevant statute should only be developed that treats the forest as a Group II special forest, guaranteeing the forest autonomy, greater freedom of action and appropriate funding.[2]

Besides, the need for the development of new labour standards to improve the quality of performed maintenance treatments and other works in forestry was raised during the discussions.

There was emphasised the necessity of conducting relevant comprehensive studies concerning, among others, setting measurable criteria for biological sustainability in the forest and means aimed at the assurance thereof, and determining the production capacity

[2] In 1968, at 1st session of the KTG [Techno-Economic Commission) for the forest, the postulate of classifying the forest as group I (special) forest was finally agreed, with a properly developed statute emphasising the forest's specific purposes and needs.

of stands, their optimal cutting age and management methods. For achieving these tasks, a dedicated experimental subdistrict might play an important role.

Issues related to the revision management plans for the forest constituted a separate group of matters discussed during the conference. They concerned guidelines for the 1st and 2nd techno-economic commission. Many important issues within that scope were discussed.

W. **Sosnowski**, MSc, BEng – deputy director of forest management director at OZLP [Regional Board of the State Forests] in Białystok – was the final speaker. Besides expressing his opinions on the more important problems mentioned previously in the discussion, the speaker thanked Professor **Krzysik**, PhD, Professor E. **Ilmurzyński**, PhD, and all members of the Forest Management Commission for their help in solving the organisational economic problems of the forest and asked the Commission for a further cooperation.

Professor F. **Krzysik**, PhD, summed up the discussion. He emphasised the necessity of dealing by the Forest Management Commission with basic issues and with establishing guidelines for the further management of the forest. He emphasised the purposefulness of considering the maintaining the stands of age class VII to X in the long-term plan.

The speaker referred positively to the statement of Jan **Jarecki**, MSc, BEng a representative of KW PZPR [Voivodeship Committee of the Polish United Workers' Party], alumnus of the SGGW [Warsaw University of Life Sciences]. He stated that the fact of active participation of a KW PZPR representative in the discussion was encouraging as to the possibility of implementing the adopted conclusions. Finally, Professor **Krzysik** warmly thanked the Forest Management Commission of the Polish Forest Society and its deputy chairman S. **Graniczny**, as well as the local administration of the State Forests and the BULiPL [Forest Management and Forestry Projects Bureau] for taking an active part in the conference organisation and in creating a pleasant and hospitable atmosphere.

Professor E. **Ilmurzyński**, PhD, while closing the session, assured the debaters that the Commission would make endeavours aiming at the implementation of the conference conclusions.

Edited by T. Gierliński

Conclusions from the conference on the 'Management of the Białowieża Forest' held in Białowieża on 5–6 April 1968

The purpose of the conference was to prepare materials and conclusions for session I of the techno-economic commission appointed for the revision of forest management plans for the Białowieża Forest. In the lectures and discussion held at the conference, the entirety of problems of the former and present forest management in the forest was raised.

The inimitable natural, economic and sociocultural values of the Białowieża Forest, esteemed by the whole society and foreign opinion, and at the same time the current situation of massive damage caused by the game and free-roaming bison encourage the General Board of the Polish Forest Society to present materials and conclusions adopted as a result of the conference to the Ministry of Forestry and Wood Industry.

The specific values of the Białowieża Forest for the national economy and assumptions of the forest management in the forest:

The Białowieża Forest, creating one joint forest complex on the side of the People's Republic of Poland and on the side Belarus, constitutes as a whole the only forest of natural origin on the Europe's lowland, similar to a primeval forest.

The variety of forest habitats and the richness of stand types, as well as diversified species composition, age structure and stratification of stands and the system of little distorted habitat and hydrological relationships in the forest, form together with the fauna a specific biocenosis of the forest.

A unique and all-embracive value of the Białowieża Forest is expressed in the specific structure of growing stock providing the most valuable assortments, in high productivity of primeval forest habitats, in the forest's role for the water and soil protection, in its economic, scientific and educational significance, and in its historical, cultural and touristic values. These specific values of the forest accord to it the nature of a protection forest, with an additional socio-economic role.

In the 19th and 20th centuries and to the present, the Białowieża Forest has been suffering from distortions and threats due to an upset of the balance between the fulfilment of the basic production objective of the forest management and the nature conservation or hunting objective. Currently, the forest is treated as a common managed forest area, with all respective consequences of this status, but meanwhile it is characterised by an excessive population of bison and other game. This too large population of herbivorous game causes catastrophic damage to the forest, accompanied by a lack of sufficient financial and personal resources for forest management and protection. Unattractive wages, difficult working conditions and the lack of precise views on the direction of forest management constitute an additional difficulty in the process of managing the forest.

In the forest, the socio-economic objective should be constituted by the maintenance of sustainability of the forest economy, leant on scientific foundations, with a simultaneous maintenance of natural forest biocenoses and a restitution of distorted biocenoses, combined with a full opening of the forest for the scientific work, nature conservation activities and tourism.

All this speaks for the necessity of a specific approach to forest management in the forest, with the purpose of protecting its unique values. Moreover, the forest management in the Białowieża Forest should rest, if possible, on the assumptions of the similar treatment of the both parts of the forest, on the side of the People's Republic of Poland and the side of Byelorussian Soviet Socialist Republic, whilst taking into account the below presented conclusions.

I. Maintaining the proper productivity of habitats and stands for the purpose of ensuring a high level of timber production, with a simultaneous consideration of the postulates of nature conservation

The recent excessive reproduction of the deer-type game, considering the extermination of predators and a large number of bison roaming freely in the conditions totally different from the primary stand and regeneration relationships in the forest, resulted in an interference of the biocenotic dependencies. It is embodied in the destruction of stands and regenerated forests as well as in the weakened biological resistance of trees, up to the limits making the proper renewal, protection and maintenance of plantations and stands impossible.

1. The necessity of reconciling the postulates of nature conservation with the main postulates of the forest economy, and at the same time the specific objective of restoring and maintaining the natural, primeval character of the forests of Białowieża enforce the classification of the forest as a group I protection forest. It is necessary to provide the Białowieża Forest with a separate statute and to issue organisational and administrative orders, which would make possible to distinguish the forest as a special object and to perform the outlined economic and social tasks.
2. It is necessary to immediately implement a long-term plan of reduction of the deer-type game population down to a number at which the forest regeneration is not endangered, limitation of the population of free-roaming bison and liquidation of livestock grazing in the forest, as well as close cooperation of the administration of the State Forests, nature conservation authorities, hunting authorities and other measures in organisational and financial terms within the scope of regulating these relationships, game management, game feeding, protection of regeneration from damage caused by the game, etc.
3. It is essential that the nature conservation authorities, together with the Regional Board of the State Forests (OZLP) in Białystok, determine an approximate target population of free-roaming bison and adjust these assumptions on the base of research results within this scope.

II. Determining the main fundamentals of a proper management of the forest according to the present state of forest science

1. The base of the forest management in the area of the forest is the maintenance and restitution of a diversified, habitat-compliant species composition and structure of stands and the production of high-grade, high-diameter timber assortments achievable in the long production term.

To this end, it is necessary to distinguish four economic categories of stands:

   a. with species composition close to the exemplary one and with an uneven-aged structure – managed with the application of cutting systems with a long (exceeding 20 years) period of regeneration,
   b. with varied species composition, but with less complex structure – managed with the application of cutting systems with a medium (10–20 years) and short (up to 10 years) period of regeneration,
   c. with incorrect species composition and structure, requiring conversion and regeneration under the shelter of existing stands,
   d. with species composition and structure requiring the use of clear cutting systems, thus so-called negative stands that cannot be used as a shelter for the regeneration introduced under the conversion process.

2. In the forest, cutting systems and felling methods indicated in an expert report of the Forest Research Institute, adopted by the Regional Board of the State Forests (OZLP) in 1962, should be applied in concordance with the regional silvicultural principles, first of all following the regeneration needs and the postulates of diversification of the species composition and structure of stands.
3. In planning the felling for shelterwood and patch cutting systems, it is necessary to apply the upper limit of the tree cutting ages, to limit the volume of a single cutting treatment to 30 or 20% of the initial growing stock and to maintain of the spatial order and the direction of the regeneration sequence. In addition, it is recommended to apply a flexible regeneration period depending on the silvicultural needs, in particular in model stands.
4. The maintenance cutting should be reinforced to improve the health condition and improve the resistance of stands.
5. The use of mature aspen and birch stands on the clear-cutting areas originating from the interwar period should be started.
6. Apart from the forest management plan, a game management project considering the problem of protected animals should be developed.
7. It is necessary to apply for the approval of partial reserves that have been planned on the area of the forest for 20 years.

III. Securing scientific foundations for the economy in the Białowieża Forest

1. The scientific research work, as well as the professional training should be concentrated in the Budy experimental forest subdistrict.

In the territory of the Budy experimental forest subdistrict and the entire Białowieża Forest, it is recommended to commence experimental works, in particular by the Forest Research Institute, with support from the staff of the State Vocational Forest School and the Białowieża National Park.

The research should include the participation of the forestry faculty chairs, biology department chairs at universities, the Department of Nature Conservation of the Polish Academy of Sciences and local scientific research and educational institutes (Laboratory of Primeval Forest Research of the Forest Research Institute, Mammal Research Department of the Polish Academy of Sciences, and Laboratory of Geobotanics of the University of Warsaw).

2. The research projects may be conducted as scheduled work, included in the plans of scientific research units or as projects contracted by interested institutions, especially the Regional Board of the State Forests (OZLP) in Białystok.

The scope of research problems should include the questions of silviculture and forest protection, forest genetics, forest management and productivity, forest ecology, game management and biology of protected animals.

Such a large scope of research requires a wide inclusion of various research institutes or obtaining additional engineering and laboratory job positions and financial resources for local institutions. In addition, it requires an agreement on the scope and partially on the research methodology by a consultative body appointed for this purpose, whose beginning may be constituted by the group appointed in 1968 for the Budy experimental forest subdistrict in the Białowieża Forest.

3. In the experimental forest subdistrict, conditions for a reasonable performance of research works must be ensured. To this end, one should:

   d. fence the entire forest subdistrict,
   e. reinforce the staffing level,
   f. grant a special bonus to the Budy forest subdistrict's employees and workers.

Edited by S. Graniczny

Eugeniusz Bernadzki

Silvicultural planning in patch selection cutting system on the example of a forest unit located in the Białowieża Forest

The basic goal of a forest management unit is to try to maximise of the production capacity of the habitats. This task is performed through numerous silvicultural treatments, starting with forest renewal, through various maintenance stages, to the collection of main forest products. One of the most important treatments is the execution of the most appropriate under the given habitat and stand conditions regeneration cutting and derivation of a young forest generation with species composition and structure allowing for a maximisation of the habitat's production capacity.

Silvicultural planning is very important for the reasonable spread of particular treatments over the time and space. Management guidelines included in the forest management plans provide only very general guidance. They may be considered sufficient when performing forest management with the clear-cutting method or the shelterwood method, but in the case of patch cutting systems, in particular the patch-selection system, detailed silvicultural planning becomes necessary.

A detailed silvicultural plan includes three basic elements: determination of an economic goal, which is being followed throughout the entire lifecycle of the stand, specification of the state to be reached by the stand at its next development stage, e.g. how to tend a sapling stand in order to obtain a pole stand with a specific composition and structure, and indication of silvicultural treatments ensuring the accomplishment of the determined goal.

The patch-selection system designated to be applied in the state-owned forests in Poland refers to the Swiss improved patch-selection system, which Chodzicki (2) also refers to as irregular shelterwood system. This consists in stand regeneration mainly by group and patch cutting, although allowing for other cutting types depending on the needs of the young forest generation and the residual overwood condition. The regeneration cutting commences near the transport boundary (8), i.e. in the part of the stand most distant from the logging road, from where the felled wood material is collected along skid tracks. A properly designed system of skid tracks and logging roads is essential for the patch-selection system.

Patches and groups established within the first phase of the regeneration process are extended and connected later, while emerging groves and patches of second-growth merge with each other harmoniously, without sharp delimitations. The pace of the regeneration process depends on the environmental requirements of the young generation of forest. It may be regulated by widening or narrowing the regeneration front. It is very important to keep the edges of emerging renewals in 'constant movement'. No distinct walls for particular groves or groups should form.

In Poland, for the patch-selection system, a regeneration period usually exceeding 20 years is foreseen. Even longer regeneration periods (often more than 50 years) are applied using this system in Bavaria and Baden-Württemberg. In Switzerland, it is not determined in advance. It is only assumed that it should be as long as possible, even longer than 60 years.

In Poland, the patch-selection system is recommended for forest stands with the participation of fir. It allows the derivation of mixed stands with a diversified vertical structure, composed of heliophilous and shade-tolerant species.

The Białowieża Forest, as a unique forest object in Central Europe, requires special management methods. Still existing residues of amazing, multi-storey mixed stands testify to the habitats' production capacities. They indicate the goal to be followed by all silvicultural treatments. In 1965, in the territory of the Zwierzyniec forest district, the Budy Experimental Forest Subsdistrict was appointed to determinate the most appropriate management methods aimed at the regeneration of primeval stands. The statute of this forest subdistrict foresaw for the fresh deciduous forest habitat the patch method with a 20–30-year regeneration period, which should be converted in future to the patch-selection method (according to the nomenclature of *The Principles of Silviculture* of 1960). In a moist forest habitat, the shelterwood method without division into manipulation strips, with a 30–40-year regeneration period, is to be applied. Just as in the fresh deciduous forest, a future transition to the patch-selection method is foreseen.

The nomenclature of cutting systems was changed with the introduction of *The Principles of Silviculture* in 1969. Long regeneration periods are basically designated only for the patch-selection method. Therefore, for the fresh and moist deciduous forest habitats in the Experimental Forest Subdistrict, there may be assumed the application of the patch-selection method allowing for derivation of stands with a diversified structure and rich species composition.

The lack of experience in silvicultural planning for the patch-selection method is forcing us to adapt and use the Swiss patterns. In *Sylwan*, **Fabijanowski** (3) presented the silvicultural planning principles being applied in the irregular shelterwood cutting system in Switzerland. However, there are no examples of a detailed silvicultural plan developed for specific objects. While participating in the work of the consultative and advisory team for the Budy Experimental Forest Subdistrict management, the Department of Silviculture of the IBL [Forest Research Institute] developed a detailed silvicultural plan for a selected object in that subdistrict. Field work was performed with the participation of the local administration of the State Forests and the Forest Management Office. As an exemplary object, compartment 337B was selected, with a total area of 44.69 ha, with prevailing fresh and moist deciduous forest habitats and the domination by stands designated for regeneration.

The execution of the silvicultural plan is possible after the elimination of damage caused by the protected bison, other game, as well as by livestock grazing. The present game population makes any reasonable silvicultural treatments leading to the attainment stands with a desired species composition and structure impossible.

DETAILED SILVICULTURAL PLAN FOR THE COMPARTMENT 337B IN THE BUDY EXPERIMENTAL FOREST SUBDISTRICT

Based on the scientific and research expertise named 'Analysis of the Forest Management Methods previously applied in the Białowieża Forest and of the Forest Management Principles', developed by a group of scientists and practitioners appointed at the Forest Research Institute in 1959 and the guidelines published in *The Principles of Silviculture* dated 1969 – the production goal for the object was determined.

Fresh deciduous forest: multi-storey stand with basic composition 4 oak, 2 spruce, 2 hornbeam, 2 (maple, linden, ash, etc.), producing high-value large-sized timber.

Moist deciduous forest: multi-storey stand with composition 3 oak, 3 ash, 2 (maple, linden, elm, etc.), 1 spruce, 1 hornbeam, producing large-sized timber.

Alder-ash carr: two-storey stand with composition 4 ash, 4 alder, 2 (spruce, etc.), producing large-sized timber.

The cutting age was determined based on the 1959 scientific and research expertise and on the resolution of the session II of the Techno- Economic Commission on the management of the Białowieża Forest of July 1960: oak – 200 years; ash – 160 years; alder – 100 years; spruce – 140 years; alder-ash carr – 100 years; hornbeam – 100 years; other deciduous species – 100 years.

The regeneration period was set based on the 1959 expertise with small changes. In the fresh and moist deciduous forest habitats, for the patch-selection cutting system – approx. 30 years, on the alder-ash carr for the typical shelterwood cutting system – 15–20 years.

Spatial order. The compartment boundary line on its eastern side and the road perpendicular thereto – the line crossing the compartment in the east-west direction, serve as logging roads. The wood material harvested in the south-west part of the compartment may be directed along the existing paths in the south-west direction and then in parallel to the forest edge through compartment 337A. The paths existing inside the compartment have been marked in fig. 1. The cutting out of additional skid tracks connecting the area of the transport boundary with logging roads is planned. Skid tracks should be 2.5 m wide.

GENERAL PRINCIPLES OF SILVICULTURAL APPROACH

The silvicultural plan provides detailed guidelines for the first five-year-period and more general ones for the second one. According to the results obtained after the first treatment, a detailed course of actions will be established for the subsequent treatments.

In the first five-year period, the plan for the stands designated to be regenerated includes clearing and afforesting existing patches, cutting and renewal of new patches, conducting one partial overstorey removal in sub-compartment a and maintenance treatments in younger stands. In the second five-year period, the old patches will be widened and merged, new patches will be established and maintenance cutting will be continued.

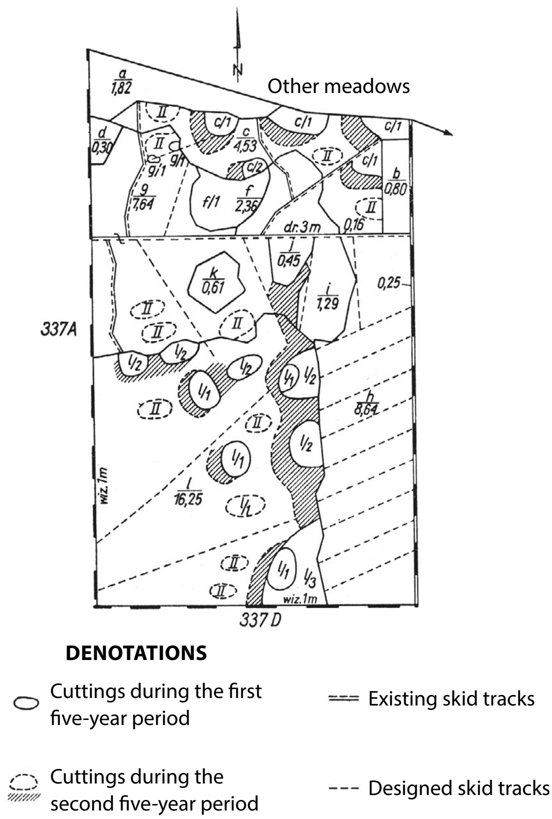

Fig. 1.
Silvicultural plan for the Budy Experimental Forest Subdistrict. Compartment 337B. Layout of cuttings and skid tracks

The patches will be renewed with oak, including on mounds or ridges in boggy areas. Other deciduous tree species and spruce will be introduced in the outer zones of patches, and after their widening, depending on the progress of natural regeneration. After elimination of damage caused by game, the emergence of a plenitude of natural seeding, mainly ash, may be expected.

The regeneration should be conducted with use of strong seedlings not less than 0.5 m high (for deciduous species).

In stands d, h and i, where the current species composition significantly differs from the targeted one, maintenance cutting is planned currently aiming at an improvement of the quality of the productive stock. These stands are not planned for a conversion in the nearest ten-year period due to their good quality and absence of symptoms indicating the need for their quick removal.

Below you may find an example section of the detailed plan of silvicultural measures referring to the most important part of the compartment.

Stand h: moist deciduous forest, 7 alder, 1 spruce, 1 birch, 1 aspen, individual linden, elm, hornbeam, 35 years old.

Moderate crown cover. Stocking 1.1.

Maintenance target: alder stand with participation of spruce and admixture of birch, aspen, linden, elm.

Treatments: improvement cutting in favour of spruce and crop alder, one cutting within five-year period. Volume of harvested wood approx. 240 m^3.

Stand i: Fresh deciduous forest, 7 spruce, 2 birch, 1 aspen, locally alder. 40 years old. Moderate crown cover Stocking 0.8.

Maintenance target: spruce stand with admixture of birch

Treatments: improvement cutting in favour of spruce and crop birch, one cutting within five-year period. Volume of harvested wood approx. 28 m^3.

Stand j: Fresh deciduous forest, 5 oak, 3 spruce, 2 birch, locally alder, hornbeam, 8 years old. Stocking 0.8.

Maintenance target: oak sapling stand with participation of spruce

Treatments: cleaning in favour of oak.

Stand k: Fresh deciduous forest, 4 oak, 4 spruce, 1 birch, 1 hornbeam, linden, 8 years old. Stocking 0.9, individual oak, linden, age class IX.

Maintenance target: spruce and oak sapling stand.

Treatments: cleaning in favour of oak.

Stand l: Moist deciduous forest. Multi-storey stand. 3 ash, individual alder, spruce, 140 years old. 3 spruce, 2 alder, individual hornbeam, ash, 100 years old. 1 oak, sporadically linden, 180 years old, 1 spruce, individual alder, maple, oak, hornbeam, linden, 60 years old. Stocking 0.9. Second-growth forest 8 spruce, 2 hornbeam, individual ash, linden on 30% of the surface up to 15 years old.

Regeneration unit 1/1.

Regeneration target: oak sapling stand with admixture of spruce, ash, alder from second-growth forest.

Treatments: cleaning of existing four patches, leaving second-growth of ash and well developing groups of spruce and alder second-growth, afforestation with oak on mounds or ridges.

Regeneration unit 1/2.

Regeneration target: oak sapling stand.

Treatments: cut out five regeneration centres with an area of 0.12–0.40 ha.

Afforest with oak, with use of existing groves of spruce second-growth. Plantation treatment. Volume of harvested wood – 480 m^3.

Regeneration unit 1/3.

Regeneration target: sapling stand with composition 8 oak 2 ash.

Treatments: remove overmature stand, leaving individual oaks, ashes as shelter.

Afforest with oak in groves 2–3a framed with ashes. Plantation treatment. Volume of harvested wood – 250 m^3. In the entire stand, ordering cutting with removal of cull trees. Volume of wood harvested in this cutting – 650 m^3.

Volume of wood harvested during the first five-year period: from regeneration cuts – 1,180 m^3, from the stand ordering – 1,130 m^3, from maintenance – 275 m^3.

Volume of wood harvested during the second five-year period: from regeneration cuts – 1,700 m^3, from maintenance – 275 m^3.

Total afforestation area: in the first five-year period – 3.70 ha, in the second five-year-period – 5.0 ha.

The presented detailed silvicultural plan developed for a particular object in the Białowieża Forest constitutes a deviation from the standard treatment of stands. While determining regeneration centres at a later stage, one may consider the microhabitat conditions through the adjustment of patch size and of the composition of introduced regenerations. The permanently cut skid tracks, which may still be extended following the progress of the regeneration process, not only facilitate the timber extraction, but mainly maintain order while establishing new regeneration centres, thus allowing the avoidance of damage to emerging sapling stands.

The patch-selection cutting system provides the administrator of the area with huge opportunities for the accomplishment of the determined economic goal. The detailed silvicultural plan ensures a continuity of particular silvicultural operations, increases transparency in the forest holding and, as a consequence, leads to making each smallest part of the forest productive.

The execution of a silvicultural plan is an easy operation and in our conditions it should be entrusted to the State Forest employees with academic education or to a cruising specialist. In the latter case, a participation of the area administrator is necessary. The labour input to the development of such a plan is disproportionately low compared to the benefits possible to achieve.

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Edward Więcko

The economy in the Białowieża Forest for the past fifty years

In its present form, while the Białowieża Forest today is a mere fragment, it is still the largest on the North European Plain and the heart of forests left over from the former great primary forests.

Royal hunting and other kinds of the forest utilisation in the former Republic of Poland did not endanger its existence. While evaluating the Polish economy in the forest within the period of four hundred years preceding the Partitions, the Russian, **Karcow** (12), wrote that 'one should thank the Poles sincerely' for maintaining the forest, as the forest has survived, after all, just like the bison that was not saved anywhere else in Europe'.

From 1795 to World War I, the forest was under Russian rule and from August 1915 to November 1918 under the occupational German military authority. The consequences of the Russian management in the forest appeared to be negative, in particular in the period 1888–1914 when its management was aimed mainly at management of huntable game, with the excessively reproduced game damaging and eating everything on the forest floor, as well as ruining the second-growth forest.

The extensive, conducted in an unplanned manner, clear-cuts and harvesting of the most valuable trees in the entire forest, processed in specially constructed industrial plants, and game extermination constituted another consequence of the German occupiers' management of the forest.

The Polish authorities took the Białowieża Forest over in 1919 (February, March) and by the year 1939 it was administered by the Directorate of the State Forests in Białowieża.

In the years 1920–1921, provisional forest management planning was conducted in the Białowieża Forest. The initially established principles of forest management underwent a change in 1924, as according to an agreement with the English company The Century European Timber Corporation, on 24 April 1924 forest exploitation was handed over to that company for a period of ten years, at 325,000 m^3 of timber per year, i.e. actually the utilisation volume was determined at 150% of the allowable cut. In every year, the cutting area was to cover 1,400 ha. As the company did not adhere to the established contractual conditions (e.g. instead of seed trees less valuable trees, mainly hornbeam, were left on the cutting

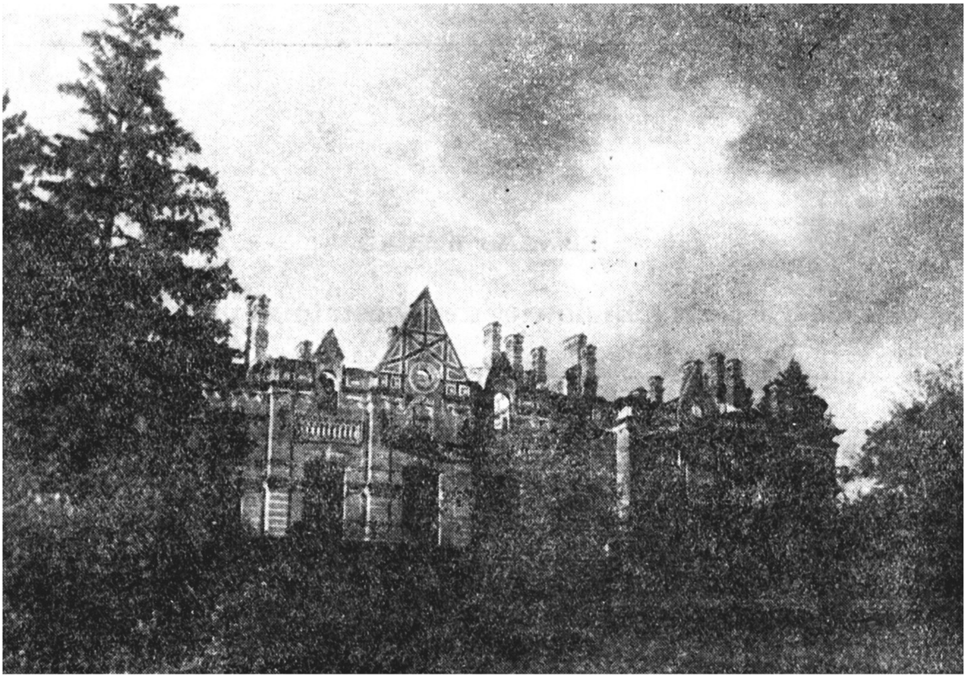

Fig. 1. Białowieża. Ruins of the Palace Photo by J. Bułhak

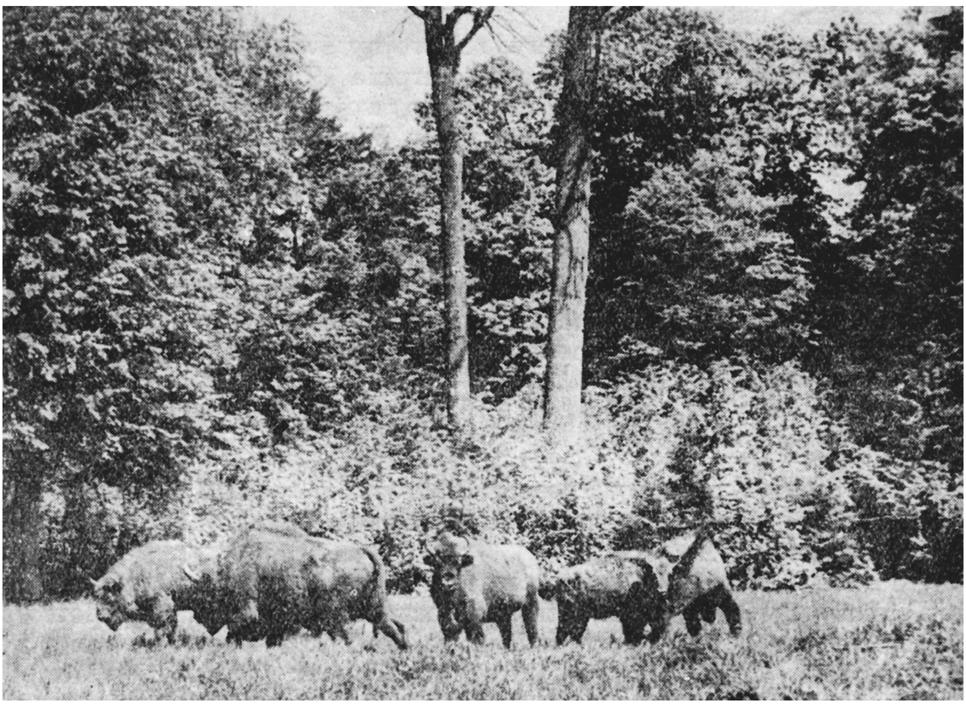

Fig. 2. Herd of bison in the reserve Photo by Z. Krasiński

Fig. 3. Białowieża. Gate to the National Park Photo by R. Pruski

areas) – after five years the agreement was terminated, on 14 July 1929, in connection with the payment of a large compensation by the Polish authorities.[1]

By the termination of agreement, the company had harvested approx. 2.5 million m^3 of timber from the forest. On the areas clear-cut by that company a natural renewal by small-seeded species took place, mainly by birch and aspen, as well as hornbeam.

The intensity of the forest utilisation in the years 1930–1939 for final cutting was 3.6 m^3/ha per year, and for intermediate cutting to 1.1 m^3/ha per year, with average growing stock of stands of approx. 220 m^3/ha. Such an utilisation intensity was similar to the one applied by The Century company.

In the inter-war period, approx. 20,000 ha of forest was cut in the Białowieża Forest (usually with clear-cuts or clear-cuts with single trees left in the cutting areas), including approx. 8,000 ha of the cuts of The Century company, approx. 6,500 ha of clear cuts from e period 1920–1924 and the rest was clear-cuts and cuts named 'partial' from the period 1930–1939 (8).

If it is about the wood industry plants in the forest, part of the provisional sawmills constructed by the Germans was destroyed. The Polish authorities took over three sawmills:

[1] According to the information received from director Franciszek **Szkiłłądź**, the then head of the financial department at the special delegate of the Ministry of Agriculture for the administration of the State Forests, who back then was Adam Loret, a compensation amount of 375,000 pound sterling was agreed, which after conversion was approx. 16.2 million zloty, from which the taxes unpaid by the English company of approx. 1.5 million zloty were deducted.

in Hajnówka, Grudki, and Stoczek. Firstly, they were leased to The Century company and after the termination of the agreement with that company, the Directorate of the State Forests in Białowieża took them over together with the forest railways. After some time, the railway network in the forest was extended to 300 km. Later, due to the construction of a new sawmill in Hajnówka, the sawmills built by the occupant in Hajnówka and Stoczek were liquidated. The processing capacity of the new sawmill in Hajnówka was approx. 180,000 m^3 of softwood timber and approx. 30,000 m^3 of hardwood timber annually. Approx. 1,300 workers were employed there. That sawmill was one of the largest and the most state-of-the-art plants of that type in Poland. In 1935, drying installations, a parquet flooring plant and a woodworking shop were added in Hajnówka.

Among the rich and diverse fauna of the forest, the bison (*Bison bonasus* L.) definitely stands out. The bison has survived for the longest time in its natural environment (living freely) right in the Białowieża Forest. From approx. 1,900 free-roaming bison in the middle of the 19th century (in 1857 – 1,898 specimens), in 1916 there were still 200 bison left in the forest, while in March 1917 there were apparently 121 of them.

The last bison in the forest was killed by a poacher on 19 February 1919[2] (14).

In 1923, at the international congress of the Union for Conservation of Nature in Paris, the Polish delegate Jan **Sztolcman** raised the issue of the care for the dying out bison. In connection with that initiative, in the same year the International Society for the Protection of the European Bison was established in Berlin. It took care of the registration of bison in zoos and menageries worldwide and determined the principles for their breeding.[3]

Already in the inter-war period, the breeding of bison was restarted in Białowieża. In 1929, the Zoological Garden in Warsaw purchased from German and Swedish breeding centres through the intermediary K. **Hagenbeck** from Stellingen near Hamburg three bison and four *żubrobizon(s)*.[4]

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[2] The information provided by **Wróblewski** in the paper 'The European Bison in the Białowieża Forest' Poznań 1927 that the last bison in the forest was killed in February 1921 is inaccurate, which follows, among others, from explanations given once to Professor J. J. **Karpiński** by Warfołomiej **Szpakowicz**, who killed the last bison (14).

[3] According to the state as of 1 January 1925, 66 specimens of bison were living then in seven countries (one third of that number in Germany). Back then, six specimens of bison were in Poland – in Pszczyna and in the Zoological Garden of Poznań. M. **Steckel** (25) provides that in 1921 in the Jankowice district (in the estate of Pless) in the Silesia four free-roaming bison were still living. According to **Romanow** (21), only 52 specimens of bison remained worldwide alive by the year 1926.

[4] A hybrid of European and American bison [translator's note].

Fig. 4. Bison

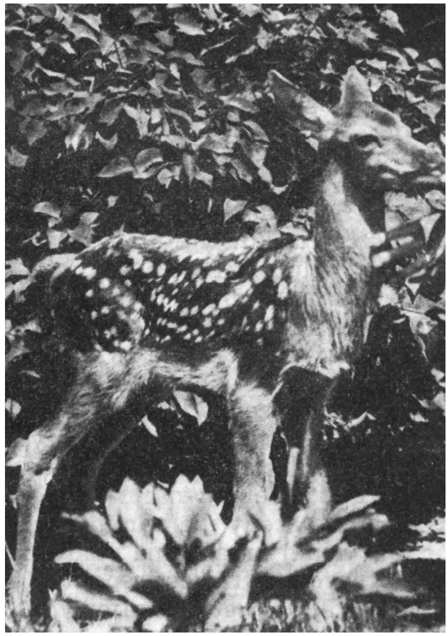

Fig. 5. Young red deer

Fig. 6. Anemone

Fig. 7. Cypripedium

Photos by J. J. Karpiński

In September 1929, one bison male named 'Borusse' and one *żubrobizon* male named 'Kobalt' were brought to Białowieża, followed in October by one pure-bred bison female ('Biserta') and one female of *żubrobizon* ('Fawority'). In August 1930, another *żubrobizon* female ('Stolce') was brought there and the bison male 'Kobalt' was sent back to the Warsaw zoo. The herd of bison and *żubrobizon* composed in this way was initially placed in a 22-hectare large reserve in compartment 420 of the Zwierzyniec Forest District. Then the *żubrobizon* females with the offspring of the bison 'Borusse', stemming from a mother with parents from Białowieża and a father with an admixture of Caucasian blood was removed from the Białowieża breeding, where only pure-bred Białowieża bison were left. In 1936, one bison male from the Pszczyna breeding ('Plisch'), where bison of Białowieża origin were still present, was brought to Białowieża. In 1939, 16 bison were in the Białowieża menagerie.

Before World War II, another former resident of the Białowieża Forest returned thereto – the forest tarpan [tranlator's note: Eurasian wild horse], ceasing to exist in the forest by the second half of the 18th century. In February 1936, the Directorate of the State Forests in Białowieża purchased six tarpan-like horses from peasants, initially in the Biłgoraj Poviat, then further purchases were made in other counties of the eastern and southern Poland.

After World War I, until 1928, the game management in the Białowieża Forest was conducted by the Forest Districts and then a gamekeeper was appointed for the forest, with assigned eight game wardens as his helpers. The forest together with the adjacent forest districts and the entire area managed by the Directorate of the State Forests in Białowieża were divided into: 1) area for entertainment hunts (approx. 86,000 ha), and 2) areas for the State Forests administration (approx. 40,000 ha). The privilege of organising representational hunts in Białowieża belonged to the president of the Republic of Poland, who invited government members and domestic and foreign guests.

The game population in the forest in 1935 was: 687 red deer, 2,400 roe deer, 1,240 boar, 2,000 hare, 650 fox, 280 badger, 95 lynx, 40 wolf, 1,300 western capercaillie, 700 black grouse.

Thanks to the effort of a group of Polish scientists, headed by Professor W. **Szafer**, on 29 December 1921 the decision was taken in the Ministry of Agriculture and State Treasury to establish a nature reserve in the Białowieża Forest. A forest subdistrict and later a forest district was established on the base of demarcated areas of the forest.

Five compartments were considered as the strict reserve: 258, 288, 289, 319, and 344. Compartments located in the fork of the Narewka and Hwoźna River and several neighbouring compartments in the Zwierzyniec Forest District composed the partial reserve. In 1923, the management of the Reserve Forest District was taken up by Professor Józef **Paczoski** (1864–1942), who commenced many scientific studies therein. Then the compartments adjacent to the Browsk road were also considered a partial reserve. On 9 September

1928, the management of the Reserve Forest District was entrusted to the later professor at the Forest Research Institute – J. J. **Karpiński**, PhD.

On 11 August 1932, a bye-law of the Minister of Agriculture on the establishment of the 'National Park in Białowieża' with an area of 4,693.24 ha was published in the *Monitor Polski* (official gazette). That organisational unit was subordinated to the Directorate of the State Forests in Białowieża, but the scientific guidance of the Park was entrusted to the Experimental Station of the State Forests (then transformed into the Research Institute of the State Forests in Warsaw).

Besides, in the territory of the Jasień forest district (compartments 814 and 836), a strict pine forest reserve was established on an area of 338 ha, covering a complex of stands with pine. In the Nikor forest district, a fir reserve (15.2 ha) and a bog reserve (95.25 ha) were located. The so-called 'by the roadside' reserve, 100–500 m wide, was created on the both sides of the road crossing the forest from Białowieża to Hajnówka and Prużana. The forest strip was considered then a partial reserve, from where snags and wind-broken trees were removed. Its area was 1,867 ha. In 1936, two small reserves were created – a spruce coppice reserve (1.8 ha) in compartment 804 (Królewski Most Forest District) and an ivy reserve (0.23 ha) in compartments 646 and 647 (Grudek Forest District).

The north-eastern geographical range limit of ivy (*Hedera helix*) in Europe (5) passes right through the forest.

In the war period, from September 1939 to June 1941, the entire the Białowieża Forest was within the territory of the BSSR (Byelorussian Soviet Socialist Republic). During the German occupation of the Białystok region (from June 1941 to the summer 1944) the Białowieża Forest, together with the Świsłocz, Szereszów and Różana Forests and with the lands of dislodged and burnt villages and settlements in that area, which numbered about 200 and the total area to approx. 270,000 ha, was considered the *Reichsjagdgebiet*, with its administrative body located in Białowieża, led by the *Reichsjagermeister*. That administration was subordinated to the Hitlerian central authorities (The other forests of the Białystok region and the Grodno region, in connection with the incorporation of those lands in East Prussia, were subordinated to the German forest authority then called *Landesforstamt Gumbinen* (Gąbin), through the agency of the *Aussenstelle Białystok*).

In 1940, the three-year annual allowable cut was logged in the Białowieża Forest (24), while in subsequent years only sanitation cutting was undertaken.

In 1944, the forest was split by the state border of the People's Republic of Poland and the Byelorussian Soviet Socialist Republic (BSSR). Approx. 58,000 ha of the area of the forest belong to Poland, while approx. 85,500 ha to the BSSR (including the Świsłocz Forest).

Of the area of the forest located in Poland, part was distinguished as the Białowieża National Park (strict reserve) with an area of 4,747 ha, while 274 ha were dedicated to faunal reserves. Moreover, the palace park covers an area of 50 ha.

The managed area in the Polish part of the forest covers 52,963 ha, including a forest area of 49,906 ha (94.20%), while other productive areas (farmland, meadows, orchards, pastures, usable waters) cover 1,572 ha (3.0%), and unused productive areas (compartment division lines, roads, ditches) 1,112 ha (2.1%), barren land 171 ha (0.3%), and other 202 ha (0.4%).

The area of the Polish part of the forest is divided into eight forest districts: Białowieża, Starzyna, Leśna, Hajnówka, Zwierzyniec, Narewka, Browsk, and Ladzka Puszcza.

The present floristic composition of the Białowieża Forest created by climatic conditions and the collective plant life is the current link of the flora transformations in the post-glacial period. At the primary post-glacial stage, the forest was composed of birch, pine and aspen. At later stages, next to pioneer species (which include e.g. birch, aspen) other species began to appear, such as e.g. oak, hornbeam, which are able to grow in already forested areas (15).

At the end of the last century (7), the tree species covered (by dominant species) the following areas respectively: pine 40%, spruce 20%, oak 30%, ash, maple, aspen, linden, birch, black and grey alder, elm, wych elm, rowan, hornbeam, wild apple and pear tree 37%. The species composition of the stands of the forest, in relation to the area covered by them in 1931 was as follows: pine 42%,[5] spruce 16%, oak 6%, and other species 36%.

The particular tree species, in accordance with the management plan of 1958 for the forest holding in the Polish part of the forest and according to the forest management data of 1968 covered the following areas (%):

Year	Pine	Spruce	Birch	Oak	Alder	Ash	Hornbeam	Other
1958	27	27	16	10	15	2	3	–
1968	26	27	15	9	17	2	3	1

The following tree species that were alien to its flora were introduced to the forest: grey alder (*Alnus incana* Moench.), European larch (*Larix europaea* D.C.), fir (*Abies alba* Mill.), mountain pine (*Pinus mughus* Scop.), horse chestnut (*Aesculus hippocastanum* L.), red oak (*Quercus rubra* L.), Douglas fir (*Pseudotsuga Douglasii* Carr.), Weymouth pine (*Pinus strobus* L.), and Banksian pine (*Pinus Banksiana* Lamb.) (15).

The following species are completely absent in the forest stands: yew, larch, sycamore maple and beech (yew was still growing in 1887 in the Nieznanowo wilderness).

At the high diversity of the stand types in the forest, including the world of herbaceous plants, grasses, ferns, mosses, lichens and fungi, stands out with its amazing variety. Among

[5] **Romanowskij** W. P. and **Koczanowskij** S. B. (22) provide that the pine in the stands of the forest covered in 1890 62.9% of the forested area, which seems to be more likely, in particular in comparison with the species composition of the forest provided earlier, while in 1938, according to the same authors, it was supposed to cover 51.3%.

the plants there are peculiarities like lady's slipper, buffalo grass (bison grass), lesser-butterfly orchid, globeflower and Siberian iris.

Fig. 8.
Elk cow
with offspring
Photo by
J. J. Karpiński

The following types of forest habitats are distinguished in the Białowieża Forest: dry pine forest, coniferous forest (pine and spruce), mixed coniferous forest (oak, spruce, pine), hornbeam-mixed deciduous forests – a drier one (fresh deciduous forest) and a damper one (moist deciduous forest), alder carrs (ash-spruce-alder forests), bog forest (dwarf pine forests, sometimes with an admixture of spruce, alder or birch). The unforested habitats include meadows (sedge) and midforest waters.

Before World War I, stands older than 100 years covered approx. 80% of the total forest area. The devastating German exploitation during World War I and the logging in the inter-war period, and partially in the post-war period resulted in a decrease in the proportion of old forest stands to 37.2% of the forest area by 1958 and approx. 30% by 1968.

The general standing volume in our part of the forest (according to the 1958 inventory) was approx. 10.2 million m^3, of which approx. 57% was coniferous species (pine, spruce), approx. 28% alder and birch, 10% oak and approx. 5% other deciduous, while according to the results of the last forest management plan (1968) the standing volume in the forest increased by 1,155 thousand m^3, i.e. by approx. 10%.

In the first post-war years (1945–1946), the utilisation volume amounted in the forest to approx. 120,000 m^3 of timber (merchantable timber). In the course of the forest management planning carried out in the years 1948–1949, the annual allowable cut in the forest was determined at 165,800 m^3 annually.

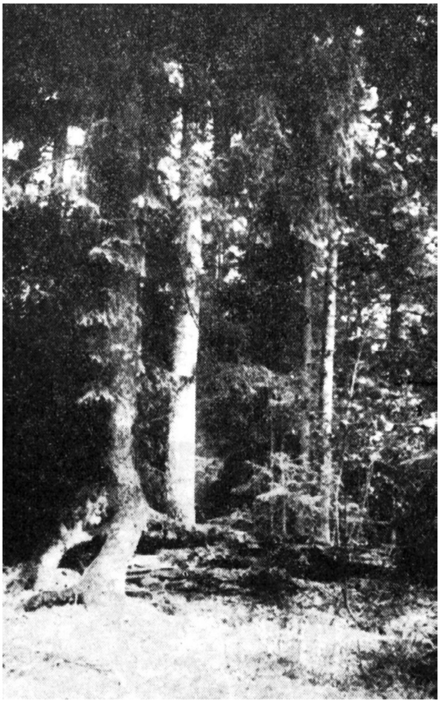

Fig. 9. Deep in the Forest
Photo by J. J. Karpiński

The actual logging in the years 1948/1949– 1957/1958 was on average 189,000 m^3 of the merchantable timber per year (timber from final, intermediate and incidental cutting). In the ten-year period mentioned, a timber volume of 114% in relation to the determined annual allowable cut was harvested.

The utilisation in the forest, with regard to the timber products, in the years 1958/1959 – 1968/1969, compared with the preceding decade, decreased by 159,438 m^3 net. The final cutting, with salvage cutting added, in the years 1958/1959 – 1968/1969 was 119% (without salvage cutting to 87% with regard to volume and to 89% with regard to the allowable cut area). A high proportion of timber from the salvage cutting (405,528 m^3 from final cutting and 19,920 m^3 from intermediate cutting) should be emphasised, as it represents approx. 24% of the entire utilisation.

Because of the necessity of satisfying the growing needs with regard to tourism, the Presidium of the Voivodeship National Council in Białystok, by its resolution dated 7 May 1970, approved the 'land management plan for the Białowieża Forest' developed by the Department of Construction, Urban Planning and Architecture of the PWRN [Presidium of the Voivodeship National Council]. The plan considers especially that approx. 380 ha of forests, the part of which is included in the landscape reserve, shall be excluded from the planned final cutting.

The wood industry plants in Hajnówka affect the demand for timber from the forest. The modern sawmill in operation there recently (1968–1970) processed from 109,000 to 115,000 m^3 of timber annually.

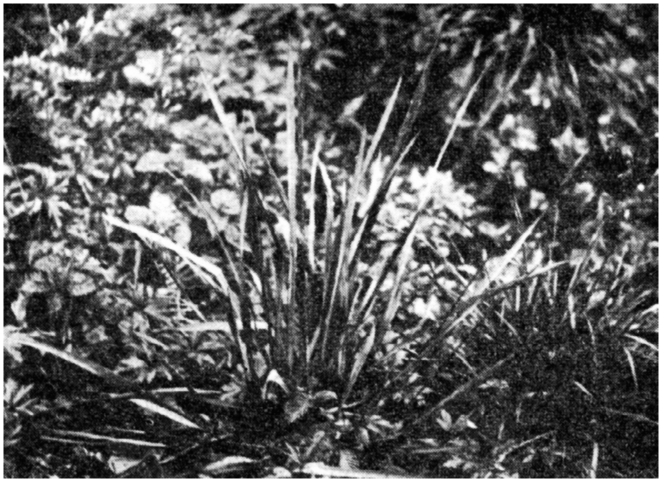

Fig. 10. Buffalo grass – *Hierochloe australis* L. (bison grass) Photo by A. Zdanowski

Moreover, the production of veneers came from 4,800 m^3 (1970) to 5,200 m^3 (1968), while flooring strips – from 360,000 to more than 380,000 m^3 (including more than ⅓ solid strips and the rest of so-called mosaic strips).

Recently, the furniture production has been extended through the construction of a new furniture division of the plant. The planned value of furniture production in 1971 is 107 million zloty. A particle board plant was put into operation in Hajnówka, along with the dry wood distillation factory there.

With regard to non-timber forest products, blueberries, nuts, fungi and resin have been collected (in 1968/1969 25,300 kg of resin was collected).

Despite the harmfulness of forest grazing for the forest holding, partial livestock grazing is traditionally permitted in the forest, due to the lack of sufficient feed base in the surrounding villages.

The total area of forest regeneration in the period 1948/49–1957/58 was 5,062 ha, while in the period 1958/59–1967/68 to 4,815 ha (including 1,036 ha under the shelter of stands). In the last decade, plantation refilling and beating up was conducted for an area of 3,452 ha. The regeneration areas in 1968/69 was 472 ha, while interplanting in the same year to 331 ha.

With regard to the forest fauna, the bison still stands out. Apart from mammals exterminated or lost to the mists of time (aurochs, tarpan, wolverine, wildcat, sable, flying squirrel). The forest deer (*Cervus elaphus balticus* Mat.) became extinct a little bit later. Then bison, elk, bear, lynx, wolf and beaver were exterminated, but those species were re-introduced to the forest or they reappeared there spontaneously. Currently there are no bears in the forest. Species alien to the fauna of the forest were introduced artificially to the forest: red deer, fallow deer *(Dama dama* L.), wapiti (*Cervus canadensis* Mitsch.), Siberian roe deer (*Capreolus mantschuricus* Noack). Wapiti, fallow deer and Siberian roe deer became completely extinct, while red deer stayed for good.

Currently, the following animals live in the Białowieża Forest: bison, beaver, roe deer, red deer, elk, boar, badger, lynx, hare, weasel, pine marten, ermine, otter, and other species.

Birds have relatively good living conditions in the forest. One may find capercaillies, black grouses, hazel grouses, eagle owls, spotted eagles, hawks, common buzzards, kites, cranes, herons, black storks, woodcocks, ducks, loons, duckers, ravens, numerous species of peacocks, thrushes, blackbirds, mistle thrushes, and many others. Ruffs from the sandpiper family constitute the forest's special peculiarity. At the beginning of March 1971, the game population in the Polish part of the forest was as follows: elk 12, red deer 1,355 (1600),[6] roe deer 980 (2,270), boar 580 (691), fox 115 (75), hare 480 (970), lynx 14 (9), capercaillie 17 (26), hazel grouse 515, duck 700. Moreover, at the same time 197 (157) free-roaming bison were living in the forest (in its Polish part), including 37 bulls, 67 cows, 60 one-year-olds, 28 calves and 5 cows excluded from breeding, while in the reserve – 31 (28) bison.[7] Nine horses of tarpan-type are living in the faunistic reserve in the forest.

Currently, there is a harsh issue of damage done in the forest by the deer-type game, bison and livestock grazing. The game population in the forest has exceeded the hunting grounds' capacity. Therefore, only in the economic year 1969–1970, it was planned to shoot 600 deer, approx. 1,000 roe deer, and 300 boars.

A part of the Białowieża Forest within the borders of the BSSR (Byelorussian Soviet Socialist Republic) (79,000 ha in 1968) is located in the Brest District (Kamieniec and

[6] The numbers quoted in brackets mean the game population as of 1 January 1969.

[7] After the end of the war in 1945, 34 bison were in Poland, including 17 in Białowieża. At the beginning of 1967, we had already 232 bison in Poland, including 155 of Białowieża (lowland) subspecies and 77 of the Caucasian-Białowieża hybrid, and also 9 in zoological gardens. On 1 January 1971, there were 336 bison, free roaming and in closed breeding centres, including 264 of Białowieża (lowland) subspecies and 72 of Caucasian-Białowieża hybrid, and over 18 in zoological gardens. The other breeding centres outside Białowieża are: the Borecka Forest, Bieszczady, Niepołomice. Pszczyna, Smardzewice. From 1946 to 1970, the export of breeding bison from Poland to 16 European countries encompassed 142 specimens (including 46 to the USSR). At the beginning of 1971, the total bison population worldwide is estimated at 1,200 specimens.
More important centres besides Poland include: the USSR, Sweden, the German Democratic Republic, the Federal Republic of Germany and 12 other countries conducting smaller breeding units. During the 9th general convention of the International Union for the Conservation of Nature and Natural Resources, at the plenary meeting of the Commission for Rare Animal Species on 29 June 1966 in Lucerne, Switzerland, the Commission approved the appointment of the European Bison Group in it and the list of its members. J. **Żabiński** (Poland), PhD, was elected the group chairman, Professor W. G. **Geptner** (USSR) – the vice chairman, while the group members included Professor K. **Krysiak** (Poland), M. A. **Zabłocki** (USSR), Professor G. **Dathe** (German Democratic Republic), E. **Mohr**, PhD (Federal Republic of Germany), K. **Curry-Lindahl**, PhD (Sweden).

Prużana region) and a part in the Grodno Region (Świsłocz region). The forested area covered 68,200 ha, i.e. 86% of the Belarussian part of the forest. The forest's non-forested area covered approx. 14%, including meadows, pastures, waters – 5.4%, roads, compartment division lines, muds, settlements – 6.1%, blanks and low stocked stands 2.8%. The total area of the Belarussian part of the forest was 85,500 ha as of 1 January 1971.

By 1957, the Belarussian part of the forest was treated as a nature reserve, which was then converted into a reserve and hunting holding. In 1958, the Vygonoschanskoye Lake and the adjacent lands (Łohiszyn region), near the Oginski Canal, were incorporated into the forest.

Pursuant to the resolution of the Council of Ministers of the BSSR dated 2 March 1958, the adjacent 5–15 km wide zone surrounding the forest, once forested and belonging to the forest, was incorporated into it.

In 1967, pine stands in that part of the forest covered 56% of it (in 1963 they covered 40.5% of the forested area of the entire forest, in 1890 – 62.9%, and in 1938 – 51.3% (22)). Among the deciduous species, alder and birch cover the largest areas. The pine stands in the Polish part of the forest in 1958 covered 27% of its area, while in 1968 – 26%.

The average age of pine stands in the Belarussian part of the forest are 89 years and with an average growing stock of 225 m^3 per hectare, the mean current annual increment comes to 3.09 m^3 per hectare.

The bison breeding in the Belarussian part of the forest was started with the handover of five bison from Poland to the USSR in July 1946. From 1946 to 1948, 19 bison were handed over from Poland, including 12 put into a reserve in the Białowieża Forest (including 5 specimen of Białowieża origin and 7 of Caucasian-Białowieża origin). Out of the bison handed over from Poland to the Soviet Union later on (in 1951 three specimens, in 1955 – one specimen, in 1960 – two specimens, and in 1962 – eight specimens), 10 specimens were put into the reserve and hunting holding in Białowieża. According to the state as of 1 January 1963, there were 82 specimens in the Belarussian part of the forest (60 of Caucasian-Białowieża hybrids and 22 of Białowieża subspecies). On 1 January 1965, there were 89 (28) bison, while at the beginning of 1971 59 free roaming bison and three specimens in the reserve. At the beginning of 1971, there were 2,015 (1,700)[8] red deer, 700 (1,100) roe deer, approx. 73 (100) elks moose in the muddy northern part, 1,446 (1,500) boars, 49 (30) lynxes. The beavers, exterminated in the middle of the last century, were re-introduced to the forest.

Approx. 216 bird species were counted in the Belarussian part of the forest, including capercaillies. The area where capercaillies are present in the forest comes to approx. 33,000 ha.

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[8] The numbers quoted in brackets mean the game population as at the beginning of 1965.

Also, the mammals and birds live there, mentioned above with regard to the Polish part of the forest.

The forests of the Belarussian part of the forest are treated as a partial nature reserve, where basically only sanitation cuttings (removal of snags, windfalls, wind-broken trees) and silvicultural-maintenance cuttings are allowed. The game management goals are maximally considered within the entirety of forest management treatments.

From 1945 to 1960, the average annual volume of merchantable timber logged in the forest as a result of sanitation cutting and thinning was 70,800 m^3. From 1950 to 1960, a total of 500 ha was afforested in the forest.

In connection with the melioration (draining) works near the Soviet part of the forest, E. **Bucholz**, PhD, (3) presents the opinion that they might result in lowering of the groundwater level in the forest, and as a consequence lead to the dying out of spruce, which actually happened.

The Belarussian part of the forest is divided into 11 forest subdistricts (equivalent to the Polish forest districts with regard to the area): Świsłocz, Browsk, Oszczepskie, Jaźwiny, Choińskie, Pererowo, Nikoroskie, Królowy Most, Paszukowskie, Jasieńskie, Dmitrowiczskie.

The administration office of the forest's reserve and hunting holding, which comprises a research unit, is located in Kamieniuki (60 km from Brest and 21 km from the regional administrative centre in the town of Kamyenyets).

Since 1958, the Belarussian part of the forest, with a natural museum located in Kamieniuki (since 1963), has been open for tourism. In 1959, it was visited by 14,500 people, in 1965 by 70,000 people, and in 1970 approx. 100,000 people.

The peculiarity of the Białowieża Forest lying within the territory of Poland is the Białowieża National Park. The resolution of the Council of Ministers of the People's Republic of Poland as of 21 November 1947 on the establishment of the Białowieża National Park (Journal of Laws no. 74 of 16 December 1947) created the new legal basis for the further existence of that remarkable object as a strict nature reserve on the area of 4,747 ha (after the incorporation of the meadows by the Narewka and Hwoźna River into the Park).

The Białowieża National Park is the only nature park in Poland classified as a strict reserve, where no economic activities are performed (apart from some cleaning works, such as removal of wood debris from roads). 'The forests, soil, flowing and stagnant waters, as well as plants and animals in the territory of the Park are subject to strict conservation'.

The park serves mainly for scientific, and also for educational and tourism purposes. For tourism purposes, compartments 398, 399 and 369 are available. Recently, Białowieża and the Polish part of the forest have been visited by approx. 100,000 people per year.

Apart from the Białowieża National Park, in the Polish part of the forest there is a sessile oak (*Quercus sessilis*) reserve with an area of 24.51 ha (Hajnówka Forest District, Subdistrict Lipiny, compartment 272D) covering a fragment of a primeval mixed deciduous forest. That reserve was established by the regulation of the Minister of Forestry and Wood Industry as of 12 December 1961. Furthermore, the forest strip along the road connecting Białowieża and Hajnówka, 500 m wide on each side of the road, still constitutes a partial reserve with the area of 1,356.91 ha. The regulation of the Minister of Forestry and Wood Industry dated 8 April 1969 on the establishment of that reserve was announced in the *Monitor Polski* (official gazette) in 1969 (no. 16, item 128).

The currently planned nature reserves in the forest include the 'Hwoźna' reserve, which is to cover meadows by the right bank of the Hwoźna River (from the state border to the mouth of the Hwoźna River to the Narewka River), together with an adjacent forest strip (Browsk Forest District) and the Głuszcowy reserve with the area of 160 ha (Browsk Forest District), which aims at the conservation of stands in fresh, moist and bog coniferous forest habitats and peat bogs as lekking grounds for capercaillies.

Outside of the Park area, many monumental trees were also distinguished in the forest as natural monuments.

In Białowieża, the scientific-research activity commenced in the inter-war period in the Reserve Forest District by Professor J. **Paczoski** and then developed by Professor J. J. **Karpiński** is being continued.

In 1945, a branch of the IBL [Forest Research Institute] was established in Białowieża, whereas the Białowieża National Park became subordinated to it. Professor J. J. **Karpiński** was the head of the Branch of the Institute established in 1952 and of the Białowieża National Park. In 1952, the Department of Primeval Forest Research was established in Białowieża, converted then in 1954 into the Laboratory of Primeval Forest Research of the Department of Forest Ecology of the Forest Research Institute. This unit was managed from 1952 to 1956 by Associate Professor S. **Graniczny**, PhD, from 1956 to 1961 by Associate Professor R. **Pachlewski**, PhD, and since 1962 by Associate Professor A. W. **Sokołowski**, PhD.

In 1952, a Geobotanical Station was put into operation in Białowieża, established on initiative of Professor W. **Matuszkiewicz**, PhD, as a continuation of the Plant Ecology Station of the Forest Research Institute existing in the years 1949–1952. In the period 1952–1962, that station was subordinated to the Polish Academy of Sciences and since 1 Maj 1962 it belongs to the Department of Applied Phytosociology of the University of Warsaw. Associate Professor J. B. **Faliński**, PhD, is the head of the Geobotanical Station.

In 1954, the Mammal Research Department of the Polish Academy of Sciences was established in Białowieża. Professor A. **Dehnel**, PhD, was the organiser and first manager of the Department. Currently, the Department is managed by Associate Professor Z. **Pucek**, PhD.

Apart from the mentioned research departments, a post of the State Institute of Meteorology and Hydrology is located in Białowieża, while the primeval forest natural museum now has the character of an exhibition for visitors. The museum is led by Cz. **Okołów**, PhD. In 1970, 77,000 guests, including approx. 2,000 foreigners, visited the museum.

As a result of the research conducted in the forest and collected materials, so far numerous papers of scientific and economic significance have been published, as works of popular-scientific or popular character, starting with such scientific works as *Lasy Białowieży* [The Forests of Białowieża] (1930) by J. Paczoski, 'Fauna korników na tle panujących w Puszczy Białowieskiej drzewostanów' [Bark beetle fauna in context of the stands dominant in the Białowieża Forest] (1933) by J. J. **Karpiński** and later papers by **Paszewski** (1935) and **Poznański** (1937) including studies on the forest history conducted with the application of the pollen analysis method. Also, in the inter-war period (1936), T. **Włoczewski** started on the established permanent sample plots the pedological research and the research on the variability of the primeval forest structure. The oldest papers concerning the flora of the forest are represented by the paper by J. E. **Gilbert** (invited from France by A. **Tyzenhauz**) titled *Indagatores naturae in Lituania seu opuscula varii argumenti* and published in 1781 in Vilnius. Approx. 2,300 papers on the forest have been published so far.

Apart from the research conducted currently in the forest by the research units based in Białowieża, it is also conducted by other units of universities, the Polish Academy of Sciences and institutes subordinated to ministries.

Considering the fact, that the research is conducted in the forest by various scientific institutes, it seems to be purposeful to entrust its coordination and general management to the Polish Academy of Sciences.

Currently, J. **Budzyn**, MSc, BEng is the Director of the Białowieża National Park, T. **Mokrzycki** BEng is the Director of the forest vocational school in Białowieża, L. **Miłkowski**, MSc, BEng is the inspector of the Białowieża Forest, while Roman **Filipowicz**, MSc, BEng is the Director of the Regional Board of the State Forests in Białystok, to which the forest is subordinated.

Based on the previous management experience in the forest, it is undoubtedly necessary to implement changes in its management by classifying the entire forest as group I forest of special destination and harmonising the management in both forest parts. Such a necessity results, among other things, from the fact that the forest constitutes one forest complex, although it is split by the state border. A failure to apply uniform principles in the both parts of the forest also with regard to the game management shall induce permanent complications, resulting e.g. from the game wandering around the entire forest and damaging it.

In April 1971, the Polish Forest Society appealed in the form of a memorandum to the Minister of Forestry and Wood Industry for the recognition of the Białowieża Forest as a group I forest and to base its management on the principles specified in a special statute. In addition, the Forest Sciences Committee of the Polish Academy of Sciences adopted in April 1971 a resolution concerning the recognition of the Białowieża Forest as a group

I forest. The Department V of the Polish Academy of Sciences sent a letter on that matter to the Minister of Forestry and Wood Industry.

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Stefan Graniczny

On the new management principles in the Białowieża Forest

In January 1975, the Minister of Forestry and Wood Industry approved the new 'Basic principles of the forest management conduct in the Białowieża Forest'. Its content is discussed later due to a special significance of this act.

The pursuit of the conservation of natural, material, and social-scientific values of the forest has a centuries-long tradition (2, 3, 12, 20, 21).

In the inter-war period, from 1918 to 1939, that activity was performed by many distinguished people, such as: W. **Szafer**, J. **Paczoski**, J.J. **Karpiński**, J. **Sztolcmann**, T. **Vetulani**, O. **Hedemann**, W. **Niedziałkowski**, J. **Kostyrko**, J. **Kloska**, T. **Włoczewski**, M. **Romanow**, and W. **Stankiewicz** (13, 20, 21).

After the war damage period from 1940 to 1945 (20, 21), the scientific and nature conservation activity was resumed and extended on the present territory of the forest, which was joined by many other scientists (13). However, periods of intensive exploitation of the forest during the Partitions by the year 1897 and in the years 1915–1918 and 1924–1929, as well as in later years and also the current increase of the not always properly obtained annual allowable cut have led to a decrease in the stands' growing stock (21). Despite the establishment of the Białowieża National Park in the People's Republic of Poland and the issuing of regulations modifying the management in the forest, strong distortions of species composition and the structure of stands occurred over a large area (21), accompanied simultaneously by a poor state of the regeneration (6) and forest maintenance, and by a successively increasing size of damage caused by the game and the free roaming bison (9, 10).

The year 1958 was a breakthrough one for the commencement of efforts to restore the stands in the forest (11, 16, 17, 20, 21, 22).

At the conferences of the Forest Sciences Committee of the Polish Academy of Sciences with participation of a group of deputies – members of the Forestry and Wood Industry Committee of the Sejm [translator's note: lower house of the Polish Parliament], as well as on sessions of the Polish Forest Society, one started to postulate the distinguishing of the forest as a special object with group I forest features and a proposal was formulated to provide it with a separate statute (W. **Sosnowski**, MSc, Professor F. **Krzysik**, PhD, M. **Czuraj**, MSc, et al.).

Further positive events within that scope included the limitation of final cutting to the calculated level of the annual allowable cut and maintaining heightened final cutting age levels.

Another action involved the initiation of expertise research in the years 1960–1962 under the leadership of Professor E. **Ilmurzyński,** with the participation of a large team of scientists and practitioners, concluded by the development of a set of regional management principles (5, 7, 14). In 1965, on the initiative of the Forest Management Commission of the PTL [Polish Forest Society] and OZLP [Regional Board of the State Forests] in Białystok, by Regulation no. 18 of the Minister of Forestry and Wood Industry as of 16 March 1965, the Budy Experimental Forest Subdistrict was appointed, where the implementation of the new principles of management was launched, with consideration of the so-called detailed silvicultural planning (1). Further research projects are now also conducted.

The efforts aimed at categorisation of the Białowieża Forest as a group I protection forest were continued in the years 1968, 1970 and later (Professor J. J. Karpiński, Professor E. Więcko (20) et al.) with the participation of thematic commissions of the PTL, i.e. the Forest Management Commission, the Commission on the History of Forestry, the Forest Economics and Management Planning Commission, and with support from the Forestry Committee of the Polish Academy of Sciences.

The appeal of the General Board of the PTL directed in that matter to the Minister of Forestry and Wood Industry on 25 April 1971 (18 p. 40; 21 p. 151–152) was a pregnant mark. Following to the pleas filed to the IBL (8, 9, 10), on 13 March 1974, the Forest Research Institute also presented its positive opinion to the Ministry of Forestry and Wood Industry (15).

At that time, the OZLP [Regional Board of the State Forests] in Białystok, with the participation of local branches of the PTL and STLiD [Association of Technicians of Forestry and Wood Industry], developed several versions of the Białowieża Forest statute, which were reviewed by a large group of scientists (10).

The efforts to provide the forest with its own statute were supported for several years by the scientists from the research units located in Białowieża, e.g. Associate Professor J. B. **Faliński**, as well as society, press and television.

At the final stages, consultation meetings were organised at the NZLP [General Board of the State Forests], e.g. on 28 May 1974 under the leadership of the then 1st Deputy of the Director General of the State Forests, B. **Mikstacki**, PhD, BEng and in Białystok with support for that matter by the 1st Secretary of the Voivodship Committee of the Polish United Workers' Party and the Chairman of the WRN [Voivodship National Council] – Zdzisław **Kurowski**, MSc, BEng and the Białystok Voivode, Zygmunt **Sprycha**, PhD (23).

An expression of collegial gratitude should be directed to numerous foresters of the Białystok region and submitted for attention of the Director of the OZLP [Regional Board of the State Forests], R. **Filipowicz**, MSc, BEng and the Deputy Director W. **Sosnowski**, MSc, BEng as well as to everyone who contributed to the successful completion of the long-standing efforts to demerge the Białowieża Forest in management terms.

Currently, it is most important to bring into being the provisions of the mentioned regulation dated 30 January 1975. In this paper, it is possible to discuss only the most significant provisions or those that require interpretation. These determinations lead basically in two directions – towards intensifying activities within the scope of nature conservation and towards a forest management method most appropriate for the forest.

The postulates striving for the maintenance of a diverse, natural species composition and often a multi-storey, uneven-aged structure of the stands, as well as for the preservation of natural hydrologic and soil formation relationships, are very important. In addition, it is vital to maintain a relative balance within the biocenosis in the sense of, among others, the impact of fauna on the forest flora (e.g. impact of the game on the condition of regeneration and stands).

The settlement of many of these issues is left in the hands of the appointed Techno-Economic Commission, if necessary extended by the participation of scientists and people relevant in professional and social terms. This is one of the fundamental stipulations, because only such a body operating permanently in the forest's area may control and adjust the economic, scientific and social activities within its territory.

The principle saying that the final cutting is to be carried out strictly according to the detailed harvesting plans is to be valid in the Białowieża Forest, meaning that any top-down assortment planning and exceeding the calculated annual allowable cuts are excluded. The calculation of the annual allowable cut is planned to be carried out on the base of the last three age classes, i.e. overmature, mature and premature stands. In the event of a shortage of premature stands it allows the adjustment of the allowable cut and for the attainment of a more beneficial age structure of the stands.

Adopted is the valid cutting age, higher than formerly, modified for some species by the Techno-Economic Commission.

The calculation method for the allowable cut itself may be modified in my opinion depending on the arrangements that will be stipulated by the Silvicultural Principles and the Forest Management Planning Instruction, which are currently being amended for the entire country.

The extension of the number of holdings by forests of tourist significance, so-called highly productive forests and other has been postulated. The need for distinguishing water protection woods in the forest has been also indicated. The specificity of forests considers the need for a conversion of stands of small-seeded species distorted stands and low productive stands being under a conversion process. In addition, it is recommended to apply more widely the improved cutting systems with detailed silvicultural planning. All these elements impose a wide scope of duties on the Techno-Economic Commission.

An increase in the acreage of protection forests, nature reserves and the number of nature monuments postulated in the regulation of the Minister of Forestry and Wood Industry induces an analysis of these matters. Firstly, it enforces the establishment of distinguishing criteria and possibly a review the previous criteria. Currently, Associate Professor A **Sokołowski**, PhD, DSc, from the IBL [Forest Research Institute] cooperates within that scope with the OZLP [Regional Board of the State Forests] in Białystok.

In addition, a modification of the forest management planning method for the forest seems to be necessary. That concerns, among others, the methods of calculating the annual allowable cut under special circumstances. It must be possible, under justified circumstances, to leave upon the removal cutting some trees not only of monumental nature, but also thinner ones, suitable for the further growth and stand structure diversification, but not disturbing the growth of the regenerated forest. Currently, the OZLP has initiated an adjustment of the cutting plans.

The regulation exacts also the establishing of a relevant game management system and the breeding of up to 230 free roaming bison, in a way that does not interfere with the growth of the stands.

The totality of the tasks discussed here requires the conducting of more extensive research in the forest and a simultaneous encouragement of the Forest Research Institute and other institutions in this sense.

The matter of organisation of properly managed tourism in the forest is also very important.

The more tasks there are, the higher is the demand for a workforce and qualified personnel, who can only be kept working in the forest through improved living and social conditions.

An intensification of duties, an enhancement of the new work tasks and investment needs may involve the necessity of various training activities and a gradual reorganisation of the management. However, as experience has shown, the managers and their support factors shall not run out of the necessary energy and initiative in this direction.

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Aleksander W. Sokołowski

Overview of forest communities of the Białowieża Forest

The phytosociological of the forests of the Białowieża Forest conducted in the course of last fifteen years has significantly broadened our knowledge about the forest communities, which is included in the studies of **Paczoski** (5), W. **Matuszkiewicz** (4), A. **Matuszkiewicz** (3), A. **Matuszkiewicz** and W. **Matuszkiewicz** (2). The review of plant communities of the Białowieża Forest authored by **Faliński** (1) also requires to be supplemented and changed within the scope of forest associations.

According to the last synthetic study, in the Białowieża Forest there are 22 syntaxa in the rank of association, divided into lower units, such as sub-associations and variants. Their taxonomy is as follows:

Class: *Vaccinio-Piceetea* Br.-Bl. 1939
Order: *Vaccinio-Piceetalia* Br.-Bl. 1939
Alliance: *Dicrano-Pinion* Libb. 1933
Association: *Cladonio rangiferinae-Pinetum* Juraszek 1927
‘ *Vaccinio vitis-idaeae-Pinetum* ass. nova
‘ *Vaccinio myrtilli-Pinetum* (Kobendza 1930) emend.
‘ *Vaccinio uliginosi-Pinetum* Kleist 1929
Alliance: *Vaccinio-Piceion* Br.-Bl. 1938
Association: *Vaccinio-myrtilli-Piceetum* ass. nova
‘ *Sphagno Girgensohnii-Piceeum* (Polakowski 1962) emend.
‘ *Betulo pubescentis-Piceetum* ass. nova
‘ *Calamagrostio arundinaceae-Piceetum* Sokołowski 1968
‘ *Querco-Piceetum* (Mat. 1952) emend. Sokołowski 1968
Alliance: *Pino-Quercion* Medw.-Korn. 1959
Association: *Pino-Quercetum* Kozł. 1925 em. Mat. et Pol. 1955
‘ *Calamagrostio arundinaceae-Pinetum* ass. nova
Class: *Querco-Fagetea* Br.-Bl. et Vlieger 1937
Order: *Quercetalia pubescentis* Br.-Bl. 1931
Alliance: *Quercion petreae-pubescentis* Jakucs 1961 em. Medw.-Korn. 1972
Association: *Potentillo albae-Quercetum* Libber 1933
Order: *Fagetalia silvaticae* Pawłowski 1928

Alliance: *Carpinion betuli* Oberd. 1953
Association: *Melitti-Carpinetum* Sokołowski 1976
' *Corylo-Piceetum* Sokołowski 1973
' *Tilio-Carpinetum* Traczyk 1962
Alliance: *Alno-Padion* Knapp 1942
Alliance: *Alno-Padion* Knapp 1942
Association: *Circaeo-Alnetum* Oberdorfer 1953
' *Piceo-Alnetum* ass. nova
' *Ficario-Ulmetum campestris* Knapp 1942
Class: *Salicetea purpureae* Moor 1958
Order: *Salicetalia purpureae* Moor 1958
Alliance: *Salicion albae* R. tx. 1955
Association: *Salici-Populetum* R. Tx. 1931 Meijer Drees 1936p.
Class: *Alneta glutinosae* Br.-Bl. et R. Tx. 1943
Order: *Alnetalia glutinosae* R. Tx. 1937
Alliance: *Alnion glutinosae* (Male. 1929) Meijer Drees 1936
Association: *Carici elongatae-Alnetum* Koch 1926
' *Carici elongatae-Quercetum* Sokołowski 1972
Alliance: *Pino-Betulion pubescens* fed. nov.
Association: *Dryopteri thelypteris-Betuletum pubescentis* Czerwiński 1972

1. *Cladonio rangiferinae-Pinetum* – *Cladonia* coniferous forest. It is equivalent to a dry coniferous forest. It is characterised by the dominance of lichens, mainly of *Cladonia* type, in the moss layer. It is very rare in the area of the Białowieża Forest. Several small patches may be found in the Browsk and Starzyna forest management units. Recently declining due to the [progress of forest] regeneration. In the territory of the Białowieża National Park not present.
2. *Vaccinio vitis-idaeae-Pinetum* – cowberry coniferous forest. It is equivalent to a fresh coniferous forest. It is divided into two sub-associations: *cladonietosum* and *myrtilletosum*. The first one includes associations present in the driest habitats and is characterised with the presence of xerothermic species, including lichens. However, they cover no more than 5–10% of the patches' area. A very limited share is also taken by *Vaccinium myrtillus, Hylocomium splendens* and *Ptilium crista-castrensis*.
   The *myrtilletosum* sub-association is characterised by a lack of extremely xerothermic species. *Vaccinium myrtillus* is the major component of the herb layer here.
   This association is found in the Białowieża Forest mainly in the following forest management units: Browsk, Starzyna, Lacka Forest and on a small area of the Białowieża National Park.

3. *Vaccinio myrtilli-Pinetum* – bilberry pine forest. It is equivalent to a moist coniferous forest. It is usually characterised with a lush growth of *Vaccinium myrtillus* and the presence of *Molinia coerulea* and a small quantity (coverage up to 5%) of *Vaccinium uliginosum*, and *Polytrichum attenuatum* and *Sphagnum apiculatum* (coverage up to 10%) in the moss layer.

   This association is present on gleyic podzols, moderately or strongly podzolic, or haplic gleysols, formed from loose sands with shallow groundwater level.

   Two variants are distinguished for the bilberry pine forest: typical variant and a variant with *Pteridium aquilinum*. The latter covers slightly richer habitats and is characterised by a high share of bracken and a lusher stand.

   This association is quite common in the Białowieża Forest. It is found also on small areas in the Białowieża National Park.
4. *Vaccinio uliginosi-Pinetum* – bog bilberry coniferous forest. It is an equivalent to the bog forest. It is characterised by a large share of *Vaccinium uliginosum* and *Ledum palustre* covering more than 10% of the patches' area and a high share of blunt-leaved bog moss in the moss layer. Raised bog species appear here in small quantities (coverage up to 5%).

   The bog bilberry coniferous forest shows a division into two sub-associations: *Vaccinio uliginosi-Pinetum molinietosum* and *Vaccinio uliginosi sphagnetosum*. The first one is formed on peaty podzols and is distinguished by a higher share of species typical for coniferous forest habitats, while the latter is found on peaty soils and is characterised with a higher share of raised bog species, mainly blunt-leaved bog moss species.

   This association is found in the Białowieża Forest mainly in the Browsk forest management unit. In the Białowieża National Park it creates a few small patches.
5. *Vaccinio myrtillin-Piceetum* – bilberry spruce forest. It is classified as a fresh coniferous forest. It is characterised by a stand composed of spruce, rarely with an admixture of common birch and sporadically of pine. Bilberry and coniferous forest moss species dominate in the ground cover composed of few species. The soil has the nature of a gleyic podzol or a haplic gleysol, formed from loose or slightly loamy sand. This association shows an expansion. Its share in forests increases at the cost of the *Vaccinio Myrtillin-Pinetum* association. It exists in small patches all over the Białowieża Forest and in the Białowieża National Park.
6. *Sphagno Girgensohni-Piceetum* – bog moss spruce forest. It is classified as a moist mixed coniferous forest or alder carr with coniferous forest species. This attribution is not appropriate due to specific habitat conditions and a specific dynamics. It should constitute a separate forest habitat type.

The bog moss spruce forest is characterised by a spruce stand with full canopy closure, with a small admixture of pine, more seldom birch and a ground cover typical for coniferous forest, with a share of bog species and a high share of peat mosses in the moss layer. It exists on moderately acid peaty soils. It shows a division into two sub-associations: *vaccinietosum myrtilli* and *dryopteridetosum thelypteris*. The first one is floristically poor, of a distinctly coniferous forest nature, with a lush moss layer, while the latter is floristically much richer, characterised with a high share of bog species, less lushly developed moss layer and strongly tufty structure of the soil surface. It is found in the forest mainly in the forest management units: Browsk, Białowieża and Leśna. In the Białowieża National Park mainly the *Sphagno Girgensohnii-Piceetum myrtilletosum* sub-association can be seen.

7. *Betulo pubescentis-Piceetum* – peat moss mixed coniferous forest. Categorised as a moist mixed coniferous, although it should constitute a separate forest habitat type.

   This association is characterised by a stand composed of spruce with an admixture, often quite significant, of downy birch, black alder and pine. Coniferous forest species dominate in the herb and moss layer, which is characterised by a low coverage coefficient. It exists on peaty soil with a high degree of decomposition. The soil surface shows a strongly tufty structure. It is found rarely in the territory of the forest, on small areas. Represented fragmentarily in the Białowieża National Park.

8. *Calamagrostio arundinaceae-Piceetum* – pine-spruce fresh mixed coniferous forest. It is equivalent to a fresh mixed coniferous forest. It is characterised by a stand composed of robust spruce showing good natural regeneration. Quite rich ground cover of a coniferous forest nature, usually with a high share of *Vaccinium myrtlillus* and an admixture of numerous mesotrophic species. Deciduous forest species appear in small amounts. It is formed on brunic arenosols or podzolic cambisols, formed of slightly loamy or loose sands.

   This association constitutes the main type of mixed coniferous forest within the northern geographical range limit of spruce. It covers large areas in the Białowieża Forest. It is well represented also in the Białowieża National Park.

9. *Querco-Piceetum* – oak-spruce moist mixed coniferous forest. It is equivalent to a moist mixed coniferous forest. It is characterised by a robust stand composed mainly of spruce with admixture of oak, aspen, birch, sporadically pine. *Vaccinium myrtillus* is the major species in the herb layer. The moss layer develops poorly. This association is present on podzolic gleysols, formed of fine-grained loose sands, more seldom of slightly loamy sands, with quite shallow groundwater level. It is quite common in the forest and in the Białowieża National Park.

10. *Pino-Quercetum* – pine-oak mixed coniferous forest. It is equivalent to a fresh mixed coniferous forest. It is characterised by a stand composed of oak, common birch and

pine. *Vaccinium myrtillus* dominates in the ground cover characterised by an extremely coniferous forest nature. The moss layer develops poorly. In the Białowieża Forest, this association is found rarely. Here, it has the nature of a relict. Its habitats are occupied by the *Calamagrostio arundinaceae-Piceetum* association. It is an association of Central European character appearing as the major type of mixed coniferous forest in Central and Western Poland. Not present in the Białowieża National Park.

11. *Calamagrostio arundinaceae-Pinetum* – reed grass-pine mixed coniferous forest. It is equivalent to a fresh mixed coniferous forest. It is characterised by a stand with loose canopy cover composed of pine and common birch. The spruce is usually present in the lower tree layer. This association is characterised by an abundant flora and with the presence of xerothermic species, including those representative for the bright oak forest. It has a typical character of a coniferous forest. The grasses take a high share in the herb layer, as they grant this association a specific physiognomy. It is found in flat sites, on brunic arenosols formed of fine-grained loose sands, with a quite high share of silt fraction. It is observed mainly in the Starzyna and Białowieża forest management units, as well as spottily in the other ones. In the Białowieża National Park, it exists on a small area.
12. *Potentillo albae-Quercetum* – bright oak forest. It is equivalent to a mixed deciduous forest. It is characterised by a stand with broken canopy closure, composed of oak, with an admixture of pine, common birch and sporadically aspen. The ground cover is very lush, with a share of xerothermic species. The mesotrophic species dominate in the lush ground cover. The bright oak forest association is found in elevated sites, on haplic cambisols, formed of light loamy sands, often of silty sands.
    At present, this association is declining as a result of becoming dominated by hornbeam and as a consequence it is transformed into the *Melitti-Carpinetum* association. In the forest it is found currently quite rarely, usually in small areas. Not present at all in the Białowieża National Park.
13. *Melitti-Carpinetum* – bastard balm oak-hornbeam forest. It is equivalent to a mixed deciduous forest. The stand with full canopy closure is composed of oak and hornbeam, with a small admixture of pine, birch, more seldom aspen and linden. Quite rich ground cover is composed of species characteristic for an oak-hornbeam forest, among which a small admixture of coniferous forest plants and plants specific for bright oak forest is found. It occurs on haplic cambisols or on luvisols formed of loamy sands.

    This association occurs in two forms: with and without spruce. Due to spruce expansiveness, the share of the form with spruce increases. In the forest, the bastard balm oak-hornbeam forest constitutes the major forest type, next to the oak-hornbeam forest and mixed coniferous forest. It covers large areas in the Białowieża National Park.

14. *Corylo-Piceetum* – hazel-spruce mixed deciduous forest. It is also equivalent to the mixed deciduous forest. It is characterised by a robust spruce stand, high share of hazel and a mesotrophic character of the vegetation in the herb layer. Numerous oak-hornbeam forest species, with a small admixture of coniferous forest plants, occur in the ground cover. It is found on similar soils to those typical for *Melitti-Carpinetum*. On the areas to the north of the Białowieża Forest, this association replaces the bastard balm oak-hornbeam forest. In the forest it is represented fragmentarily.
15. *Tilio-Carpinetum* – oak-hornbeam forest. The most common forest type. It exhibits a differentiation into a number of units dependent on the habitat yield and its humidity. It includes the following associations:
    a. *Tilio-Carpinetum typicum* – typical oak-hornbeam forest; it covers communities of a mesotrophic character referring, on the one hand, to the *MelittiCarpinetum* association, and, on the other hand, to the *Tilio-Carpinetum calamagrostietosum* sub-association. However, it features a clear individuality. It is found mainly on small surfaces. It is an equivalent of the fresh deciduous forest.
    b. *Tilio-Carpinetum stachyetosum* – hedge woundwort oak-hornbeam forest; it includes the most eutrophic oak-hornbeam communities. It's clearly distinctive species include *Stachys silvatica*, *Anemone ranunculoides*, *Corydalis solida*, *C. cava*, *Gagea lutea*, *Isopyrum thalictroides*. The soil for this sub-association has a luvisol or cambisol character, formed of very diverse substrates: from heavy loams to light loamy sands.

    This sub-association features a differentiation into two variants: the fresh variant and the moist one. They depend on the soil humidity. The fresh variant is an equivalent of fresh deciduous forest, while the moist variant of moist deciduous forest.

    c. *Tilio-Carpinetum caricetosum remotae* – sedge oak-hornbeam forest; it is floristically poorer than the previous one and is distinguished by a poorer development of a stand composed mainly of hornbeam with admixture of oak and spruce, more seldom of linden and others. It is found on carbonate-free gleysols or albeluvisols with various granulometric composition, poorly permeable. During the thaw and after heavy rains water stays on the soil surface for a long time. The sedge oak-hornbeam forest is an equivalent of the moist deciduous forest.
    d. *Tilio-Carpinetum calamagrostietosum* – reed grass oak-hornbeam forest; it constitutes the poorest sub-association of the oak-hornbeam forest. It is characterised by a reduced share of oak-hornbeam forest species and with a low share of coniferous forest plants. It is found on gleyic podzols formed of loose or slightly loamy sands with a shallow groundwater level. Patches of this sub-association are classified as mixed deciduous forest.

e. *Tilio-Carpinetum circacaetosum alpinae* – sapric oak-hornbeam forest; it occurs usually in a mosaic arrangement with the riparian forest of *Circaeo-Alnetum* type. Besides the oak-hornbeam forest species, riparian forest species and oligotrophic species may be found here. It results from the diversity of the microrelief of the soil surface that creates a number of distinct microhabitats. The soil features the character of a sapric gleysol with a shallow groundwater level. The communities of muck oak-hornbeam forest are classified as moist deciduous forest.

All sub-associations of the oak-hornbeam forest are well represented in the Białowieża National Park.

16. *Circaeo-Alnetum* – ash-alder riparian forest. It is equivalent to an alder-ash carr. It is widespread in the forest. It features a division into two sub-associations:
    a. *Circaeo-Alnetum ranunculetosum* that is found on muddy soils, with a relatively thin humus accumulation level.
    b. *Circaeo-Alnetum urticetosum* that is found on sapric soils, with a bloomy growth of nettle.

    Both sub-associations appear on large surfaces in the Białowieża National Park.
17. *Piceo-Alnetum* – alder-spruce riparian forest; it is characterised by a stand composed of spruce with an admixture of alder. Ash and birch constitute a small admixture. Apart from numerous riparian and oak-hornbeam forest species, the ground cover includes also oligotrophic species, such as *Vaccinium myrtillus*, *Pirola secunda*, *and Lycopodium annotinum*. It occurs on sapric soils of significant thickness. In the Białowieża National Park it is found fragmentarily. The riparian forests of this type are classified as alder-ash carr.
18. *Ficario-Ulmetum campestris* – ash-elm riparian forest. It is equivalent to a riparian forest. It is characterised by the occurrence of *Ulmus scabra* and *U. campestris* in the stand, while in the herb layer, next to riparian forest species, by the presence of *Anemone ranunculoides, Gagea lutea, Ficaria verna, Adoxa moschatellina*. It is found on fine grained gleysols. It is found on small areas, while only fragmentarily in the Białowieża National Park.
19. *Salici-Populetum* – poplar-willow riparian forest; it exists in form of very small fragments in several spots by the Narewka River.
20. *Carici elongatae-Alnetum* – alder carr, equivalent to a typical alder carr; it features an extremely tufty structure and a stand development being much poorer than in case of *CircaeoAlnetum*. Ash is only a small admixture here that gives way to alder with regard to dimensions. It is widespread in the forest and in the Białowieża National Park.
21. *Carici-elongatae-Quercetum* – sedge-oak forest; it is distinguished by a robust oak stand, with the ground cover composed of different sedge species and alder carr species. It grows on gleysol, with a shallow groundwater level. In springtime, water

stagnates for quite a long time on the soil surface. This association is well-developed in the Białowieża National Park. It exists on small areas in the managed part of the forest.

22. *Dryopteri thelypteris-Betuletum pubescens* – pine-birch bog forest; it is marked by a stand composed of downy birch and pine, with an admixture of spruce. In the ground cover, apart from numerous alder carr species, one may find many species typical of a coniferous forest, bog forest and raised bog. It occurs on peat soil of significant thickness. It is particularly well-formed in the Białowieża National Park and in the Browsk forest management unit. It may also be found in the Białowieża forest management unit. This association has no equivalent forest habitat type.

In the Białowieża Forest, out of the forest associations present in north-eastern Poland, only two are missing, that is *Stellario-Alnetum* chickweed-alder riparian forest and *Populo tremulae-Quercetum* aspen-oak moist mixed coniferous forest. The first one is found in lake lands on the alluvia of swift-flowing streams, while the latter is widespread in Central Poland, as in the Białowieża Forest its habitats are occupied by the boreal association *Querco-Piceetum*. Therefore, an almost full set of associations existing in north-eastern Poland may be found in the forest. In addition, associations of Central European and boreal character occur here next to one another. In the class of *Vaccinio-Piceetea* coniferous forests, communities of boreal character prevail. However, in the class of *Querco-Fagetea* deciduous forests, communities of Central European character prevail.

This rich abundance and diversity of flora of the Białowieża Forest, accompanied by a good condition of the maintenance of natural environmental relations testifies to its high scientific value. It meets all the conditions imposed on biosphere reserves. Therefore, it may widely serve for the needs of forest experimental research and for studies on the fundamentals of the conservation and formation of the natural environment.

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Stefan Graniczny

Changes in the principles of forest management in the Białowieża Forest from 1929 to 1976[1]

The Białowieża Forest has been the object of special interest for foresters, biologists and society in general, which is proven by the rich literature from the last 150 years, exceeding 3,250 items in all (8, 12). All authors emphasise the environmental specificity of the forest, its multifunctional role and the need for a non-standard economic approach to it. The economic role of the forest has changed its character, depending on the historical period.

In the period of Royal Poland, the forest performed the role of a breadbasket and a site of the beginnings of the country's industry (hunting, beekeeping, extraction of potash, bog iron ore, etc.) (2, 14). Gradually, the forest became of increasing interest with regard to timber logging, the settlement period began and after the Partitions – the period of extensive logging followed (Karcow G. – 6). Forest fires, as well as treating the forest as tsarist menagerie at the turn of 19th and 20th century (14) also caused large changes in the forest stands.

Since 1915, the Białowieża Forest began to be considered a bottomless warehouse of valuable timber, which caused catastrophic clear-cuts and high-grading during World War I, and then forest exploitation under an agreement with an English company – The Century European Timber Corporation, and then further harsh utilisation conducted with diverse methods (14). The indicators of such a great interest in wood resources are constituted by changes in the cutting age of major tree species (Table 1) and the timber logging volume in particular periods. Approximate figures of the timber logging volume in the Białowieża Forest are as follows (1, 14):

a. In the 18th and 19th century, several million m^3 were logged (periodically up to 260,000 m^3/year). In the years 1915–1918, the German occupant logged, according to J. J. **Karpiński**, 5 million m^3, according to others 2.6 million m^3. From 1918 to 1923, the Polish administration exploited approx. 2 million m^3. From 1924 to 1929, the English company C. E. T. C. [Century European Timber Corporation – Ed.] harvested nearly 2 million m^3. In the years 1931–1939, over 3 million m^3 were harvested.

[1] Abstract of a paper presented on the conference organised by PTL [Polish Forest Society] and OZLP Białystok [Regional Board of the State Forests in Białystok] in Białowieża, on 23 and 24 June 1978.

b. During World War II, from 1940 to 1941, 1–1.5 million m^3 were harvested. According to the data from A. **Czerwiński**, in the years 1949–1978, from an area of half the size, approx. 4 million m^3 were obtained from final cutting and approx. 1.5 million m^3 from intermediate cutting. In addition, the annual allowable cut also continued to increase, in particular after 1968. The cutting intensity in the years 1949–1958 amounted to 3.7 m^3/ha/year on average and was periodically increasing to 4.6 m^3/ha/year (1, 14).

TABLE 1

Cutting age of particular tree species

Year	Pine	Spruce	Oak	Ash	Linden, Elm, Maple	Horn-beam	Alder	Birch	Aspen	Willow
1843	180	90	180	other 90						
1921	120	120	140	90			60			
1931	Holdings Pine Spruce Oak 100			Ash Horn-beam 80 i 60*			Holding Ash Alder 80 i 160*			
1946/ 50	**120**	**100**	**160**	**160**		**80· 100·**	**80· 100·**	**80**	**80**	
1958	**120**	**80· 100· 120·**	**160· 200**	**120· 140·**	**100**	**80· 100·**	**80· 100·**	**80**	**60**	**50**
1968	**120**	**100· 120·**	**140· 160· 200·**	**120· 140·**	**100**	**80· 100·**	**80· 100·**	**80**	**50**	
1975	**140**	**120 140·**	**160· 200· 240·**	**140· 180·**	**100**	**·08 100·**	**80· 100·**	**80**	**50**	

Explanation:

* – double cutting age in a holding,

· – cutting age differentiated depending on forest habitat type

The growing stock per hectare was subject to fluctuations and a decrease, in 1916 – 372 m^3/ha, in 1948 – 191 m^3/ha, from 1958 to 1968 slightly raised to 205–229 m^3/ha, as a consequence of an increased increment of stands in the age classes III and IV, represented mainly by stands with small-seeded deciduous tree species (approx. 20% of the total area of stands) and pine (1). The present growing stock comes only to approx. 40–60% of the potential growing stock, which is 400–500 m^3/ha (15).

The state of stands and the direction of renewal have been always affected by the methods of forest management, which are briefly presented in chronological order (1, 4, 14).

- After a period with incidental and periodic clear cutting and plundering cutting by the end of 18th century for commercial and agricultural purposes, construction of settlements, etc., there came a period of more organised, but often exploitative forest use in the 19th and 20th centuries.
- In the years 1915–1918, clear cutting and plundering cutting were applied.
- After 1918, sanitation cutting, and clear cuts were carried out.
- In the period of exploitation by the C.E.T.C. company (1924–1929), clear cuts, referred to as strip clear cuts, were conducted.
- During a short period after 1929, the clear cut system based on patches of approx. 20 ares size was applied, called also hollow cutting, and since 1930 – also the shelterwood cutting (with adoption a doubled cutting age of 80 and 160 years). The clear-cutting was applied as well.
- Right before the war, in 1939, clear cuts were applied. The plantations were usually fenced and tended.
- After World War II, for the first couple of years sanitation cutting and high grading was conducted to obtain valuable timber.
- After 1949, the patch cutting system was applied in all habitats, with patches of 2–5 or 10–30 ares and with leaving a partial shelter; the so-called biogroup cutting (individual and in groups) was used as well, usually facilitating the harvesting of valuable assortments (forced by the authorities nearly until 1975). Initially, the cuts were conducted on large areas, with division into manipulation strips.

After 1952, biogroup cutting was abandoned, while patches in the patch cutting method were increased to 30 or even 50 ares and that cutting was carried out also on manipulation strips. One counted on the establishment of natural seeding and applied unsuccessful undersowing and regeneration by planting in loose spacing, on a manually prepared soil. The outcome of those was often unsatisfactory, both in biogroups and on too large patches exceeding 20 ares (1, 6).

In 1956, clear-cutting was resumed in coniferous forest and alder carr habitats. In other habitats, the patch system, group selection system and shelterwood system were applied, periodically referred to as strip shelterwood systems.

Due to higher hourly rates and a better technical equipment the reforestation success was improved, but damage done by the game (**S. Wroczyński** – 6) was revealed, while older stands were changing their character.

The share of pine, oak, ash, maple and elm in the old-growth forest significantly decreased. It was observed that it also resulted from damage caused by game and the livestock grazing on plantations and in sapling stands of age classes I and II, in particular in those over ten years old and in more fertile habitats of mixed deciduous forest, fresh deciduous forest, moist deciduous forest and alder-ash carr (1). In 1968, the crop age classes III and IV occurred only sparsely – 24.9% and IV and V – 15.2% (**Filipowicz** – 6).

As a result of clear-cutting being applied in World War I and in the inter-war period, a large area (approx. 20%) became covered by stands with false species composition, i.e. mixed stands with birch, aspen, alder, hornbeam and spruce, currently of age class III/IV (9).

Plantations and regenerations conducted after 1945 with economical methods, browsed by bovine and forest animals, had to be frequently refilled on an area covering periodically up to 90% of the total afforestation area (1).

Breaches and economic errors were the object of critical studies and reports, while the entire forest and silvicultural management was subjected to a criticism in 1958 (assessment of the Ministry of Audit, conventions and debates: at the PTL [Polish Forest Society], field session of the Forest Sciences Committee of PAN [Polish Academy of Sciences], session of members of the Forestry Committee of the Sejm [lower house of the Polish Parliament] (**W. Sosnowski** – 6). All debates were organised together with the OZLP [Regional Board of the State Forests] Białystok.

In 1961, the *Silvicultural Principles* were published, in which, apart from the major cutting systems, the application of the clear-cutting system also in richer habitats, in stands with a higher share of spruce or hornbeam was permitted. The shelterwood cutting was still used for the single-tree timber harvesting or it was replaced by the patch system, whereby the patch cutting was used sometimes in form of small clear-cuts of 0.5 ha. The cutting location was usually not in line with the silvicultural planning (**E. Bernadzki** – 6, 4).

In 1965, by a regulation of the Minister of Forestry and Wood Industry, the so-called Budy Experimental Forest Subdistrict was established in the Zwierzyniec Forest Management Unit, with the purpose to carry out and improve in practice the management principles adopted by the OZLP Białystok in 1962, and determined by the IBL in 1959–1961 on the basis of research (6, 5). The research is continued in this object mainly to improve the technique of the patch selection system and other polycyclic cutting systems.

The *Silvicultural Principles* of 1969, developed for the entire country (without distinguishing the Białowieża Forest) put in order the nomenclature and methods of cutting systems. However, new methods for the calculation of the annual allowable cut adopted in the Instruction of Forest Management Planning of 1970, as well as the determination of short regeneration periods amounting to 25 years at the utmost, resulted in an increase of the total annual allowable cut, which was demonstrated by logging of approx. 30% of the growing stock of a given stand within a ten-year-period (4).

The changing age structure of stands in favour of younger stands, low average growing stock of 229 m^3/ha, improper species composition of regenerations (scarcity of oak and ash), increasing damage done by game, increasing tasks within the scope of nature conservation and tourism and other phenomena led in the years 1970–1975 to an intensification of efforts of foresters grouped in the Polish Forest Society and the Regional Board of the State Forests, as well as of scientists and of society in general, to furnish the forest with a separate status (5). To some extent, it was achieved by the regulation of the Minister of Forestry and Wood Industry as of 30 January 1975 (11).

The results of research within the scope of management methods aimed at directing the economy in the Białowieża Forest may be outlined in the following items:

The concepts of H. **Gennko** 1903 (6) within the scope of habitat and stand diversification of the Białowieża Forest did not leave a permanent mark in the further development of that problem.

The research by J. **Paczoski** and M. **Romanow** (6) established, in the inter-war period, foundations for distinguishing various forest stand types for various habitats, with a specific structure, usually multi-generational, and complex with regard to species, age, diameter and storeys. The Romanow concept considered the fundamental elements of the soil fertility and humidity. That provided a basis for a subsequent distinguishing of biotopes (J. J. **Karpiński**) (6) and forest habitat types. The use of natural seeding and the avoidance of clear-cutting were recommended, and the shelterwood and patch cutting systems were supported. In addition, the expansion of small-seeded deciduous species on clear-cutting areas and of hornbeam and spruce under the shelter of stands were indicated.

The studies conducted by the Department of Silviculture of the Forest Research Institute in the years 1949–1954 (6) proved the environmental purposefulness of the management in mixed-species forests by the utilisation of patch cutting systems.

In addition, the occurrence of high growing stock volume in model stands of the forest, coming to approx. 400–500 m^3/ha, was evidenced, just like a high diversity of species composition, structure and regeneration processes being dependent on habitat types (6, 15). A complex structure was observed, as well as a heterogeneity of age and storeys of stands and the necessity to diversify over time and space the introduction of particular species into the regeneration, which arises as a result of the differences in their growth pace and from a relatively slow growth of oak and ash. The need for a gradual conversion of the stand structure was also declared.

– An expertise study conducted in 1954 (6) proved numerous errors made in the cutting and regeneration technique in the years 1949–1954 (unsuccessful regeneration in biogroup cutting and on too large patches). Those errors were gradually corrected in accordance with the research recommendations (size and shape of patches, arrangement and spacing of reforestation, soil preparation methods, and protection of reforestation from the grazing by the game and bovines, maintenance treatments).

– The research conducted in the years 1959–1961 (6) on approx. 100 plots showed that the occurrence of self-seeded renewals of more valuable tree species in the forest happened mainly before the commencement of the final cuts. The research allowed the specification of the most appropriate stand species composition for various habitats and claimed the maintenance of higher cutting ages, proper techniques and intensity of cutting, an adjustment of method for the calculation of the annual allowable cut, an adoption of longer regeneration periods and the preparation of assumptions for the creation of holdings.

The research conducted from 1972 to 1976 in the Budy Experimental Forest Subdistrict (6) confirmed the results of previous observations. They proved the possibility of applying patch and shelterwood cutting systems in the forest, and, in combination with the previous studies, they allowed giving direction to the principles and detailed techniques of the management methods applied in the forest, the methods for the calculation of the annual allowable cut and cutting intensity, the silvicultural planning of the temporal and spatial order, etc.

In the entire study, the demands stipulated in the regulation of the Minister of Forestry and Wood Industry as of 30 January 1975 and in the guidelines established in the amended *Silvicultural Principles* (16) and in the Instruction of the Forest Management Planning (7) were adopted.

That direction was subject to consultations of the PTL and OZLP Białystok held in 1978 in Białowieża (1, 6, 9, 10, 13, 15). Hereafter, a draft of definitions directing the Białowieża Forest management methods is presented:

1. In the Białowieża Forest, due to its environmental specificity and its social and economic goals, the forest management planning works should be conducted in a modified way, partially different from schemes valid in other commercial forests of the country (5).
2. One proposes to base the forest management planning works on an extended network of forest habitat types, which would adopt the habitats being used to date and new subtypes and variants.
3. While determining the targeted stand composition types, taking into account regional conditions (Włoczewski – 6), one proposes to apply approximate target species compositions of stands being close to those observed in the forest. It is possible to modify them according to new expertise from BULiGL [Forest Management Planning and Geodesy Bureau]. In the initial phase of regeneration, there should be maintained the share of oak and ash approx. by 20–50% higher than the one planned for the stand.
4. The target growing stock in the forest's stands should come in richer habitats to 400–500 m^3/ha in mature stands prior to the commencement of their use.
5. The stands in these habitats should have an uneven-aged and a two- and multi-storey structure (Ilmurzyński – 6).

6. In the Białowieża Forest stands, due to the potential for the production of valuable large-sized timber assortments, the cutting age should be adopted in accordance with the regulation of the Minister of Forestry and Wood Industry as of 30 January 1975 (11), with an optional increase of the cutting age of spruce to 140 years (5, 11) and with a decrease in the cutting age of pine only when it is of definitely poor quality or health condition.
7. During the removal cutting or in the clear-cutting system, it is recommended that more than a dozen (up to 30) trees per hectare (in the felling age and possibly middle-aged trees) are left, for the sake of diversity, multi-storey structure, as seed trees, future trees, prospective monumental trees (11, 16) and for the production of valuable large-sized timber assortments (15).
8. Due to the needs to use the regeneration from natural seeding and to diversify the structure of stands, the use of clear-cutting system should be limited to the habitats: dry coniferous forest, fresh coniferous forest, moist coniferous forest, fresh mixed coniferous forest, moist mixed coniferous forest, and possibly birch alder carr and typical alder carr, using for some of them also self-seeding regeneration when possibly applying the shelterwood cutting system IIb (6).
9. Under the conditions of a slow growth in height of the young oak and ash regeneration and their sensitivity to ground frost, the regeneration period for stands with share of these species, when applying polycyclic cutting systems, should be set to 20 years for the fresh mixed coniferous forest, moist mixed coniferous forest, fresh mixed deciduous forest, moist mixed deciduous forest and alder-ash carr and to 30–40 years for the fresh deciduous forest and moist deciduous forest, with the IIIc cutting system (6, 16).
10. Taking into account the oak regeneration period of at least 20 years, its occurrence in groups and observing after 7–10 years from the regeneration start the need for the overstorey removal and the extension the patches, the IIIa cutting system is to be excluded in the Białowieża Forest and replaced with the IIIb cutting system, or respectively with the IIIc system for a longer regeneration period (6). For the entirety of stands with the species composition being similar to the targeted one, the cutting systems provided in Table 2 should be applied.

TABLE 2

Cutting systems for various forest habitat types (major cutting systems)

Forest habitat types and their codes	Symbols of cutting systems adopted for use
Bs [dry coniferous forest], Bśw [fresh coniferous forest], Bw [moist coniferous forest]	I b
Bb [bog forest}	IV
BIśw, BIw, currently BMśw [fresh mixed coniferous forest], BMw [moist mixed coniferous forest] (without oak in the overstorey)	I b
LMśw [fresh mixed deciduous forest], LMw [moist mixed deciduous forest]	III b
Lśw [fresh deciduous forest], Lw [moist deciduous forest]	III c
Olt [typical alder carr]	I b
Olj [alder-ash carr]	I b or III c

Explanation of cutting system symbols:
I b – clear-cutting system with narrowed cutting strips, 40–60 m wide,
II b – shelterwood system, typical,
III b – patch shelterwood system,
III c – patch selection system (shelterwood),
IV – selection system

11. Due to the weeds quickly overgrowing the ground, the expansion of self-sown small-seeded species and the sensitivity of oak and ash to ground frost, regeneration cutting should be initiated concerning the 'dark ones' (group cutting, small and medium sized patches 5–8a). While carrying out these cuts, 10–15% and maximally 20% of the initial growing stock should be taken out within a ten-year period, whereby for the IIIb cutting system the patches should occupy approx. 20%, and maximally 30%, of the manipulation area, and respectively 15–20% for the IIIc cutting system (6, 3). While cutting large patches of 10–15 ares and possibly larger ones, it is necessary to apply a temporary shelter for the regeneration by leaving some tress on the patches (6).
12. While applying polycyclic cutting systems, in particular the patch selection system (irregular shelterwood IIIc), applied should be the principle of establishing the transport limits, extraction directions, skid tracks and other silvicultural planning principles for a period of 2 × 5 years, i.e. for a ten-year period (E. **Bernadzki** – 6).
13. The regenerations and their refilling require a properly selected soil preparation method (trenches, elevated strips, mounds, possibly ridges, posts) and a properly conducted weeding and cleaning by removing small-seeded species and the expansive hornbeam

(6). Therefore, an appropriate workforce and technical equipment must be provided for this purpose.

14. The condition for the reforestation success, prosperous development of the technical quality of timber and the good sanitary condition of the stands is contingent on the protection of the reforestation and stands against free roaming bison and other herbivorous game. This requires a development of principles for the game management and bison breeding, determining and satisfying a reasonable population of animals, its proper additional foddering and the protection of plantations and stands against browsing, trampling and bark stripping (6, 10).
15. In the Białowieża Forest, more than 20% of the area is covered by flawed forest stands with an improper species composition and completely negative stands, where also the stocking is insufficient, which require an inventory aiming at the decision taking on the conversion methods or, in extreme cases, on the liquidation of such stands (conversion with use of tree shelter, liquidation through clear-cuts) (6, 9). The determination of criteria for distinguishing flawed stands (for conversion) and completely negative ones (for liquidation) and of the conversion or liquidation methods should be carried out by a selected team of experts.
16. As the woods in the Forest vary in terms of their commercial and social character and management methods, pursuant to the draft of the amendment to the instruction of forest management planning, it is necessary to distinguish a number of holdings with different methods of annual allowable cut calculation and different management methods (6, 7). While distinguishing the holdings, one should take into account the specificity of the reserve forests, protection forests of different types (water protection forests and other, forests with time-limited use, etc.) and handle them as special holdings.
    In the managed forests holdings are to be created, where the following shall be applied:
    - Ib, Ia and Ic clear-cutting system, with calculation of annual allowable cut based on three oldest age classes (11) (without the regeneration period to be considered),
    - IIc shelterwood system and IIIb patch system with a medium-length regeneration period taken into account for an annual allowable cut calculation based on age classes,
    - the patch selection system group and selection method (irregular IIIc) with a long regeneration period and the annual allowable cut calculation based on the silvicultural needs in the individual stands (10–15% of growing stock of mature trees to be cut within a ten-year period).

A consistent record should also cover all flawed forest stands, intended for a gradual conversion under the shelter of the stands and with use of different cutting systems; the record should also cover forest stands intended for a short-term liquidation (6, 9).

17. While calculating the annual allowable cut on the base of age classes or age classes plus the regeneration period, or on the base of silvicultural needs, in the stands with

composition and structure close to the model ones, it is necessary to consider for comparison purposes also the actual species' composition and age structure, and not only with regard to the dominating species (6).

18. While calculating the annual allowable cut, one should consider (deduct) the growing stock percentage resulting from the need to leave some trees upon removal cutting and on clear-cuts for the purposes provided in item 7 (6).
19. While determining the volume of so-called cuts not accounted towards the annual allowable cut or calculating the annual allowable cut on the base of the regeneration class, it would be purposeful to analyse and adjust the management definitions and recommendations with regard to low stocked stands (see item 7 and 18) as per the conditions of the forest, and to the definition of regeneration class (6).
20. A severe competition between the species in mixed-species stands of the forest and the species compositions in younger age classes being often different from the desired ones, speak for the application of non-standardised, selection maintenance, with the calculation of the annual allowable cut for intermediate cutting in accordance with the actual needs of the stands, and not based on tables (6).

EXTRACT OF THE LITERATURE LIST (COMPREHENSIVE LITERATURE LIST – INCLUDED IN THE STUDY UNDER ITEM 6)

Czerwiński, A. 1978 'Gospodarka leśna w Puszczy Białowieskiej i problemy jej modernizacji' [The forest economy in the Białowieża Forest and the problems of its modernisation]. Paper for the scientific conference 'Status and development of functions of the Białowieża Forest', Białowieża 18–19 May 1978, Ośr. Badań Nauk. in Białystok. (1)

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Conference in the Białowieża Forest on the principles of forest management and directions for forest management planning methods in the Białowieża Forest

On 23 and 24 June 1978, a conference on the above topic took place in Białowieża. It was organised by the Commission of the Natural Foundations of Forestry and of the Forest Management of the General Board of the PTL [Polish Forest Society], with participation of the OZLP [Regional Board of the State Forests] in Białystok.

The conference aimed at the preparation of materials for papers, discussions and conclusions for 1st session of the KTG [Techno-Economic Commission] for the forest, scheduled for the beginning of 1979.

During the conference, three problem-focused lectures were given, whereby the presented conclusions were illustrated with numerous demonstration sites located in the stands of the forest. These papers were:

1. The orientation of the management principles for the Białowieża Forest based on the historical timeline of research conducted in the years 1929–1976 with consideration of the current ministerial regulations and amended instructions – Associate Professor **S. Graniczny**, DSc, PhD;
2. Definition of the needs and proposals of the orientation of assumptions, methods and organisation of the conversion of stands with improper species composition in the Białowieża Forest – **M. Kutrzeba**, BEng;
3. Assumptions for the organisation of the game management in the Białowieża Forest with consideration of bison breeding and postulates concerning the protection of stands and regenerations against damage caused by the game – **L. Miłkowski**, MSc, BEng.

The conference participants appointed a seven-person Application Commission under the leadership by Professor Bolesław **Zabielski**, PhD. After discussing the conclusions presented in the papers, debates and during the field trips by the conference participants, the Commission decided to adopt the entirety of the conclusions as a preliminary enunciation. The final edition of those enunciations was developed by a working team appointed for that purpose by the director of the OZLP, under the leadership of the chief of the Forest Management Department, Tomasz **Gątkiewicz**, MSc, BEng.

In order to familiarise the readers with the content of papers and the conclusions formulated therein, shortened versions of the papers are presented in this issue.

Stefan Graniczny

Edward Więcko

Management of the Białowieża Forest between World Wars I and II

From August 1915 to December 1918, the Białowieża Forest was subordinated to the German occupiers' military administration. In that period, 6,500 ha of stands were cut without a plan on large areas and the best trees with a total volume of approx. 2.6 million m^3 of merchantable timber were selected and cut over the entire territory of the forest.[1] From the calculation of that volume against the forest's wooded area one can conclude that the cuts per hectare was 7.7 m^3 of timber annually. The most affected parts of the forest were the ones neighbouring with standard gauge railroads (Hajnówka, Narewka and Leśna forest districts) and adjacent to [narrow gauge] forest railways constructed by the Germans (Białowieża, Gródek and Zwierzyniec forest districts).

In order to process the harvested timber, the German military administration built in the first 20 months of occupation a number of sawmills in the forest: in Hajnówka with ten gang saws, in Czerlonka with three gang saws, in Gródek and Stoczek with four gang saws each, in Nowy Most with two gang saws, and in Mała Narewka with one gang saw. Moreover, a wood wool factory, a mechanised woodworking shop and a factory of self-assembly houses were put into operation, the German company Scharing built in Hajnówka a factory for dry wood distillation, with 128 vertical retorts and a processing capacity of 300,000 steres of deciduous timber per year, with an additional annual consumption of more than 150,000 steres of timber to heat the factory. Charcoal piles and seven tar kilns were also used for chemical wood processing.

Steam railroads, 130 km in length, with track gauge of 60 cm, connected with standard gauge railroads and approx. 200 km of transportable horse-drawn railroads spread across the forest, were used as transport means.

From the report of Major Escherich, who administered the forest, we can learn that 'from 1915, when the occupation of the forest began, to the end of 1918, when the military administration had to leave that region, a volume of timber was harvested that not only the investment cost of 12 million marks was covered, but also a large surplus was achieved. If

[1] In his paper 'The Białowieża Forest and the National Park in Białowieża' (1930) Professor J. J. Karpiński states (p. 28) that Germans 'during the three-and-a-half-year occupation cut and transported away from the forest approx. 4 million m^3 of timber in the way of an accelerated plundering exploitation'.

the military board had not been forced to leave those areas, they would have been able to gain profit of 25–30 million marks per year' (5).

During the Germans' retreat from the forest, some of the above plants were partially disassembled (including two steam machines with a power of 180 and 220 horsepower from the Hajnówka sawmill). After the Germans left the forest, it was under temporary Lithuanian management (for six weeks).

At the beginning of 1919 (February, March), under the Treaty of Riga, the Białowieża Forest was taken over by the Polish State and incorporated to its state forests.

The main complex of the Białowieża Forest (including the future National Park) covered an area of 103,756.36 ha and was located in the Bielsk Podlaski Poviat of the Białystok Voivodeship. The total area of the forest together with wildernesses located beyond the main complex was 105,281.76 ha.

The later management plan for the forest holding was developed for an area of 100,592.33 ha, excluding the area of the Białowieża National Park, which was formally established by the regulation of the Minister of Agriculture and Agricultural Reforms as of 4 August 1932 (Polish Official Gazette no. 183, item 219) on an area of 4,693.24 ha. The Białowieża Forest wooded area (status as of July 1933 according to the forest management plan) was 89,210 ha, including forested area of 96.9%. The low stocked stands came then to 782.30 ha, while clear-cut areas and blanks to 1,962.25 ha. The non-forested lands (meadows, farmlands, orchards and gardens, buildings and farmyards, industrial plants, depots and open spaces) covered in total 5,720.60 ha. The area rated as wasteland was 4,014.26 ha.

The standard gauge railroads crossing the forest were 35 km long, while the forest [narrow gauge] railways were 325 km long. For water transportation, the Narew and Narewka Rivers were of great significance, while the Leśna Prawa River was of minor significance.

After the forest takeover by the Polish authorities at the end of winter 1919, the former Russian division into five administration units referred to as forest districts (Browsk, Królewskie, Starzyna, Hajnówka, and Świsłocz) was maintained and the Białowieża Forest Inspectorate was appointed. That Inspectorate was subordinated to the District Administration of State Properties in Siedlce, and then to the District Administration of National Treasury in Siedlce, which was relocated in June 1919 under the name District Administration of State Treasury to Brześć on the Bug.

After the temporary seizing of those lands by the Red Army, that administration unit was evacuated in July 1920 to Koźmin (in Poznań region). The District Administration of State Treasury in Brest was subordinated to the Civil Administration of Eastern Lands and after its cessation by the end of 1920 the administration of those lands was taken over by the Administration of Stage and Front-Line Territories, which handed them over afterwards to relevant ministries (9). The Regional Administration of State Treasury in

Brześć was renamed the Regional Board of the State Forests with its seat in Białowieża, and as of 1 December 1920 Jan Szreders was appointed as its chief (director). That Board was subordinated to the Forestry Department of the Ministry of Agriculture and State Treasury.

Pursuant to the regulation of the President of Poland dated 28 June 1924 on the statute of the enterprise Polish State Forests (Journal of Laws No. 56, item 570), the Minister of Agriculture and State Properties appointed district directorates of state forests, including the Directorate of the State Forests with its seat in Białowieża.

Pursuant to the regulation of the President of Poland dated 30 December 1924 on the organisation of administration of state-owned forests (Journal of Laws No. 119, item 1079), by the regulation of the Council of Ministers as of 16 January 1925 (Journal of Laws No. 9, item 62), ten directorates of state-owned forests were established, including the Directorate of the State Forests in Białowieża.

In the years 1919–1923, the management in the forest strived for the liquidation of the consequences of the occupant's activities, which was expressed in the large number of trees left in the cutting areas, snags and debris and resulted in an invasion of bark beetle (4), affecting mainly spruce. At that time, pure spruce stands covered approx. 7% of the forest's area, while on 25% of the forest's area spruce occurred as a significant admixture.

The most affected spruce forests were the ones in the Hajnówka Forest District, where bark beetle attacked forest stands on an area of 7–8,000 ha, and the volume of damaged timber together with deadwood was estimated there as 350,000 m^3. In the remaining forest districts the endangered areas covered respectively: Starzyna – 1,000 ha with timber volume of 100,000 m^3, Browsk – 600 ha (180,000 m^3), Królewski – 300 ha (30,000 m^3), and Świsłocz – 270 ha (21,000 m^3). The bark beetle control was conducted by laying trap trees, removal of snags, deadwood and infested trees.

A total of 1.2 million m^3 of timber was harvested from the liquidation of trees remaining in the cutting areas and from the removal of infested trees. Moreover, within the framework of a provisional forest management plan, 1,700 ha of stands with volume of 350,000 m^3 were clear-cut.

As a result of the provisional forest management planning carried out in the years 1920–1921, the growing stock of Białowieża was estimated at 23 million m^3. The forest management planning for the forest's holding was aimed at extended use in order to increase the income of the state; however with due diligence so that the valuable forest complex, already considered a natural monument, was not destroyed.

The number of forest management units corresponding then with the borders of existing forest districts was limited to five. The planned nature reserves were marked out in particular forest management units. The stands within every forest management unit were divided into four groups:

1) coniferous group (composed of pine, pine-oak, spruce and pine-spruce stands);

2) oak (composed of oak and oak-hornbeam stands locally referred to as *brud*);
3) ash (composed of ash-spruce-alder stands referred to as 'alder-ash carr');
4) alder (composed of alder coppice stands – 'alder carr').

The following rotation was adopted: for the group of coniferous stands – 120 years, oak – 140 years, ash – 90 years, and alder– 60 years.

Fig. 1. Moist oak-hornbeam forest

The cutting directions were determined from east to west, while the width of the cutting area was determined as 50–60 m for the coniferous, oak and ash groups, and 100 m for the alder.

The annual allowable cut was determined at 300,000 m^3 of timber from planned cuts and 250,000 m^3 from snags, windthrows and spruce damaged by bark beetle (7).

The average annual utilisation was intended to be 4.91 m^3 per hectare, while actually 7.35 m^3 were harvested from 1 ha, i.e. approx. 50% more (11).

An artificial regeneration was planned for cutting areas, blanks and low stocked stands in all groups of stands, excluding the alder stands. In order to profit from the existing natural regeneration, the Commission on Regeneration and Conservation of the Forest was appointed. Its tasks included watching over the course of regeneration of cutting areas and

Fig. 2. Alder forest

blanks and the organisation of research on natural reforestation and the methods of artificial regeneration in various habitat conditions.

On 24 February 1924, an agreement was concluded with the English company 'The Century European Timber Corporation', under which that enterprise was to exploit the Białowieża Forest and the Dukszty state forests near Grodno and Słonim throughout a period of ten years. A note published in *Sylwan* (2) shows that the State expected an annual income of 10 million gold francs from that transaction.

In the ten-year-period, the harvesting in the Białowieża Forest were to cover the 15-year annual allowable cut calculated in a provisional forest management planning. The annual utilisation volume was specified for the English company as 325,000 m^3, which corresponded with an area of approx. 1,400 ha. Following to the company's wish, clear-cuts 100 m wide and 1 km long were applied, selecting 100-hectare compartments with the most valuable stands for cutting. Seed trees were to remain on clear-cuts. The harmfulness of that cut size consisted mainly in the weed infestation of the soil and site degradation, as it hampered the forest renewal or sometimes even made it impossible.

The contractual condition of handing over the cutting area by 1 March of the third year after harvesting was not met by the company. When classifying harvested timber as merchantable, top-quality timber was selected, simultaneously increasing excessively the output of fuelwood (also from a part of merchantable timber). Such an operation contributed to losses to the Treasury of the Polish State. Instead of seed trees, trees of little value, mainly hornbeam, were left on cutting areas. Under those circumstances, making use of an opinion of the General Prosecution Office, on 29 May 1929 the Ministry of Agriculture terminated unilaterally the agreement, paying a large compensation. It came to 375,000 pound sterling, i.e. 16.2 million zloty, from which 1.5 million zloty was deducted in lieu of taxes not paid by the company.[2]

By the agreement termination, the company harvested approx. 2.5 million m^3 of timber.

The plots clear-cut out by the English company and post-German clear-cuts underwent largely natural regeneration, but with species of little value – mainly birch, aspen, hornbeam, partially alder. Forest stands grown in that way now constitute approx. 20% of our (western) part of the forest.

After the termination of the agreement with the English company, in 1929, so-called 'hollow' cuts (patch cutting system with a patch size of 5–20 ares) were introduced in all habitats of the forest, with a 20-year regeneration period and a fourfold cutting. As a result of insufficient natural renewal, the use of that method was ceased.

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[2] According to the information received from F. Szkiłłądź, the then chief of the financial department at the special delegate of the Ministry of Agriculture for the administration of the State Forests, whom back then was Adam Loret.

In the following years of the inter-war period, the forest management in the forest was conducted according to the final forest management plan. The field works for forest management planning, to draw up a management plan for the Białowieża Forest, commenced in 1927 and were completed in 1930. The Białowieża Forest area was divided into 14 forest districts (Browsk, Narewka, Czoło, Jaźwiny, Hajnówka, Zwierzyniec, Białowieża, Leśna, Jagiellońskie, Nikor, Starzyna, Biała, Królewski Most and Jasień) and the Białowieża National Park, moreover the Oszczep Forest District from Świsłocz Forest was incorporated to the Białowieża Forest. Two other forest districts of Świsłocz Forest (Świsłocz and Zamosze) with an area of 13,600 ha were returned in 1935 to the heirs of General T. **Tyszkiewicz**, as a property confiscated from insurrectionists. The Białowieża Forest had 50 forest subdistricts (average area of 2,010 ha) and 133 forest ranges (average area of 750 ha).

In the years 1928–1930, the former Russian territorial division breaking down the main complex of the Białowieża Forest into 924 compartments with sides equal to 1 verst (1,066.8 m) was supplemented (excluding the Białowieża National Park) by cutting them crosswise with new division lines. Therefore, the number of compartments in the forest increased by a factor of four. The newly established compartments were marked with the letters: A, B, C and D, while keeping the former numbering.

Under the final forest management planning, 12 stand types were distinguished, which served as a basis for the grouping. The coniferous forests: dry, fresh and moist (24% of the forest's wooded area) were included in the pine stands group, where cutting age was determined as 100 years. The pine-spruce and spruce coniferous forests (25% of area) constituted the pine-spruce group of stands, also with cutting age of 100 years. The mixed coniferous forest (18% of the area) constituted the oak-spruce-pine group of stands with a cutting age of 100 years, the fresh oak-hornbeam forest (9%), the oak-hornbeam with a cutting age of 80 years, the moist oak-hornbeam forest (6%), the ash-oak group of stands with a cutting age of 160 years for oak, ash and elm and 80 years for spruce, alder and hornbeam, the alder-ash carr (11%) and the alder carr (5%) forming the ash-alder group of stands with a cutting age of 80 years for spruce and 160 years for ash. The coniferous forest on peat bog and birch-alder carr (2% of the area) formed the boggy group of stands.

The utilisation in the pine, spruce-pine, oak-spruce-pine and oak-hornbeam group of stands was conducted with clear-cuts 80 m wide (4-year cutting interval, artificial regeneration through planting on strips or scalps). In other groups of stands, the utilisation was conducted by shelterwood cutting on areas of up to 15 ha. The stand removal in those groups was to be conducted in three cuts with a 10-year regeneration period, expecting the natural renewal to be supplemented with oak interplanting.

The actual growing stock of the forest's stands, based on the final forest management planning, was specified as 16,217,000 m^3 and 187 m^3 per hectare. The actual increment was specified as 2.25 m^3 per hectare and the normal increment 4.20 m^3 per hectare (7).

TABLE 1 draws attention to a low share of area of age class II (4.53%) and a relatively low share of the age class IV (8.74%).

Age class structure of stands of the Białowieża Forest (1931)

Type of area, age class	Area	
	ha	%
Cuts and blanks	1,962.25	2.20
Low stocked stands	782.30	0.88
I	17,067.46	19.14
II	2,419.17	2.71
III	4,040.24	4.53
IV	7,802.95	8.74
V	13,478.28	15.11
VI	16,897.60	18.94
VII and higher	24,759.75	27.75
Total	89,210.00	100.00

The determinations included in the forest holding management plans were implemented in accordance with the regulations concerning forest renewal. They were issued by the director of the State Forests in Białowieża. The last regulation of 11 February 1938 determined the general guidelines and detailed instructions as to, among other things, the application of treatments facilitating the natural regeneration with self-seeding. Wherever the natural regeneration failed or was difficult, artificial regeneration was recommended. Main tree genera recommended for growing in appropriate habitats included pine, spruce, alder and oak. The establishment of mixed plantations was recommended, not with individual mixing, and not with large groups either. The current cutting areas were to be regenerated basically in the year of stand logging. As an exception, their regeneration could be postponed for one year on soils not too susceptible to weed infestation. On fertile soils or those prone to become weed-grown, the regeneration should be performed partially or entirely several years before the removal cutting; after the establishment of preparatory cutting an artificial regeneration under the stand shelter should be applied. When the conditions allowed the selection of a regeneration system with pine, it was recommended to sow seeds from seed stands of the local seed district and circuit. The planting was recommended as the only fill-in method. All plantations and stands were to be tended and subjected to reasonable cleaning and thinning.

In the years 1930–1939, approx. 20,000 ha of outstanding and current cuts were regenerated in the Białowieża Forest. In the years 1931–1939, 3,352,880 m^3 of merchantable timber (under bark) were harvested in the forest, from which 2,608,880 m^3 originated from final cutting and 744.00 m^3 from intermediate cutting. The timber logging was 4.8 m^3 per hectare of the forested area per year (final cutting 3.7 m^3 and intermediate cutting 1.1 m^3).

The average annual harvesting in that period was approx. 420,000 m^3 of timber (merchantable timber), including approx. 270,000 m^3 of timber products (64%) and approx. 150,000 m^3 of fuelwood (36%).

The domestic market absorbed the entire volume of fuelwood produced in the forest and approx. 30,000 m^3 of timber products per year. Approx. 90% of timber products was dedicated for foreign markets, a part of which was processed in the Woodworking Plant in Hajnówka, with a processing capacity of approx. 150,000 m^3 per year in 1933 and in the Gródek sawmill with a processing capacity of approx. 50,000 m^3. In the subsequent years, the Hajnówka sawmill's processing capacity increased to more than 200,000 m^3 of timber per year. For processing hardwood, two gang saws, three band saws, block saws and three split band saws with auxiliary machines were put into operation. Frieze making devices were also installed. In 1935, a drying plant, flooring strip production plant and woodworking shop were brought into service. Other more important industrial plants in Hajnówka included the Chemical Factory (dry wood distillation) and the plant of the Terebenthen company (mainly turpentine and wood tar production installations).

The major foreign recipients of timber originating from the Białowieża Forest were England, Belgium, Germany, France, the Netherlands, South Africa, and Palestine.

The political and economic situation in Poland led to numerous strikes, which included the workers of the Hajnówka and Gródek sawmills.

During World War I, the game population decreased drastically, and certain species became completely extinct.

Bison. According to the data of the German occupying authorities (1), 727 bison were in the forest at the beginning of 1914, and then on 1 February 1918 only 152. According to **Wróblewski** (10), during the winter there were still nine bison in the forest. The last bison in the forest was killed by a poacher on 19 February 1919.[3] As a result of the regenerative bison breeding carried out in the forest, commenced in 1929 (Zwierzyniec Forest District), their number before the outbreak of World War II was 16, on 1 January 1944 it was 27, and on 1 January 1945 it was 17.

In the inter-war period, at the initiative of J. **Sztolcman**, Polish delegate to the International Congress of the Union for Conservation of Nature in Paris, the International Society for the Protection of the European Bison was established in Berlin. It took care of the registration of bison left alive worldwide and determined the principles for their breeding.

Elk. At the beginning of 1914, 59 specimens (1) were in the forest, while in 1918 only 5–6 of them were left. The elk became completely extinct (3) during the German occupa-

[3] According to declarations of the bison keeper G. Sawicki and the killer of the last female bison, Warfołomiej Szpakowicz, it happened exactly on 19 February 1919, which was confirmed by a protocol submitted in the office of the Chief Nature Conservator (3).

tion. In 1938, elk breeding was initiated in a three-hectare reserve in the Jagiellońskie Forest District, where nine specimens lived just before the outbreak of World War II (3).

Red deer. The stock of red deer in 1914 was 6,778, in the winter of 1915/1916 – 2–3,000, in January 1918 – 1,769 (1), but by 1919 there were only few left. In 1928, 210 specimens of red deer lived in the forest, while in 1939 there were over 1,000.

Fallow deer. The fallow deer population at the beginning of 1914 was 1,488, and in March 1917 – 209 (1). After World War I, only five specimens of fallow deer were left in the forest, while the last one was devoured by wolves in 1930 (3).

Roe deer. At the beginning of 1914, there were 4,966 specimens (1). Based on tracking, in the winter of 1915–1916 its population was determined as 2–3,000, while in March 1917 – 1,063. In 1928, approx. 2,000 still lived in the forest.

Boar. At the beginning of 1914, the boar population was determined at 2,225, in March 1917 at 446, while in January 1918 at 560 specimens (1). In 1928, there were approx. 250 specimens, while by the outbreak of World War II their number had increased to more than 1,000.

Tarpan. In 1936, at the initiative of T. **Vetulani**, regenerative breeding of forest tarpan was initiated – based on specimens purchased in the Biłgoraj and Krasnystaw regions – initially settled in a reserve in the Jagiellońskie Forest District and then in the Zwierzyniec Forest District. In August 1939, 40 horses lived in the forest, while in 1944 (in summer), after the takeover of the forest by the Polish authorities, there were 13.

Bear. Once common in the forest, it was completely exterminated in the second half of the 19th century (the last primeval forest bear was killed in 1871 and a straying one in 1879). After World War I, bear breeding was initiated in the forest and directly before the outbreak of World War II two males and one female bear were roaming there freely.

According to J. J. **Karpiński** (3), in 1928 the forest was inhabited also by approx. 30 lynxes, 50 badgers, 90 wolves, 230 foxes and 1,400 hares. Sporadically, the mountain hare has been seen in the forest (3).

Almost entire area of Białowieża Forest for hunting was intended for representational hunting.

Already by 1920, while striving to conserve Białowieża Forest nature, at the initiative of Professor W. **Szafer**, with the co-participation of representatives of the Ministries of Education, Agriculture, Culture and Art and Public Works, the State Commission for Nature Conservation developed a project for the National Park in Białowieża. Initially, at the end of 1921, based on demarcated parts of the forest, a forest subdistrict and then a forest district was created. The management of the nature reserve was taken over in 1923 by J. **Paczoski** and in 1928 by J. J. **Karpiński**. On 4 August 1932, by the regulation of the Minister of Agriculture and Agricultural Reforms (Polish Official Gazette no. 183, item 219), the National Park in Białowieża with an area of 4,693.24 ha was established. That organisational unit was subordinated to the Directorate of the State Forests in Białowieża, but the scientific guidance of the Park was entrusted to the Experimental Station of the State Forests (then transformed into the Research Institute of the State Forests). Apart from the Białowieża National Park, so-called 'by the roadside' reserves were established by 1938 in the forest to protect the primeval forest landscape along the most significant communication routes crossing the forest from Białowieża towards Hajnówka and Pružana (1,867 ha in total), as well as the Bory Nikorskie pine reserve (337 ha), Nikor fir and bog reserve (110 ha), twinflower reserve (*Linnaea borealis*, 2.25 ha), ivy reserve (0.23 ha), coppice spruce reserve (1.80 ha), and the menagerie preserves of bison (297 ha), forest tarpan (25 ha) and elk (10 ha).

The number of guests visiting this remarkable environmental complex, which in 1938 was approx. 36,000 people, proved the social interest in the Białowieża National Park in the inter-war period.

During World War II, from September 1939 to June 1941, the entire Białowieża Forest lay within the BSSR [Byelorussian Soviet Socialist Republic] borders. By the resolution of the Council of People's Commissars of the BSSR dated 25 December 1939, the entire forest area was considered a state reserve.

During the German occupation of the Białystok region (from June 1941 to the summer 1944), the Białowieża Forest, together with the Świsłocz, Szereszów and Różana Forests and with lands of dislodged and burnt villages or settlements with the total area of approx. 270,000 ha, was considered the state hunting area (*Reichsjagdgebiet*), whose administration was located in Białowieża and led by the *Reichsjagermeister*. That administration was subordinated to the German central authorities.

After the German occupation, numerous graveyards of murdered victims remained in both parts of the Białowieża Forest (east and west). Mass graves of Hitlerism victims may be found in compartments 369, 370, 399 and in many other places (9).

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Aleksander W. Sokołowski

The Białowieża Forest as an area of natural research

For a long time, the Białowieża Forest has been attracting researchers with its specific values, especially naturalists and foresters. It is expressed in a rich scientific literature presenting research results, numbering some 1,600 items (3, 6). Today, the forest is a European-wide unique research object.

The incorporation of the Białowieża National Park into the list of biosphere reserves allows the inclusion of research conducted in the forest in international [research] programmes and for analysing certain natural phenomena on a global scale.

High cognitional values that determinate the particular usefulness of the Białowieża Forest for environmental research have been emphasised many times (1, 4, 7). Other forests in Poland are already very distorted by their intense use over many centuries.

The essential features distinguishing the Białowieża Forest from other forests in Poland and Europe include:

1. High level of naturalness and compactness of the forest complex.
2. Large size of the forest complex and the presence in its territory of all habitat types represented in central and north-eastern Poland, as well as its representativeness of a broad geographical area.
3. Abundance of flora and fauna and a great diversity in plant communities.
4. Position on the borderline of central and eastern Europe with the concurrent appearance of many environmental elements typical for western European and eastern European conditions.
5. Position in the territory of the Middle-Polish glaciation covering than extensive zone of central Europe.
6. Location on the European watershed, on flat land, having as a consequence the water availability in its territory of great significance, and its high impact on habitats.
7. Sustainability of hydrological relationships guaranteed by the Regulation of the Minister of Forestry and Wood Industry as of 30 January 1975.
8. Distance from larger sources of emission of toxic dust and gas.
9. Zonal arrangement of the forest's naturalness, reaching from entirely natural, even primeval, [eco]systems, through stands constituting the first generation of forests developed as a result of artificial regeneration of clear-cuts with a network of forest reserves, to artificial single-species stands on former arable soils (figure).

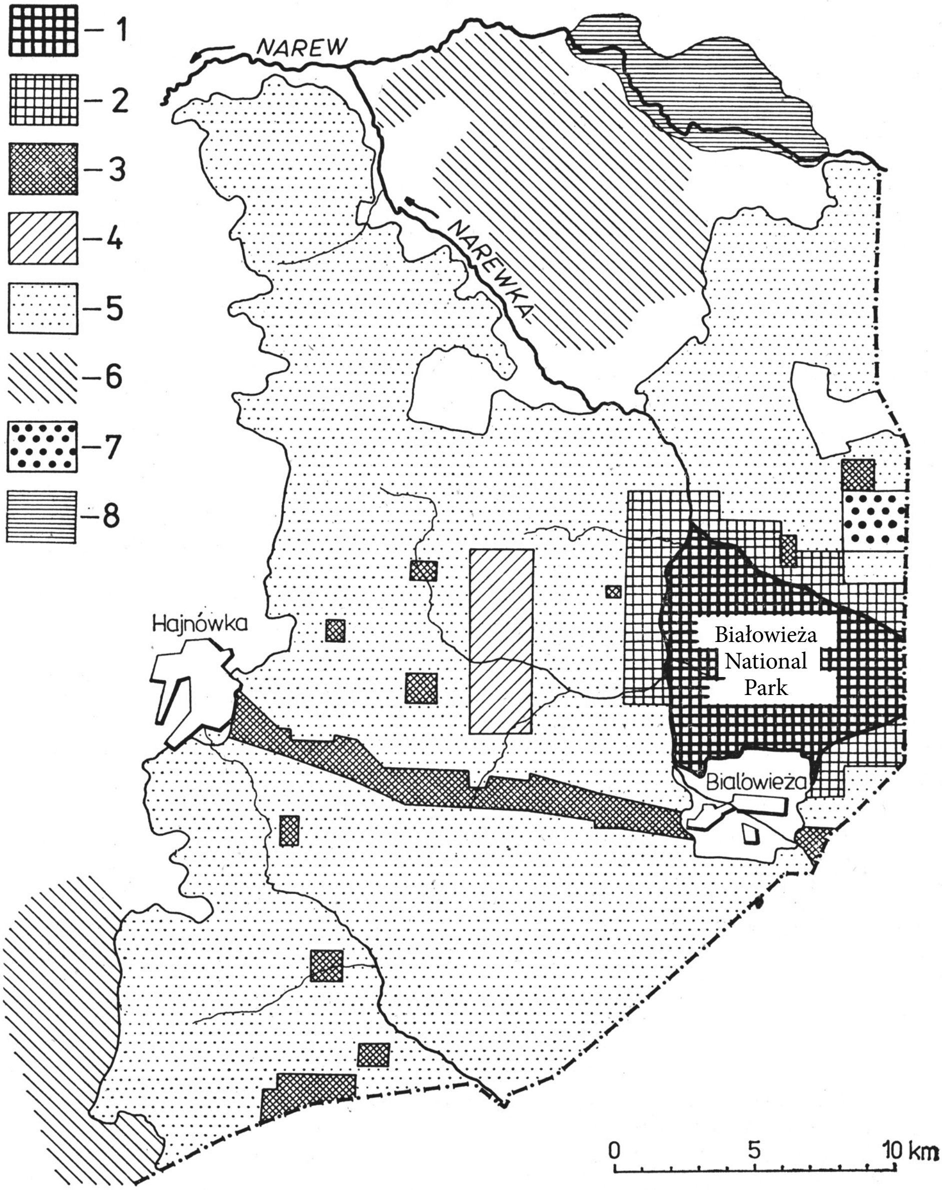

Fig. Zonal arrangement of the Białowieża Forest naturalness and various forms of its conservation. 1 – strict nature reserve of the Białowieża National Park, 2 – buffer zone of the Białowieża National Park, 3 – partial nature reserves, 4 – Experimental Forest Subdistrict, 5 – managed part of the forest, 6 – afforestation of wasteland formerly arable, 7 – soil model plot, 8 – water reservoir Siemianówka (under construction).

10. Presence of an experimental forest subdistrict constituting a site for implementation and verification of concepts in the area of forest management, improved cutting system, regeneration methods, etc.
11. Presence of soil model plots.
12. Intensive development, at the forest's edges, of agriculture and livestock breeding with all forms of process-specific impact on the environment, including the impact on the forest's woods.
13. Presence of quite intensive tourism concentrated in several small areas. It enables the observation of the impact of tourism on the forest's nature.
14. Long-term research tradition and inspirational impact of the forest on the epistemic activity.
15. Relatively high level of recognition of main elements of the forest's physiognomy and history.
16. Existence of scientific institutions with numerous, high qualified research staff, equipped with abundant documentation, flora and fauna collections, good premises and equipment, which may be helpful for researchers from other institutions.
17. Existence of a level 2 meteorological station in Białowieża, operating uninterruptedly since 1948.
18. Presence of a training centre for the forest administration employees and of a forest vocational school, which facilitates the transfer of research results to the forest practice.

A full-scope utilisation of natural forests is being conducted in the managed part of the forest. Next to the preserved fragments of natural stands, which are becoming smaller and smaller, emerging is the first forest generation formed by human hand, with stands of various age – starting with plantations, through sapling and pole stands, to forest stands being already approx. 60–65 years old. Frequent changes in the management principles followed through many decades (2) resulted in the existence in the forest of stands next to one another developed as a result of the application of various cutting systems.

At the northern edge of the forest, in the Narew valley, a large (3250 ha) water reservoir is being built, which will change the hydrological relations in the northern part of the Browsk forest management unit and which will add a new element to the forest's physiognomy.

Therefore, the conditions in the territory of the Białowieża Forest allow a wide scope of research on environmental systems, either functioning under totally natural conditions, or being subject to diverse anthropogenic impacts resulting from the conducted forest, agricultural, breeding and tourist management and from hydrotechnical projects implemented over the entire country on an increasingly larger scale.

Thus, the forest should be used more fully than so far for the development of biocenotic and ecological research to gain ever greater significance for the sustainable utilisation of natural resources and the formation of the natural environment. Here, first of all, one should develop comparative research on the structure and functioning of forest ecosystems characterised by various forms of economic use and to a great extent serve the multilateral studies on natural foundations of the forest production.

First of all, scientific studies focused on factors and mechanisms determining the ecological balance of ecosystems should be conducted here, as they are essential both for the progress of forest sciences and for the interpretation of research results on ecological systems being subject to human impact, as well as for the assessment of results of the impact of management practice aimed at the conversion of forest ecosystems and the transformation of the natural environment in general. Research should also be developed on the emergence and regime of forest diseases, for which a concept was developed by **Obmiński** (5) in 1956.

The Białowieża Forest is particularly predestined to allow genetic research into forest tree populations: on the frequency of occurrence of particular genes in populations, on the correlation between the population's gene composition and types of gene composition for various forms of stand use. Here the tree population diversification with regard to its sensitivity to pathogens should be studied. The research on interactions between floristic and faunistic components of ecosystems, both under natural conditions and at various stages of regeneration based on selection cutting system, should be conducted. The research of this type is of basic significance for the intensification of forest production and for the conservation of the natural resources of our forests.

The Białowieża Forest constitutes also a very suitable area for the implementation of research conducted within the framework of the scientific cooperation between the RWPG [CMEA – The Council for Mutual Economic Assistance] countries concerning the problem of 'Conservation of ecosystems (biocenoses) and landscapes', and in particular the following topics:

1. Analysis of structures and functions of biocenoses of different complexities and of different levels of violation by humans.
2. Basic tendencies, patterns and pace of changes in the major types of biogeocenoses and populations under human impact.
3. Development of bioindication methodologies and development of methods for the bioindication of anthropogenic impact on the environment.

The research on the structure and functioning of natural environmental systems is essential for the reasonable use of the country's natural resources in general, and of the particular components of the environment in particular. It is highly significant also for an efficient operation within the scope of reclamation of damaged lands and sozological activities.

Time is of the essence for the development of environmental studies in the territory of the Białowieża Forest. In the managed part of the forest, the remnants of the natural old-growth forest will disappear within the next 15–20 years. Therefore, the forest will lose one of its major epistemic values consisting in the existence of fully natural and artificially established stands side by side. The natural forests will be replaced by plantations and young stands formed by the human hand, while mature and overmature stands will cease to exist. Currently, the oldest stands of artificial origin are approx. 65 years old. The regeneration of clear-cutting areas also results in significant changes in the natural soil structure, making it impossible to conduct many fundamental pedological studies. The soil conditions existing in a primeval forest cannot be ensured by a soil model plot, on which a common forest utilisation is conducted, followed by the renewal of cutting area with the application of mechanical soil preparation damaging the natural system of genetic levels, formed throughout many centuries.

The intensification of unfavourable changes in the natural environment, and in particular in forests, requires an intensification of in-depth fundamental environmental studies. Without them, we will not be able to handle the enhancement of tasks that results from the need for a reasonable environment formation and from the necessity of making it resistant to increasing degradation processes.

From the Department of Nature Conservation,
Forest Research Institute
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Edward Więcko

The Białowieża Forest. Timeline – part I

The timeline was developed with use of the main basic publications within that scope, which were: Hedemann, O. 'Dzieje Puszczy Białowieskiej w Polsce przedrozbiorowej (do 1798)' [History of the Białowieża Forest in the pre-Partition Poland (until 1798)], ser. A, no. 41, Warsaw, IBLP 1939; Faliński, J.B. (ed.): *Park Narodowy w Puszczy Białowieskiej* [The National Park in the Białowieża Forest]. Collective work. Warsaw, PWRiL, 1968; Więcko, E. *Puszcza Białowieska* [The Białowieża Forest], Warsaw, PWN, 1984, and other.

I. HISTORY OF CONTROL OVER THE BIAŁOWIEŻA FOREST

10th century and early 11th century In the 10th century and at the beginning of the 11th century, the lands by the Bug and Górna Narew Rivers probably belonged to Poland. In the 11th century, Ruthenian princes took possession of them.

13th century Leszek the White took that land back for some time from Daniel Romanowicz, the Prince of Halych. Tatar and Teutonic Order invasions reached the Białowieża Forest. In 1240, Tatars reached Grodno, Wołkowysk and Słonim. By conquering them, the Lithuanian Prince Mindowe seized Grodno and Wołkowysk in 1241, while in 1246 he arrived at the Białowieża Forest.

The Lithuanian invasions in the 13th century (preceded by Yotvingian invasions) resulted in the destruction of, among other things, the settlements in the territory of the Białowieża Forest and in its neighbourhood.

1279 The Yotvingians negotiate (period of famine) with Prince Vladimir of Volhynia.

1281 Complete defeat of the Yotvingians by Lithuanian Duke Trojden.

13th century Fighting for the lands by the Bug River in the 13th century. The lands, after some time under the reign of the Dukes of Mazovia, were taken over by Lithuanian Dukes.

1345 After the death of Gediminas, the real founder of the united large Lithuanian State, his sons Algirdas and Kęstutis took power over the entire Lithuania – plagued by Teutonic raids. The younger son Kęstutis received: Brześć, Kamieniec Litewski, Bielsk and Wołkowysk, hence also the Białowieża Forest.

1348 Casimir III the Great, King of Poland, conquered the forests by the Narew River for a temporary period.
1377 Rule over Lithuania was taken by Jogaila [Polish: Jagiełło – Ed.], Algirdas' son and successor, who in 1385 entered into the Union of Krewo with Poland, was baptised and married Jadwiga, and became the King of Poland. From then, the Białowieża Forest was under the sovereignty of Poland. The border between the Bielsk Forest and the Białowieża Forest constituted the border between the Kingdom of Poland and the Grand Duchy of Lithuania until the time of the Partitions.
1422 The post-Yotvingian lands were divided by the Treaty of Melno in 1422 between the Teutonic Order and the Lithuanians, and the border established then was sustained as the eastern boundary of Prussia until World War II.
1566 From the Podlaskie Voivodeship established in 1520, the counties of Brześć, Kamieniec and Kobryń were separated and incorporated into the Brześć Voivodeship together with Polesie. The Białowieża Forest, as it belonged to the Kamieniec poviat, remained in the Grand Duchy of Lithuania, while the Podlaskie Voivodeship was incorporated in 1569 into the Crown as a former Polish land.
1569 The Union of Lublin was signed. It introduced a real union in lieu of the previous personal union between Lithuania and Poland, while the central governances of each were maintained separately. The documents issued in July 1569 state: 'The Kingdom of Poland and the Grand Duchy of Lithuania are one, uniform and inseparable body, but also the Republic, which became bound into one nation and state from two nations and states, is not distinct, but one common.'
1697 Polish was introduced as the official language in the Grand Duchy of Lithuania in lieu of the Russian language.
1795 The Białowieża Forest became part of the Russian Partition.
1812 The Białowieża Forest became a battlefield, when the Russian army started to fight the Austrian army (the acts of war in the forest lasted four and a half months).
1831 The Białowieża Forest was the site of insurrectionist fighting. The forest guard with the *forestmeister* E. de Ronco, as well as the gamekeepers, beaters and peasants joined the uprising.
1863 Fighting by insurgent troops of Roman Rogiński, Onufry Duchiński and Walery Wróbewski (the then inspector of the Sokółka forest school, and later one of generals of the Paris Commune) in the forest.
1915–1918 From August 1915 to the end of November 1918, the Białowieża Forest was under the occupying German military authority (under the management of Georg Escherich).
1919 In February–June 1919, the Białowieża Forest was taken over by the Polish authorities and until September 1939 it lay within Polish borders.
1939–1941 From autumn 1939 to June 1941, the Białowieża Forest was incorporated into the Byelorussian Soviet Socialist Republic.

1941–1944 From June 1941 to June 1944, the Białowieża Forest was under the Hitlerian occupation.
1941–1944 Activity of the Soviet and Polish resistance movements in the area of the Białowieża Forest.
1944 The Białowieża Forest was divided by the state border between the People's Republic of Poland and the Byelorussian Soviet Socialist Republic.

II. DEVELOPMENT OF SETTLING

15th century The formerly uninhabited primeval forest strip from the bogs of Polesie, through the Białowieża Forest, to Kaunas, being in the 15th century under the authority of Lithuanian dukes, became populated through a surge of settlers from the west and the south.
15th century The formerly unsolicited settling during the time of Grand Duke Vytautas [Polish: Witold – Ed.] (ruling in Lithuania from 1410) was put into the framework of rationed colonisation under the German law.

At the time of Władysław II Jagiełło and Vytautas, the large-scale landholding had its beginnings.
Mid-15th century and 16th century The majority of the Bielsk Forest area bordering the Forest was colonised.
17th–18th century The Białowieża Forest, surrounded by private land properties, was subject to various claims brought by the gentry due to its 'rights' of use [Polish: *wchody*] and others.
1699 The grange, existing already by 1699, established probably in the place of the present Palace Park, constituted the beginning of the emergence of the Białowieża Glade.
1843–1846 In the second half of the 19th century, 120 various settlements lay within the borders of the Białowieża Forest, belonging to two communities, Białowieża and Masiewo (in 1862, there were 668 homesteads and 5,790 residents).
1975 Three communities within the range of the Białowieża Forest: Białowieża, Hajnówka and Narew were populated in 1975 by 32,500 people (16,066 in towns and 16,397 in villages).
1977 3,437 people were living in the Białowieża Community.

III. CHANGES IN THE TERRITORY OF THE BIAŁOWIEŻA FOREST

1559 Partial separation of the Białowieża Forest from the Bielsk Forest.
1584 and 1592 'Decrees on the demarcation of the Białowieża Forest' issued.
1639 In the 'Ordinance of the Białowieża and Kamieniec Forest Districts' dated 1639, a ring road around the Białowieża Forest was indicated.

1780 Separation of the Białowieża Forest District (first delineation of a real border of the Białowieża Forest).
1806 The Białowieża Forest area determined by the surveyor Golisewicz in 1806 on the base of measurements of the year 1739 was 128,494 ha, after consideration of donations of parts of the forest made by Catherine II.
1843–1846 According to the forest measurements made at that time, its area was 122,447 ha, including 96,106 ha of woodland.

The Białowieża Forest was divided into 541 compartments and the Świsłocz Forest into 125 compartments (the rectangles established as a result of demarcation and cutting through compartment division lines had an area of two square versts each, i.e. 208.33 dessiatines = 227.60 ha, except for outer compartments).
1861–1862 According to the measurements, the Białowieża Forest area was determined as 123,139 ha, including wooded area of 912,365 ha.
1870–1871 Based on the then measurements, the forest area was specified as 102,318 ha, including 90,282.4 ha of woodland.
1883 Changes were introduced to the forest spatial division by cutting complementary compartment division lines (from east to west) at one verst intervals. (The area of the newly formed compartments, except for the outer ones, was approx. 113 ha each).
1884–1885 After partial verification of the Białowieża Forest measurements, its area was determined as 101,986.1 ha, including 90,057.5 ha of woodland area.
1890 Based on the measurements ended in January 1890, the forest area was determined as 101,904.6 ha (with addition of meadows being at issue – 102,056.6 ha), including 87,534.8 ha of wooded area, which constituted 85.9% of the forest area. Other usable areas covered 5.8% (without disputed meadows), non-productive lands of 8.2%, roads and waters slightly above 0.1%. The Świsłocz Forest covered an area of 23,645 ha.

End of 19th century On the west, the Białowieża Forest bordered with a completely woodless land (Bielsk Poviat). On the north-western side, the Ladzka Forest adjoined that forest over approx. 6.5 km. On the north, the Białowieża Forest bordered with the Świsłocz Forest, separated from it by the riverbed of the Narew and peasant meadows. On the east, the forest border crossed bogs, covered with forest only in some places, over approx. 43 km. On the north-eastern side of the Białowieża Forest, governmental woodlands of the Szereszów Forest and woods of various owners were spread, while on the south (near Grabowiec) the Omelianiec governmental woodlands adhered. Peasant lands bordered the forest in some places, while they partially lay within its borders.
1930 The area of the Białowieża Forest together with the Świsłocz Forest was 128,921 ha, from which the Białowieża Forest area was approx. 105,282 ha (together with wildernesses of 1,525 ha area located beyond the main complex). Together with the Ladzka Forest

and the Szereszów Forest, the Białowieża Forest and the Świsłocz Forest covered an area of 1,429.26 ha.

1933 According to the forest holding's management plan, the Białowieża Forest (without the Białowieża National Park with an area of 4,693.24 ha) covered 100,592.33 ha (status as at the beginning of July 1933), including forest area of 89,210 ha, of which 96.9% was wooded.

IV. MANAGEMENT OF THE BIAŁOWIEŻA FOREST

15th century The emergence of the intendant – tenant post in the 15th century (i.e. commercial and financial agents of the grand duke) marked the beginning of the administration of properties, which included also the forest.

1567 An act regulating duties and privileges of forest wardens in the royal forests was issued; its main author was P. Falczewski.

1589 In Lithuania, in the constitution titled *Ordinario o prowentach królewskich* [Regulation on Royal Estates], from the entirety of state properties there was separated 'Brześć with Kobryń and everything else', i.e. with the Białowieża Forest, which formed that part of royal properties which was dedicated to the maintenance of the royal court.

1639 The 'ordinance on the Forest of the Białowieża Forest district' was issued.

The 'ordinance' on the royal forests of the Grand Duchy of Lithuania included a description of 11 primeval forest areas (including the Białowieża Forest) prepared by the commissioners Piotr Dałmat Isajkowski, J. Pac and Krzysztof Białozór. The power over the Białowieża Forest District, consisting then of three quarters: Orzeszkowo, Dmitrowo and Fałowo, was wielded by Gerard Doenhof.

1641 The ordinance of 1641 on royal forests set out the strict conservation of Crown forest lands, in particular the Białowieża Forest. The royal forest warden living in Jaroń was authorised to directly contact King Władysław IV at any time.

17th century In lease contracts of the 17th century concerning the Brześć estate and the Białowieża Forest district, as well as other forest districts, the obligation of forest and game conservation was repeatedly indicated.

1765 Antoni Tyzenhauz, Master of the Horse of the Grand Duchy of Lithuania, became the general administrator of all estates thereof. In 1777, a 12-year-contract (covering all forest districts) was concluded with him already as the treasurer.

The supreme post in the administration of royal forests of the Grand Duchy of Lithuania was occupied by the Masters of the Hunt. The local administration in the Białowieża Forest (like in other royal forests) was composed of Deputy Masters of the Hunt, forest wardens, deputy forest wardens (senior guards), dizainiers, hunters, guards, beaters, and shooters.

1795 Mikołaj Sochacki developed the 'Ordinance on service dedicated for people in charge of forest warden's duties', defining functions of the Master of the Hunt, the duties of a forest warden (forest district), deputy forest warden (quarter), guards (guard district) and 'obligations of the shooting service' ([game management] unit). The ordinance aimed at the specification of all rights and obligations of the royal forest administration.
1796 M. Sochacki became the 'main supervisor' of the Brześć and Grodno Forest Districts. The Białowieża Forest composed then of two quarters: Białowieża and Jamno, was a part of the Brześć Forest District.
1797 In 1797, Krzysztof Engelgardt – supervisor of the Brześć Forest District – was appointed 'supervisor' of the Białowieża Forest. In the years 1793–1797, Jerzy Targoński was the deputy forest warden of the Jamno quarter, while in 1798 the position of the deputy forest warden in this quarter was taken by Aleksander Pac (Patz), who was the deputy forest warden of the Białowieża quarter with its seat in Lipiny for the last 20 years. In 1798, Fryderyk Hoffmeister became the deputy forest warden of the Białowieża quarter.
1798 The Forest Department of the *Admiraltejstwo Kolegii* took over the administration of the governmental forests and then the implementation of the Russian management system was initiated in the forests of the Grand Duchy of Lithuania.
1837 Changes were introduced to the forest management organisation (in 1837 three forest districts were established, from 1841 four, and after 1846 five).
1872 The position of 'forest inspector' was introduced instead of the forest supervisor.
1888 The Białowieża Forest and the Świsłocz Forest were incorporated as private tsarian estates and handed over under the rule of the tsarian domains administration (*udielnyje wiedomstwa*).
1889 The area of the both forests (Białowieża and Świsłocz) was divided into three districts renamed then as properties (*udzielnyje imienija*), the number being increased to five in 1891.
1889 A local administration of the Białowieża Forest named 'Uprawlenije Białowieskogo Udielnogo Okruga' was created, which in 1898 was renamed 'Uprawlenije Biełowieżskoj Puszczi'.

In the Białowieża Forest five senior gamekeepers (*Oberjäger*), 15 gamekeepers (*Jäger*), 11 shooters, 34 bison guards, and four other people were employed. Moreover, the forest guard included 20 supervisors and 125 guards.
1915–1918 From August 1915 to November 1918, the Białowieża Forest was under the German military authority.
1919 After the takeover of the Białowieża Forest by the Polish authorities, the former Russian division into five administrative units referred to as forest districts (Browsk, Królewskie with its seat in Białowieża, Starzyna and Hajnówka with its seat in Hajnówka and Świsłocz in the village of Oszczep) and the Inspectorate of the Białowieża Forest was maintained initially.

1920 By a regulation of the Council of Ministers as of 23 November 1920 (Journal of Laws No. 114, item 753) on the organisation and scope of the activity of the regional boards of state forests, the regional boards were established for the state forests in Warsaw, Radom, Siedlce and L'viv. The Regional Board of the State Forests in Siedlce covered the Bielsk, Biała Podlaska and Białystok counties, thus also the Białowieża Forest.

By a regulation of the Council of Ministers as of 9 August 1921 (Journal of Laws No. 71, item 175), the regulations concerning the organisation of administration of state properties and forests as of 23 November 1920 on the reorganisation of the administration of state properties (Journal of Laws No. 114, item 752) and of 23 November 1920 on the organisation and scope of activities of regional boards of state forests (Journal of Laws No. 114, item 753) was extended to the Nowogród, Polesie and Volhynia Voivodeships and to the Grodno, Wołkowysk and Bialystok counties of the Białystok Voivodeship, and the Regional Board of the State Forests in Lutsk, covering the Volhynia Voivodeship area.
1922 By the regulation of the Council of Ministers of 21 July 1922 on the changes in territorial jurisdiction of the regional boards of state forests in Warsaw, Radom, Białowieża and Lutsk, the Regulation of the Council of Ministers as of 9 August 1921 was amended, among others, by the following: 'a) The Regional Board of the State Forests in Białowieża, encompassing the Brześć, Drohiczyn, Kobryń, Kosów, Łuniniec, Pińsk and Prużana counties of the Polesie Voivodeship, the Baranowicze, Nieśwież and Słonim counties of the Nowogród Voivodeship, and the Białowieża, Masiewo and Suchopol communities of the Bielsk Podlaski counties of the Białystok Voivodeship.'
1924 Pursuant to the regulation of the President of the Republic of Poland dated 28 June 1924 (Journal of Laws No. 56, item 570), the Minister of Agriculture and State Treasury appointed the regional directorates of state forests, including the Regional Directorate of the State Forests in Białowieża.
1925 By the regulation of the Council of Ministers as of 16 January 1925 (Journal of Laws No. 9, item 62), 10 directorates of state forests were created in Poland, including the Directorate of the State Forests in Białowieża.
1929 Pursuant to the regulation of the Minister of Agriculture dated 12 September 1929 (MP [Polish Official Gazette] No. 212, item 499) amended by the regulation of that Minister dated 1 April 1933 (MP No. 72, item 92), the area of the Białowieża Forest was divided into 14 forest districts (Browsk, Narewka, Czoło, Jaźwiny, Hajnówka, Zwierzyniec, Białowieża, Leśna, Jagiellońskie, Nikor, Starzyna, Biała, Królewski Most and Jasień), as well as the Oszczep Forest District from the Świsłocz Forest was incorporated thereto.

Jan Szreders was the first chief of the Regional Board of the State Forests in Białowieża (by December 1923) and Edward Szemioth was the next one (by October 1924). The Regional Directorate of the State Forests in Białowieża, and then the Directorate of the State

Forests in Białowieża was headed consecutively by Stanisław Zaniewski (1924–1928), Antoni Sym (1928–1930), Stefan Modzelewski (1930–1934), and Karol Nejman (1934–1939).
1939 Pursuant to the resolution of the Council of People's Commissars of BSSR [Byelorussian Soviet Socialist Republic], the Białowieża Forest was considered a [nature] reserve.
1941 In December 1941, the Hitlerian authorities decided to create a state hunting area (*Reichsjagdgebiet*) from the Białowieża, Ladzka and Świsłocz Forests.
1944 From July 1944, the western part of the Białowieża Forest lying within the borders of the People's Republic of Poland was divided, except of the Białowieża National Park, into eight forest districts: Białowieża, Browsk, Hajnówka, Ladzka Puszcza, Leśna, Narewka, Starzyna, and Zwierzyniec.
1973 Pursuant to the order of the Director General of the State Forests, the Polish part of the Białowieża Forest (except for the Białowieża National Park) was divided into three forest districts: Białowieża, Browsk and Hajnówka.

The Directorate of the State Forests in Białystok, and then of the Regional Board of the State Forests in Białystok, to which the Białowieża Forest was subordinated, was consecutively headed by: Edward Więcko (August 1944 – March 1945),[1] Zygmunt Łukaszewicz (1945–1948), Tadeusz Owczarek (1948–1951), Franciszek Rawa (1952–1954), Władysław Jurkowski (September 1954 – January 1960), Wacław Sosnowski (February–October 1960), Roman Filipowicz (1960–1976), Wacław Sosnowski (1977–1979 July) and Edward Badyda (since August 1979).

The paper was received by the Editorial Committee on 8 December 1982.

[1] For approx. one month in autumn 1944, the Directorate of the State Forests was headed by Jerzy Pruszkowski.

Edward Więcko

The Białowieża Forest. Timeline – part II

V. THE ECONOMY IN THE BIAŁOWIEŻA FOREST

a. In the period before World War I

1409 The first great royal hunt of Władysław Jagiełło began in the Białowieża Forest in the autumn of 1409 and continued throughout the winter. The following were hunted: aurochs, bison, bear, elk, deer and boar. Forest horses – tarpans – were caught for the use of the Lithuanian army. The Grand Ducal hunting constituted the oldest form of utilisation of primeval forests.

15th–16th century Probably, by that period a huge potash plant existed in the Białowieża Forest. At that time, colliers from Mazovia, Samogitia, and possibly from Moravia were brought to the Białowieża Forest and exterminated parts of the forest. They settled in the villages of Termiska, Pohorelce, Budy, and Masiewo.

1551 At the Vilnius Sejm [lower house of parliament] session, requests from the gentry [were directed] to King Sigismund II Augustus for the recognition of rights to use the forests '(…) so that boyars, gentry and common people, according to the former custom, are allowed to kill animals, harvest trees for construction and catch fish in the lakes'.

1554 At the following Sejm session, the gentry's petitions to the King for 'ancient' (*wchody*) [rights of use] to wild beehives, lakes, weirs, and hay-making [were again announced].

1557 The 'act on voloks' was issued, which included the provisions of the surveying 'who, on what legal basis has *wchody* rights and for how many services' and 'where it is beneficiary, the forest should be handed over to settlers for free clearing for 5–10 years', however it was reserved that 'backwoods and hunt sites should not be touched'.

1558 The Piotrków Sejm recommended 'signing over' of all domestic forests of the Grand Duke of Lithuania, which was partially performed in 1559 by Grzegorz Wołowicz – the Starost of Mścibogów. Among described 38 forests which existed then in the Lithuanian territory, The Białowieża Forest was mentioned as one position together with the Bielsk Forest. The owners of the *wchody* rights were obligated to submit legal evidence confirming their areas, locations and utilisation types. Wołowicz studied ten objects (land estates) located in vicinity of the Białowieża Forest, possessing *wchody*.

1567 In the 'forestry act' of 1567 there was a reservation that forest wardens 'do not profit or let third parties profit from birch tar, wood ash, pine tar and other woodland products from the forests'.
1591 King Sigismund III, in connection with the breaches by the forest warden Trojanowski, stated: 'we know that the forest warden (…), by crossing the ancient border between the Bielsk and the Białowieża Forest, occupies quite a large part of the Białowieża Forest and incorporates it to the Bielska Forest, exploiting it by burning forest products without our permission'. The utilisation of the forests of the Grodno estate increased over time – by collection of the so-called *pniewszczyzna* [charge for timber obtained from the forest].
1636–1640 The 'ordinance' prepared by Piotr Dołmat Isajkowski, the Master of the Hunt of the Grand Duke of Lithuania, included an exhaustive list of *wchody*. The revisions of the Białowieża Forest of 1680 and 1703 repeated to that extent the provisions of the ordinance. Almost all *wchody* rights were grouped at the southern and south-western side of the Białowieża Forest.
1641 The ordinance for royal forests issued under the rule of King Władysław IV introduced strict protection of Crown forests, in particular the Białowieża Forest. The King's written permission was required for entering the forest. The utilisation of the forest also required such a form of permission.
17th century The utilisation of the Białowieża Forest became extended to include the production of timber destined for trade.
1700 Augustus II delegated a special commission to the Białowieża, Sokółka and Nowy Dwór Forests to examine the matter of *wchody*. Another commission for that matter was appointed in 1712. The results of the acts of both commissions were limited because *wstępnicy* [people with rights to enter the forest] were hampered the documentation of their 'rights to *wchody*'.
1705 Augustus II re-introduced to the forest the old traditions of royal hunting. He liquidated the ore mills (iron factories), potash and pine tar factories established in the middle of the 17th century. This was accompanied by removing many people from the forest who were killing the game as poachers. The hunting guard was increased to 150 people.
1752 One of hunts took place in the Białowieża Forest, with the participation of King Augustus III and the Queen. To commemorate that hunt, a sandstone obelisk was erected in Białowieża, on which the names of the people present at the hunt and the quantity of the killed game were given.
1755–1780 A. Tyzenhaus led the action aiming at expelling the *wstępnicy* from the forest.
1764 After Stanislaw II Augustus assumed the throne, Godfrid Henryk Harnak, 'the hunting secretary of His Majesty the King', prepared an official note regarding the increase in the profitability of forestry, composed of three parts: revenue multiplication, forest conservation and the hunting ordinance. The Harnak's projects were completed to some extent

when estate management was taken over by Antoni Tyzenhaus, the 'general administrator of estates for His Majesty the King'. The Treasury administration showed much initiative within the scope of independent performance of forest works and floating.

1764 The timber selling system in the 17th and 18th century with collection of the so-called '*pniewszczyzna*' [charge for timber obtained from the forest] was criticised by Harnak who, striving for increasing treasury income, thought that it would be the best if '(…) the Treasury took over that trade and conducted it, selling cribwork, beams, masts, oak logs, etc, with which the hunting administration would be entrusted'.

1767 In 1767, the Białowieża forest district generated 20,803 zloty of *poleśne* [forest tax], i.e. a fee paid to the Treasury for the right to harvest fuelwood and smaller sized merchantable timber by subjects (peasants, Jews). During the Hanak's activity, that fee was '8 or 10 *szóstaks* [a silver coin with value of 6 Groschen] per horse'.

1781 The annual income from the Białowieża quarter was 10,252 zloty and from the Jamno quarter to 9,765 zloty, which then belonged to the Brześć forest district.

1789 In the *universał* [act] of the 'Republic Commission of the Treasury of the Grand Duchy of Lithuania' it was stated, among other things, that '(…) in places with few forests, the Commission cannot allow their destruction (…) and in places with no forests – one has to plant and maintain them (…) in favour of the complete provision of trade income (…) and the best possible saving of forests (…), the Commission will not neglect to conceive measures for their propagation and sowing'.

1795 Directly after the Partitions of Poland, the Russian government started to receive requests from the elite of the country's society, first of all from the Radziwiłł family, for their *wchody* rights, of which they were deprived by Tyzenhaus. After a short period of tolerance, the Russian government deemed the principle appropriate, which was formulated in the 'Forest management plan' by Szczepanowski, the chief governor of the Brześć estate, who thought that it was an absurdity for 'private citizens to have a partnership with the royal Treasury'.

1796–1798 In 1796, 632 beehives with bees and 6,601 empty beehives were counted in 13 guard districts of the Białowieża Forest. Under the position 'non-constant income' of the Białowieża and Rudy forest districts in the year 1797/1798, there was mentioned the amount of 1,435 zloty 'for bees'.

1802 The interest of the Tsar Alexander I in bison was expressed in the rescript of 10 September 1802, in which peasants from the village of Czwirki (Ćwirki), Panasiuki, Kamienniki and Myzinary Pauckie were 'assigned' to the forest to 'protect' bison 'from its extermination, scaring and for feeding'. Instead of Myzinary Pauckie, the villages of Kawaczkin and Roszkówka were then assigned.

1811 A huge forest fire in the north-eastern part of the forest, lasting for more than four months, disturbed its life.

1821 and 1823 At the order of the Russian government, J. Brincken, the former superior forest manager for governmental forests of the Kingdom of Poland, visited the forest and assessed its former economy critically.

1834 Another fire broke out in the forest, and damaged 874 ha of woodland.

1838 The valid prohibition of logging in the forest was amended when the Maritime Authority, after exhausting the growing volume in stands supplying timber suitable for ship building, located in governorates by the Volga River, became interested in the Białowieża Forest. The logging suspended in 1820s was restarted and intensified.

1840 After new attempts to harvest timber for shipbuilding in the Białowieża Forest, the logging for that purpose was ceased due to difficulties with timber transportation.

1862–1863 Permission for the sale of timber from increasing stock was granted, but later sales were suspended (except mandatory sales), justifying the prohibition with the necessity of bison protection.

1870 As the result of discussions by an expert commission delegated to the Białowieża Forest by the Ministry of State Treasury, the rotation was increased from 180 to 225 years for pine, while for other species from 90 to 180 years, and a recommendation was made to carry out the management of the forest considering the peaceful existence of bison living there. For the local needs, approx. 10,000 logs, 13,000 poles and perches and approx. 28,000 m^3 of fuelwood were produced on average per year (in the period 1862–1871), i.e. twice as much as on average per year in the preceding 17 years (1845–1861).

1877 As the Ministry did not approve the proposal of the forest management planning experts concerning the logging of snags in the forest – the Administration of State Treasury in Grodno applied in 1877 for permission to exploit the outer parts of the forest, where no grazing places for bison existed. That permission was granted. In the same year, the preparation of a utilisation plan for the part of the forest with no bison was commenced, on an area of 49,891 ha.

1871–1884 In that 14-year-period, 125,557 pines and 7,323 oaks and ashes were felled or sold from snags of overmature trees, which had been marked in 1877. Moreover, 99,138 logs, 94,930 perches, and 295,934 m^3 of fuelwood were sold for cash or given away for free from down woody debris. The sales for local needs in every year were lower than in the preceding period.

The mean global annual revenue from the forest amounted to 48,599 roubles, expenses to 16,376 roubles and the net income to 32,223 roubles, i.e. 65% of the mean total revenue.

1884 According to the resolution of the commission's council of July 1884, the rotation adopted for pine, oak and ash was 200 years, while for other species 100 years – with a recommendation to establish one [clear-]cut for every six compartments.

1885 From that year, the utilisation of the forest stands intensified.

1887 In 1887, the revenue from the forest was 142,967 roubles and in 1888 to 188,967 roubles, i.e. on average 2.02 roubles from 1 ha of land in use (93,430 ha).
1888 After transferring the forest from the control of the state administration to the administration of the tsarian domains of the Department of Appanage Estates, two forest management planning teams were delegated in 1889 to the forest and engaged to prepare a renewed management plan for the forest. A total of 678 sample plots were established with a total area of 323 ha (data from 643 sample plots were used).
1888–1889 688 ha (630 dessiatines) of the forest were sold to Schultz, a German citizen.
1889 The total growing stock of the stands in the forest was determined as 28.8 million m^3, including the growing stock of mature stands of 20.7 million m^3 (72%). The average growing stock of merchantable timber calculated above 8.88 cm (2 vershoks) was 351 m^3 per hectare. The highest stock occurred in coniferous forests with spruce, at 424 m^3 per hectare.
1891 70,800 m^3 of tree volume on an area of 8,881 ha, including 28,900 m^3 of pine, were designated for logging in the next two years.
1890/91–1896/97 In that period, 2,341,826 m^3 of timber were sold for 1,467,092 roubles, i.e. 334,547 m^3 of timber for 209,585 roubles on average per year. After the suspension of sales of growing stands, in the period of the next five years 113,105 m^3 of timber were sold on average per year, for which 65,407 roubles were received yearly. On average, 0.92 m^3 of timber were harvested from 1 ha from dead or declining trees, taking for them on average 75 kopecks per hectare. That relatively small volume of wood harvesting and insignificant revenues from sales resulted from the hunting-oriented nature attributed to the forest.

The revenues for the livestock grazing were 6,943 roubles in 1900, 6,149 roubles in 1901 and 5,909 roubles in 1902.
1891 A sawmill was built in the Hajnowszczyzna wilderness for 10,858 roubles, and after its destruction by a fire in 1893, a new sawmill with four gang saws was built at the Strabla railway station for 188,676 roubles.
1891–1892 In that period, the river bed of the Narewka was straightened over a distance of 32 km, starting from compartment 505 to the forest border in compartment 80; its tributary – the Lutownia River – was canalised over a distance of 16 km from compartment 119, the same as the Hwoźna River over 11.7 km from compartment 324. These works cost 35,551 roubles with a free-of-charge timber allocation.
1894 A railroad from Bielsk to Hajnówka station was built (30 km) prior to the tsar's arrival to Białowieża for hunting; an extension to the village of Białowieża (22.4 km) was constructed in 1897, before the next tsarian hunt.
1897 While hunting, the tsar expressed his wish that the administration of the forest did not strive for the highest income, but that it cared only about maintaining the typical character of the forest. Then, cuts were completely withheld in the forest. Only down woody debris and old fallen bark were removed on the area of 80 compartments; in 1901 that area was

specified as ⅙ of the territory of the forest. Simultaneously, cleaning of dense coniferous sapling stands was introduced.

End of the 19th century. The local administration of the Białowieża Forest adopted certain measures towards the natural regeneration and soil preparation for future artificial regeneration.

1903 The project of the forest administration of logging snags on ⅙th of the forest's area, pines with dry tops and overmature spruces with a diameter at breast height above 49 cm was approved.

1906–1912 Renewed forest management planning was conducted in the forest.

1914 The population of big game in the forest: bison – 785, elk – 58, red deer – 6,800, fallow deer – 1,488, roe deer – 4,966, boar – 2,320.

b. The economy in the forest between World War I and II

1915–1918 From August 1915 to December 1918, when the forest was subordinated to the German occupying military authority, 6,500,000 ha of stands were clear-cut on large areas and in the entire forest the best trees, with a total volume of approx. 2.6 million m^3 of merchantable timber, were selected and cut.

1915 On 15 September 1915, with the intention of protecting the bison, the Germans issued a protective hunting order for the forest, bringing a forest guard from Bavaria to protect the game from poaching.

1915–1918 In the first 20 months of the occupation of the forest, the Germans built sawmills: in Hajnówka – with ten gang saws, in Czerlanka – with three gang saws, in Gródek – with four gang saws, in Stoczek – with four gang saws, in Nowy Most – with two gang saws, and in Mała Narewka – with one gang saw. Moreover, a wood wool factory, a mechanised woodworking shop and a factory of self-assembly houses were put into operation in Hajnówka. The German company Scharing built a factory in Hajnówka for dry wood distillation (the largest one in Europe), with 128 vertical retorts and a processing capacity of 300,000 steres of deciduous timber per year

1920 The Białowieża Forest was affected by a gradation by bark beetle.

1924 On 24 February 1924, an agreement was concluded with the English company The Century European Timber Corporation, under which that enterprise was to exploit the Białowieża Forest and the Dukszty state forests near Grodno and Słonim for a period of 20 years. On 29 May 1929, the Ministry of Agriculture terminated unilaterally the agreement with the company, paying a large compensation. By the time of the agreement termination, the company had harvested 2.5 million m^3 of timber.

1929–1930 The former Russian area partition dividing the main complex of the Białowieża Forest into 924 compartments with sides equal to 1 verst (1,066.8 m) was supplemented by cutting it with new division lines criss-cross wise.

The actual growing stock of the stands in the forest, based on the definite forest management plan, was specified as 16,217,000 m^3 and 187 m^3 per hectare. The average increment was specified as 2.25 m^3 per hectare and the harvesting as 4.20 m^3 of timber.

1930 The collections of the created Natural and Forest Museum were made accessible to visitors.

1932 In its assessment of strike movements in Poland at the end of 1932, the Political Office of the Central Committee of the Communist Party of Poland mentioned also the forest workers' strike in the Białowieża Forest.

1932–1933 The common strike of forest workers in the Białowieża Forest at the turn of 1932 and 1933 was rated as one of the longest episodes of the class struggle in the Białystok region. (The total number of workers employed in the forest came then to approx. 6,000 people).

On 17 December 1932, 97 delegates of smallholders who gathered in Białowieża elected the Forest-Wide Central Strike Committee, with its seat in Białowieża.

1939 Game population in the forest in 1939: bison – 16, elk – 9, red deer – 1,700, roe deer – 2,938, boar – 1,900.

c. The economy in the forest in the People's Republic of Poland

1949 The growing stock of merchantable timber in stands in the Polish part of the forest was determined in 1949 at 9.5 million m^3, in 1958 – 10.2 million m^3, and in 1968 – 11.3 million m^3 (The growing stock in stands of the entire forest in 1890 was 22.8 million m^3, in 1916 – 32.6 million m^3, and in 1931 – 16.2 million m^3).

1958 The cutting age adopted in the forest management plan of the forest holding: pine – 120 years, oak – 160–200 years, spruce – 100–120 years, ash – 120–140 years, hornbeam – 80–100 years, birch – 80 years, aspen – 80 years.

1948/49–1957/58 The average volume of merchantable timber harvested annually was 189,000 m^3 (timber from final, intermediate and salvage cutting), i.e. 114% against the annual allowable cut.

1958/59–1967/68 Within the forest management planning works preceding that period, the forest woods were divided into protection forests (group I) and managed forests (group II), with an additional delineation of reserve forests and lairs of rare animals.

The annual allowable cut calculated from two last age classes of the forest's stands for that ten-year-period was determined at 1,218,852 m^3. Actually, 1,738,376 m^3 of timber (merchantable timber) was harvested in that ten-year-period.

In that period, 3,831.35 ha was regenerated or afforested.

1975 The Regulation of the Minister of Forestry and Wood Industry as of 30 January 1975 defined the 'Basic principles of the forest management in the Białowieża Forest'. The following cutting ages were adopted: for pine – 140 years, spruce – 120–140 years, oak – 160–200 and 240 years, ash – 140 years in alder carr habitats and 180 years in moist deciduous forest and alder-ash carr habitats. The annual allowable cut as of 1 October 1968 was determined at 241,574 m^3 of net merchantable timber per year, and after recalculation according to the 'principles' at 192,083 m^3.

1975–1978 The harvesting of wood (merchantable timber) in 1975 was 217,500 m^3, in 1976 – 202,700 m^3, in 1977 – 203,800 m^3, and in 1978 – 191,000 m^3. In 1978, the regeneration and afforestation area was 430 ha.

1975 Population of animals in the entire forest: bison – 335 (245 and 90),[1] elk – 175 (31 and 144), red deer – 2,880 (760 and 2,120), roe deer – 1,380 (500 and 880), boar – 2,295 (760 and 1,535) specimens.

1978 The number of permanent workers in the forest was 274, white-collar workers – 232. The average monthly salary in that year was: workers 4,324 zloty, white-collar workers from 3,810 zloty (Hajnówka Forest District) to 4,029 zloty (Białowieża Forest District).

1980 The industry of the forest located in Hajnówka is composed of: Hajnówka Wood Industry Enterprise, Dry Timber Distillation Enterprise, Forestry Mechanical Engineering Works, Forest Production Works 'Las', Prefabricated Component Production Works for the Construction Industry, and Milk Processing Plant.

VI. BISON IN THE BIAŁOWIEŻA FOREST

16th century In the beginning of the 16th century the protection of bison was introduced. (For killing a bison, a royal permission was required.)

19th century From the beginning of the 19th century, the principle of almost yearly verification of the bison population in Białowieża was implemented. In 1821, there were 722 bison in the forest, in 1857 – 1,898, in 1899 – 380, in 1901 – 747.

1919 At the beginning of 1919, nine bison remained alive in the Białowieża Forest. On 19 February 1919, the last bison was killed by a poacher.

1925 The International Society for the Protection of the European Bison was established in Berlin (on the initiative of J. Sztolcman), which took care of the registration of bison living in zoos worldwide and determined the principles for their breeding.

[1] The first number given in brackets refers to the population of animals in the Polish part, while the second one in the Byelorussian part of the Białowieża Forest.

As of 1 January 1925, 66 specimens of bison lived in seven countries. (Romanov W.S. (1965) indicated that by the year 1926 only 52 bison were left worldwide). At that time, six bison lived in Poland (in Pszczyna and in the zoological garden in Poznań).
1929 The zoological garden in Warsaw purchased from German and Swedish breeding centres three bison and four of *żubrobizon*. In autumn 1929, the first pair of pure-bred European bison was brought to Białowieża ('Borusse' and 'Biserta') and put into a reserve (in compartment 420 of the Zwierzyniec Forest District), by what the regenerative breeding of these animals in the Białowieża Forest was launched.
1939 At the end of August 1939, 16 bison lived in the Białowieża menagerie.
1944 After the conclusion of the acts of war, 17 bison were left in the forest.
1947 The 'European Bison Pedigree Books' has been published in Poland since 1947, until 1973 in Białowieża and then in Warsaw.
1952 Free-ranging bison breeding was commenced in the Białowieża Forest. (Firstly, two males were released in the forest and in 1953 one female with one calf and one heifer. A total of 35 further bison were released in the forest in the years 1955–1966).
1978 At the end of 1978, the free ranging herd of bison consisted of 219 specimens (12 males, 16 females, 68 young one-year-olds, and 123 calves). By the end of 1979, in the herd were 230 specimens and by the end of 1980 – 242. At the end of 1979, 567 specimens of bison (459 of Białowieża [lowland] subspecies and 108 of Białowieża-Caucasia hybrid) lived in Poland. In the years 1946–1980, 209 breeding bison were taken from Poland to other countries.

VII. THE BIAŁOWIEŻA NATIONAL PARK

1921 By the Decision of the Minister of Agriculture and State Treasury as of 29 December 1921, the expediency of establishing a nature reserve in the Białowieża Forest was stated. As the strict reserve, compartments 258, 288, 289, 319, 344 were regarded.
1923 Establishment of the Reserve Forest District managed by Józef Paczoski.
1921 In 1921, the so-called 'by the roadside' reserve was established and then modified in 1925 – on both sides of the road cutting through the forest from Białowieża to Hajnówka, with a total area of 1,566 ha (500 m wide on each side of the road), and such a reserve along the road to Prużana established in 1931, 100 m on each side of the road, with a total area of 337.59 ha.
1928 Jan Jerzy Karpiński assumes the post of the head of the Reserve Forest District.
1932 Regulation of the Minister of Agriculture as of 4 August 1932 (Polish Official Gazette No. 183, item 219) on the establishment of the 'National Park in Białowieża' from the Reserve Forest District, with an area of 4,693.24 ha.

1947 Regulation of the Council of Ministers as of 21 November 1947 on the establishment of the Białowieża National Park (Journal of Laws No. 74, item 469) as a strict reserve on an area of 4,716 ha.
The park borders are delineated by: in the west by the Narewka River, in the north by the Hwoźna River, in the east by the BSSR [Byelorussian Soviet Socialist Republic] border, in the south by the Białowieża Glade. Besides that area, the Park includes also the bison reserve, the tarpan reserve and the settlement of Zwierzyniec with an area of approx. 15 ha, as well as the Palace Park with an area of 50.01 ha.

Forests, soil, flowing and stagnant waters, as well as plants and animals on the area of the Park are subject to a strict protection.
1969 The forest strip adjacent to the road connecting Białowieża and Hajnówka, 500 m wide on both sides of the road with an area of 1,356.91 ha (demarcated already in the inter-war period) was considered the partial reserve (Polish Official Gazette No. 16, item 128 of 1969).

VIII. RESEARCH IN THE BIAŁOWIEŻA FOREST

1781 The study by J. E. Gilbert *Indigatores naturae in Lituania*… contains certain information about the flora of the Białowieża Forest.
1822, 1823, 1826 In 1822, research on the Białowieża Forest was commenced by S. B. Gorski (1802–1864), student of J. F. Wolfgang – professor of the Vilnius University and organiser of team floristic research. S. B. Gorski conducted his research in the forest based on the *Instrukcja w celu botanicznym do Puszczy Białowieskiej* [Botanic Instruction on the Białowieża Forest] developed by J. F. Wolfgang. In 1823, Gorski spent two weeks in the forest and ten weeks in 1826.
1887, 1888 In 1887, attempts to acquaint themselves with the flora of the Białowieża Forest were made by the botanists F. Błoński, K. Drymmer and A. Ejsmond, and in the Ladzka and Świsłocz Forest in 1888 by F. Błoński and K. Drymmer.
1921 Since the reserve establishment in the Białowieża Forest (transformed in 1932 into the Białowieża National Park), a permanent research activity has been developing there. Research works in the Reserve Forest District were commenced by J. Paczoski and developed by J. J. Karpiński in connection with the Experimental Station of the State Forests (transformed in 1931 into the Research Institute of the State Forests in Warsaw) headed by J. Hausbrandt and his deputy J. Kostyrka.
1945 In Białowieża, there was established a branch of the Forest Research Institute (IBL), to which the Białowieża National Park was subordinated.
1952 The branch of the Forest Research Institute was transformed into the Department of Primeval Forest Research, then the Laboratory of Nature Conservation, and in 1979 into the Department of Nature Conservation of the Forest Research Institute.

1949–1952 In that period, the Plant Ecology Station of the IBL [Forest Research Institute] was in operation in Białowieża, while in 1952 it was transformed into the Geobotanical Station subordinated in the years 1952–1962 to the Polish Academy of Sciences and then it was incorporated into the University of Warsaw (by 1967 into the Laboratory of Forest Phytosociology, University of Warsaw, and then to the Institute of Botany, University of Warsaw).
1972 Since 1972, the Białowieża Geobotanical Station and the Department of Plant Phytosociology and Ecology of the University of Warsaw have been publishing the Phytosociological Bulletin *Phytocenosis*. The research of the Geobotanical Station was incorporated into the works of the International Biological Programme.
1954 In 1954, the Department of Mammal Research of the Polish Academy of Sciences was established in Białowieża; it has been publishing the *Acta Theriologica* journal (the publishing was taken over in 1958 from the Institute of Zoology of the Polish Academy of Sciences, where it had been published since 1954).
1965 The 'Experimental Forest Subdistrict' was demarcated in the Białowieża Forest.

The Białowieża Forest is a unique forest complex – maybe even in on a global scale. Described by scientists and artists, it has survived so far and should continue to exist not only as a scientific and educational environmental laboratory and commercial object, but also as a source of beauty and as a museum of history. To this end, a special conservation status of the forest must come into effect.

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Michał Kowalski

Alterations in species composition of forests on the background of climate changes in the last two centuries[1]

Alterations in species composition of Polish forests

The first information on changes in the species composition in forests was obtained from sample plots in the Białowieża National Park established in 1936 by Professor T. Włoczewski. They concerned the formation of multiple young generations of linden, hornbeam and ash, being abundant in numbers, and that phenomenon was explained by a reaction to the absence of game after its extermination in 1915. It was logical, as there was plenty of game in the forest for a long time, however, it was particularly numerous in the period 1889–1915, when the forest served as hunting area of Russian tsars; the territory of the forest was also well used for grazing livestock and hogs.

However, that explanation proved to be poorly useful, as:

- linden, hornbeam and ash appeared during the simultaneous decrease in the number of conifers – pine and spruce, on which the game had no impact,
- meso- and eutrophic species of broadleaved trees grew in stands, where those species had been absent before, mainly in coniferous forests on sandy sites, which indicated their expansion and the simultaneous eutrophication of the sites
- a similar process consisting of the transformation of pine stands to oak stands also occurred in the Rogów forests, located far from Białowieża.

The ongoing process of change from pine stands to oak stands can be observed in numerous forests in Poland.

Apart from oak, the share of other deciduous species increased [too]. A young generation of linden appeared, not only in Białowieża, but also in other forests, e.g. in the Pieniny National Park, in nature reserves and maintenance forests (13); in particular, the linden appeared numerously in stands of south-eastern Poland and in Lithuania, Latvia and Belarus (4).

[1] Paper presented on the symposium: ‘Forest ecosystems against climate changes’, Białowieża, 1993.

TABLE

Percentage share of area of dominant tree species in the stands in Poland*

	1948	1956	1967	1977	1983	1985
Pine	7,6	73,1	72,5	71,6	71,5	69,3
Spruce	8,8	8,5	7,3	7,1	7,0	6,9
Fir	2,7	2,1	2,5	2,4	2,4	2,9
Total of coniferous	87,1	83,7	82,3	81,1	80,9	78,1
Oak (ash, maple, hornbeam, elm, sycamore maple)	4,0	5,3	5,3	5,6	5,7	5,6
Beech	3,6	4,0	3,8	4,0	4,1	4,1
Birch	2,2	3,1	4,2	4,6	4,6	5,4
Alder	2,8	3,2	3,4	3,8	3,8	4,8
Other deciduous	0,3	0,7	1,0	0,9	0,9	0,9
Total of deciduous	12,9	16,3	17,7	18,9	19,1	20,9

* In the period 1949–1983 – according to Kamiński (1988), in 1985 – according to *Habitat-Related Foundations of Silviculture* (1990).

The hornbeam appeared on an extensive part of territory of Poland, not only on fertile soils, but also in poorer coniferous forest habitats – in pine, spruce and oak stands, as well as in bright oak forests in the course of transformation (8).

In the bottom storeys of numerous pine stands, the share of hazel, hawthorn, alder buckthorn and, in northern Poland, of red elder, increased. Fungi originating from countries with tropical and subtropical climate: netted stinkhorn and two stinkhorn species – octopus and latticed stinkhorn (6) – are a new occurrence in our country.

On poorer sites, the species alteration process is less intensive: the alterations in species are not observed on large territories of poor pine forests. Although the changes occur only in some part of our forests, mainly on richer soils, they are, however, visible in statistical reviews (5, 9). Since the 1940s, an increased share of deciduous species and a decreased share of coniferous species (table) are observed, despite such management activities as afforestation and regeneration with pine and spruce.

The presented changes occur in both, natural and managed forests, being formerly or presently under strong anthropopressure. The raking of litter, agricultural use of forest areas, creation of artificially regenerated pine and spruce monocultures, livestock grazing and maintenance of an overabundant game population led to a degradation of forest habitats. Therefore, an impoverishment of habitats should be expected, but after the game extermination in the Białowieża Forest (in 1915) and the grazing cessation in Rogów forests (approx. 1920) large, young generations of abundantly growing meso- and eutrophic tree species emerged there, proving not an oligotrophication, but just the opposite – a eutrophication of habitats.

The observations described here have indicated the occurrence of changes in biotopic, but not in edaphic, conditions, although in the last 10–20 year this cannot be excluded, but the impact of global, thus climatic factors. Therefore, a hypothesis of a climatic reason for changes in species composition of Polish forests was formulated.

Climate change in the last two centuries

As for the climate of the last few centuries, the cooling period (Little Ice Age) in the centuries 17th–19th was distinguished. From the first half of the 19th century, the mean annual temperature has grown slowly and at the turn of centuries its transition from negative to positive anomalies took place; since that time, the contemporary warming up period has been observed (Fig. 1A). Compared to the cool period, the mean annual air temperature is currently higher (2, 23), the vegetation periods are much longer – the meteorological ones, longer than the phenological ones (Fig. 1B), the sum of active temperatures (temperature of growth) – determining the tree cropping – significantly increased (Fig. 1C). It may be supposed that the climatic conditions were subject to changes significant to the vegetation of plants, which occurred in the years 1915–1920, when the sum of active temperature reached a high value, with a simultaneous significant elongation of vegetation periods. Since the 1980s, the mean air temperature has significantly increased, just like the duration of vegetation periods and the sum of active temperatures.

Alterations in species composition of stands on the background of climate changes

The alterations in the species composition in our forests correspond well with climate changes. To illustrate these dependencies, data on species composition of three forest complexes were used, in which observations were being made over a longer period.

- **The spruce-alder stand with admixture of ash, in an alder-ash carr habitat in the Białowieża Forest District** was established in the 19th century. The then prevailing conditions of cool continental climate were beneficial for spruce and small-seeded species. Pine and alder regenerated on hillocks raised over the surface of stagnating water, which did not quickly evaporate in a cool climate. In the warming period, beneficial conditions for cropping, regeneration and quick growth of young deciduous trees emerged (Fig. 2).

In approx. 1930, a young tree generation was formed with dominant ash, with an admixture of alder, hornbeam and linden – species that earlier were absent in the stand. The share of ash and hornbeam grew, while spruce decreased. These changes might be explained with the lowering of groundwater levels in the period of warming and with a weaker competitiveness of spruce towards dynamically growing, numerous young ash.

Over a period of approx. 60 years, the stand established in the past century, with its species composition resembling a poorer form of alder carr, was transforming into a moist oak-hornbeam forest with ash in the overstorey and hornbeam in the understorey.

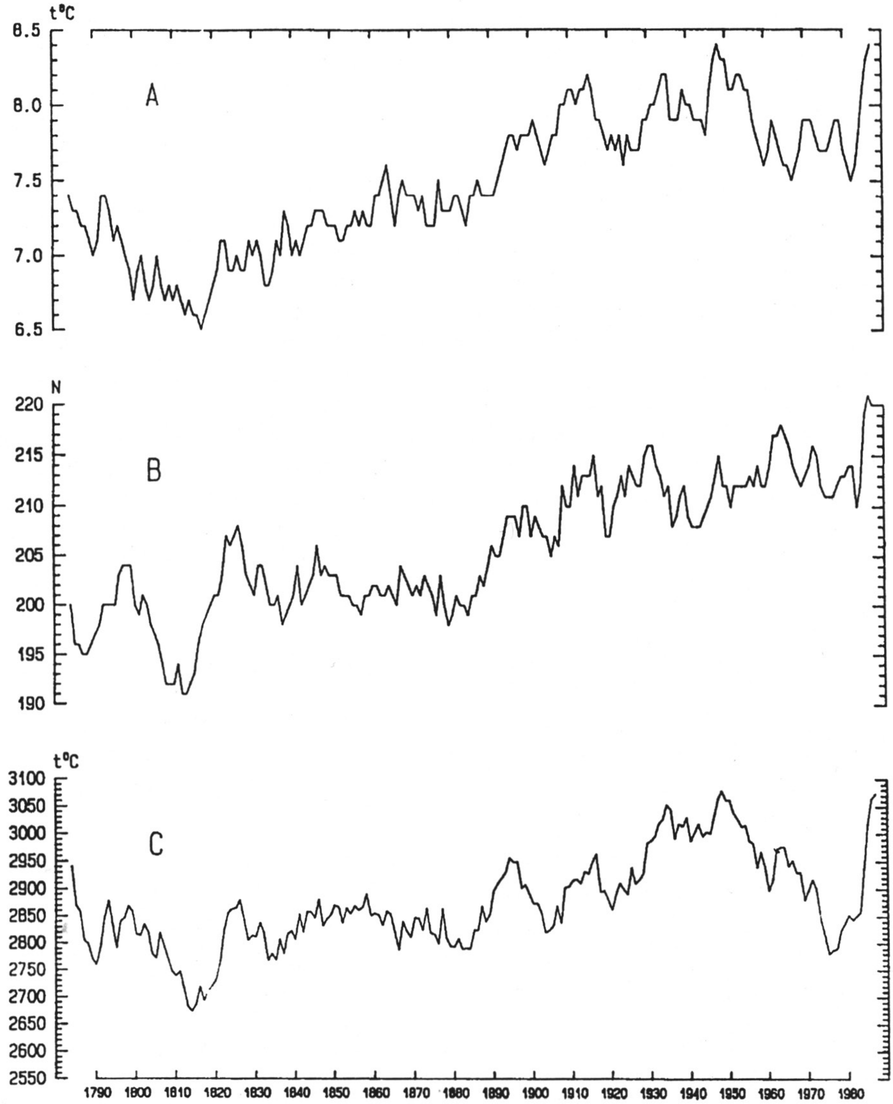

Fig. 1.
11-year moving average calculated based on the series of measurements of air temperature in Warsaw in the years 1979–1992, provided by the Institute of Meteorology and Water Management:
A – annual air temperatures, B – duration of vegetation period (number of days with temperature of 5.5°C or higher), C – sums of active temperature in the vegetation period

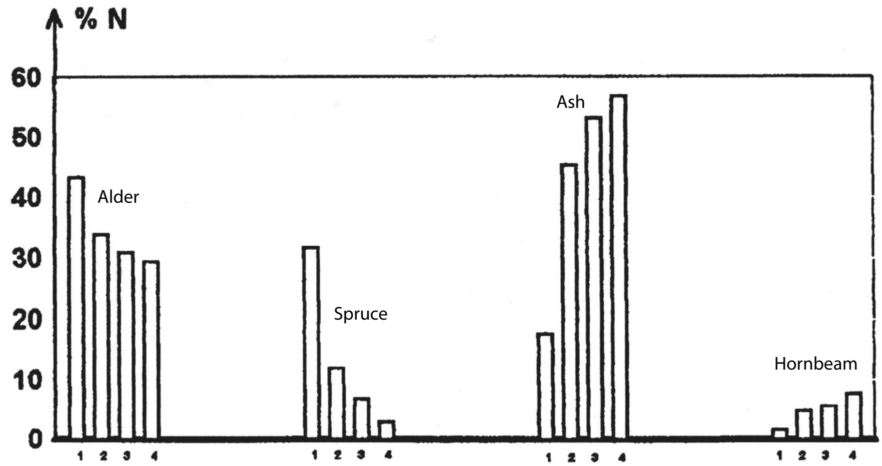

Fig. 2.
Changes in species composition of the stand on the Białowieża alder carr [habitat]: 1 – 1949, 2 – 1966, 3 – 1972, 4 – 1986

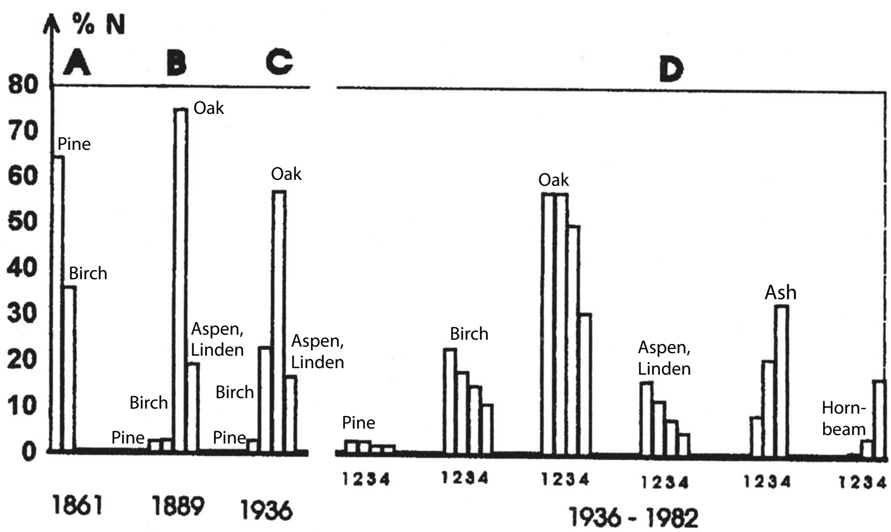

Fig. 3.
Changes in species composition of the stand on the Białowieża coniferous forest [habitats]: A–B Reconstruction based on measurements executed by N. Henko (1902) in 1861 and 1889, C – [species] composition of the stand on the sample plot in 1936, D – its changes throughout the research period 1936–1982 (1 – 1936, 2 – 1957, 3 – 1971, 4 – 1982)

- The stand in the **Białowieża coniferous forest [habitat]** measured in 1861 by the Russian N. Henko (7) **was composed of dominant pine and an admixture of birch** (Fig. 3A). The young spruce that had begun to overrun the Białowieża coniferous forests since 1820s was not measured then. That period was the coldest in Poland, with very short vegetation periods. This species prefers a cool, humid climate (21), with an abundance of precipitation, mainly snow (17).

By 28 years after the first measurement, the stand in question was already a spruce stand, with an admixture of pine and birch, as well as oak and aspen (Fig. 3B), which, as it seemed, found favourable conditions in the inner climate of the spruce-dominated stand.

Stands with a similar species composition like the stand measured in 1889 by N. Henko were found on test areas in the Białowieża National Park in 1936 (Fig. 3C), and their habitat was specified as fresh mixed coniferous forest, while according to Karpiński (10) coniferous forest.

Such relatively young and dense spruce stands were observed in the 1920s by Paczoski, who came to the conclusion that a cooling had happened in the forest, as a result of which 'gloomy spruce forests grew, providing entire stretches of the primeval forest with the stigma of the north (…) it seems that taiga took possession of significant areas of the forest (18).

In those and other stands, originating probably from a seeding around 1920, large in number, young generations of linden and hornbeam – i.e. species absent before (Fig. 3D) – grew, which was concurrent with the occurrence of favourable climate conditions.

Special attention should be paid to the appearance of linden in the Białowieża Forest, which was represented in the first decades of 20th century only by thick, old trees (18). The emerged young generation of rejuvenated linden populations in oak-hornbeam forests, as well as, although less represented, under the spruce storey in coniferous forests and in alder carrs, where those trees were earlier absent or appeared sporadically. The gap between the old and young linden generation in the Białowieża Forest is estimated at 350 years. It may be supposed that in the cooling period the linden did not produce germinable seeds. Paczoski (18) supposed that 'the young linden is absent not because of game, as the reason must be more permanent and general', and all what was needed in the past for its appearance was 'a temperature in the forest like in Poznań'.

The lack of self-sowing and regeneration of linden on the northern limit of its geographical range in Northern England may be explained by insufficiency of heat, i.e. low sum of active temperature. The linden seed production requires an adequately high temperature in July, allowing for quick growth of the pollen tube. This takes place at a temperature of 18–23°C (19), which is important as the linden blooms over a very short period – approx. eight days.

From 1936 to 1982, on the research areas in the Białowieża National Park, the share of helophytes and non-self-regenerating pine was decreasing significantly; however, this was especially noticeable in case of spruce, whose population experienced significant depletion (Fig. 3D). Not only were single trees in decline, but also groups of spruces on smaller or larger areas. A substantial depletion of spruce occurred firstly (before 1957) on moist and fertile soils, mainly on moist deciduous forest [habitats], in forest stands with high share of that species, then on alder carrs, while on coniferous and deciduous mixed forests last, with the largest decrement occurring there in the years 1971–1982.

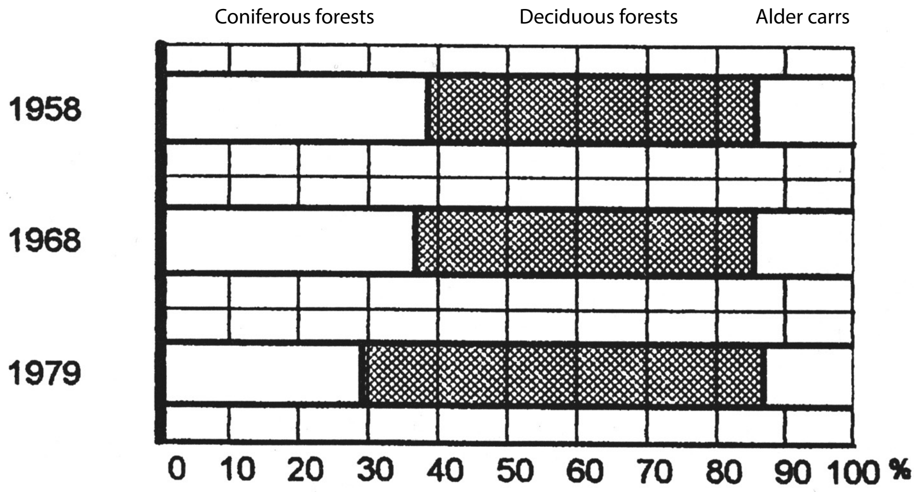

Fig. 4.
Groups of forest habitat types in forest districts of the Białowieża Forest in the years 1958–1978 (according to J. Tołwiński 1992)

The spruce depletion occurring in the stands of the Białowieża National Park is not an isolated phenomenon. It has already been observed in the United States of America, Canada and elsewhere in Europe (3, 12, 14), and in the European part of the former USSR, from the Urals to the Baltic States and the border to Poland. The spruce dieback started there in 1930s, mainly on fertile and moist soils, covering stretches of land from few hectares to several hundred hectares (15).

The reason for spruce dieback is explained in the literature by adverse climatic conditions in the period of the contemporary warming: drought alternately with humid periods, high temperature amplitudes, increased evapotranspiration and associated decrease of groundwater level (1, 3, 24).

The formation of young generations of linden and hornbeam, with a simultaneous decrease in the share of heliophilous and coniferous species in the Białowieża coniferous forests, on sands, made them similar to oak-hornbeam forests. The eutrophication of habitats, noticeable in that process, is confirmed in the forest management planning practice, which can be demonstrated in districts of the forest by the increase in the share of deciduous forest habitats to the detriment of coniferous forest and alder carr habitats (Fig. 4).

The subsequent phases of development may be noticed in the present history of Białowieża coniferous forests since approx. 1820: pine (pine forest) – spruce (coniferous forest, fresh mixed coniferous forest) – linden and hornbeam (deciduous forest).

- The protocols from inspection of the Łowicz Duchy properties, which took place in 1830, show that **natural pine stands** existed on the fertile soils of **Jasień**, one of the wildernesses in the forests of SGGW [Warsaw University of Life Sciences] in Rogów**.** That description was confirmed in 1854 by Połujański (16), who wrote that Rogów forests 'were dominated by high forest pine mixed with spruce and in some places with fir and oak'.

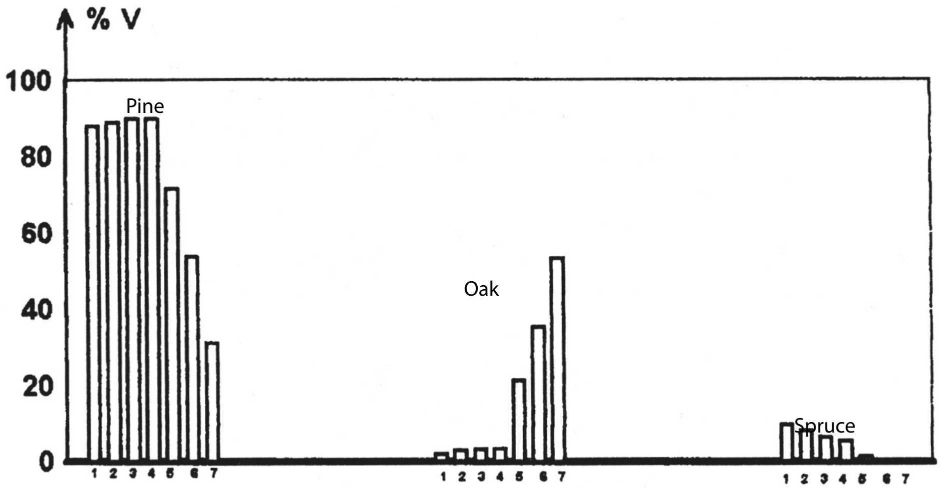

Fig. 5.
Changes in the species composition of stands of the Jasień wilderness in the years 1931–1988, 1 – 1931, 2 – 1935, 3 – 1949, 4 – 1958, *5* – 1968, 6 –1978, 7 – 1988

Such a status lasted until the first decades of the current century. The absence of a dependence between the natural species composition of stands and soil (on an endorheic plateau, silt soils on boulder clay) was explained by the depleting impact of livestock grazing. Since 1927, when a numerous young generation of sessile oak has emerged, the transformation process of species composition of stands has begun; the share of spruce, a species that was no longer present in stands, decreased in a natural way (Fig. 5); the share of pine, being replaced with pure oak stands, is decreasing naturally and as a result of commercial activities.

In 1929 in the Jasień forests, there existed forest habitat types ranging from fresh coniferous forest to fresh mixed deciduous forest, with a domination of fresh mixed coniferous forest (Fig. 6). Over time the share of coniferous forest habitats has decreased, while the share of deciduous forest habitats has increased. After approx. 60 years of observation, fresh coniferous forests and mixed coniferous forests have ceased to exist, while fresh mixed deciduous forests and fresh deciduous forests have become dominant (25).

Synopsis of the research

The natural transformation of the species composition of stands presented for several forest units should be treated as an episode of the 'general process of change in the flowing river of species of the plant world, known as succession, which occurs suddenly or gradually and is caused by internal or external factors' (Cooper 1927, cited in Kershaw 1978). Therefore, the succession occurs when significant changes in the abiotic part of ecosystem come into being, by what conditions emerge that are unfavourable for certain species and favourable for other species, which are usually more shade tolerant, live longer and are more demanding with regard to habitat fertility than the preceding ones.

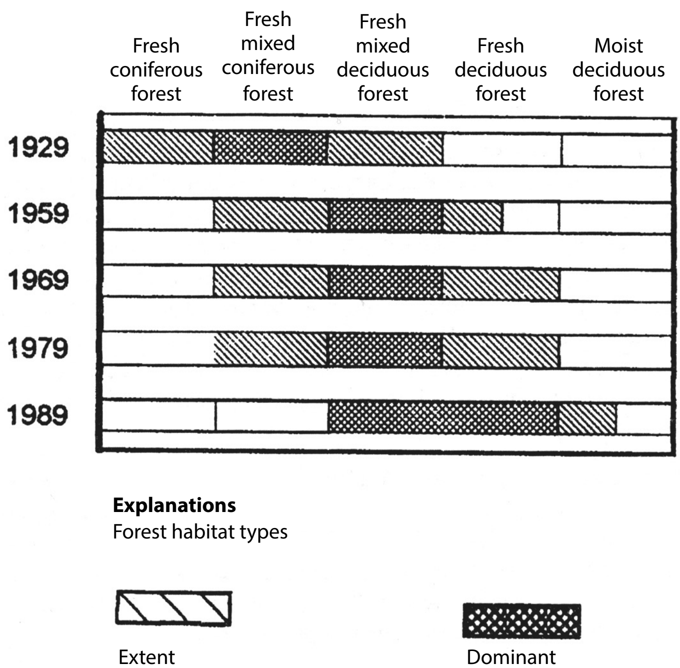

Fig. 6.
Forest habitat types in the Jasień wilderness of the Rogów Forest District, LZD [Forest Experimental Station] in Rogów, in the years 1929–1989 (according to R. Zaręba 1989).

As it is known that one of the main habitat-related factors in the abiotic part of ecosystem has changed – i.e. heat, the increase in air temperature in our century should be considered the reason for the eutrophication of habitats and alterations in species composition of numerous forest areas.

For the explanation of the contemporarily observed succession and eutrophication of habitats it is helpful to apply the ecological term of habitat fertility, meaning its ability to satisfy all the edaphic needs of various plants within the framework created by other habitat-related factors. A separation of the impact of soil-related factors from the entirety of habitat-related conditions is always fictional, and a temporary composition of certain soil properties, favourable under some circumstances may appear to be unfavourable under different circumstances (20).

Therefore, it may be said that in the cooling period fertile soils of Rogów and less fertile sands of Białowieża formed coniferous forest habitats with dominant coniferous species – pine and spruce, while deciduous species had less opportunities for expansion. In the climate warming period, favourable conditions for cropping, regeneration and expansion of deciduous trees, in particular thermophilic and meso- and eutrophic, developed. The transition from the vegetative (growth) to the generative (seed production) phase requires an appropriate quantity of heat. The advantageous conditions for frequent and abundant cropping and an expansion of trees occurred when the sum of active temperature reached a high value, with the simultaneous significant extension of the vegetation periods. The increased heat led to the acceleration of the physiological processes in plants, lush growth of deciduous tree species on the same [types of] soils in which deciduous forest habitats form in warm up periods.

It may be assumed that unfavourable conditions for coniferous trees emerged in the warm-up period and hence their share decreased. The increase in temperature caused a moisture deficit resulting from reduced water retention in soil in the winter period, as well as from the earlier start of vegetation and increased evapotranspiration. The effectiveness of precipitation depends not only on the annual sum of precipitation, but also on the temperature, the rise of which intensifies the evaporation and transpiration. The sinking groundwater level, in particular on fertile and moist soils, should be regarded as a reason for the reduced biological resistance of pine and spruce, which are no longer resistant to harmful fungi and insects and not competitive against intensively growing deciduous trees.

The description of the changes in the species composition of our forests reaches to the end of 1980s. Subsequent measurements and observations in managed forests and on research plots shall allow determining the direction of further changes. The tracking of the transformation of the species composition of stands is necessary from perspective of the forecasted global climate warming in the nearest decades, caused by the uncontrolled increase in the share of greenhouse gases in the atmosphere.

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Opinion of the Polish Forest Society on the principles of conservation and management of the forest ecosystems of the Białowieża Forest

The wealth of forests, their protection from threats, as well as a proper orientation of the management of forest resources ensuring their propagation, with a simultaneous consideration of the general needs of nature conservation have constituted one of the fundamental objectives of the activity of the Polish Forest Society (PTL). Our society, as an independent organisation, grouping representatives of science and a broad circle of practitioners, has always spoken about matters important for forestry, regardless of changing political configurations and ministerial structures.

In recent years, the PTL has presented its standpoint, 'On selected issues of the current forest policy', in reference to the integration of forestry and wood industry, adopted at the meeting of the General Board on 20 February 1986 in Warsaw and addressed to the supreme authorities of Poland. On 10 June 1992, on a plenary session of the General Board of the PTL, a critical opinion was expressed on the 'Development programme for selected areas of forestry' addressed to the central ministerial authorities. Several times, the society has also submitted to the state and parliamentary authorities alarming reports on the state of Polish forests and threatening factors.

The society has been interested in problems of the Białowieża Forest for many decades. In the post-war period, the actions, appeals and opinions of the PTL covered the following topics:

- separate principles of primeval forest management;
- extension of protected areas;
- modification of the forest management planning concept for the districts in the Białowieża Forest in all forest management planning cycles in 1958, 1968, 1978 and 1991;
- implementation of principles of cutting and regeneration within the complex, improved silvicultural methods;
- directions of operations in forests covered by various forms of conservation;
- damage caused to forest plantations by large herbivorous ungulates and associated issues of free-ranging bison breeding and game management.

In addition, there was considered the necessity for a comprehensive solution for the principles of the strategy on silviculture and nature conservation in the Białowieża Forest, in connection with an amendment to the regulations and implementing guidelines in this regard.

These statements are documented in materials from numerous nationwide meetings, conferences, seminars and debates organised by the society. For example:

- conference in Białowieża in 1958, on which there was initiated the provision of the forest with a special statute and further yearlong efforts of the General Board of the PTL in that matter, which contributed to the implementation of basic principles of forest management in the districts of the [Białowieża] forest,
- conference of the Commission for the Environmental Foundations of the Forest Management of the General Board of PTL on 23 and 24 June 1978,
- scientific symposium in June 1985 at the convention of the society's regional office delegates, held at the PTL regional office in Białystok,
- seminar in Malinówka and Borki on 5 and 6 June 1990 dedicated to the free-ranging breeding of bison,
- meeting at the Browsk Forest District on 27 and 28 May 1991 concerning conservation measures (with participation of the then ministerial authorities and independent researchers of various specialisations from several sectoral institutes and universities).

Moreover, there can be mentioned the participation by the PTL representatives in and the provision of their opinions on the arrangements of the Techno-Economic Commissions and on the studies concerning the Białowieża Forest, as well written motions of the Chairman of the General Board of the Polish Forest Society as of 8 April and 23 October 1991, addressed to the Director General of the State Forests, appealing for the performance of measures aiming at the revision of the principles of silviculture and organisation of nature conservation by integrating pro-ecological activities in this unique forest complex.

The current standpoint of the Polish Forest Society on the plans concerning the Białowieża Forest is expressed in the following statements:

- The environmental values of the Białowieża Forest comprise, among others, the exceptional biodiversity of the biocenoses existing here. They result from a spatially differentiated composition of habitats, variability of species composition, structure and age of forest stands, as well as from the occurrence of a wide range of forest development stages, which is caused by the variety of methods of its use and management in recent centuries. In order to maintain and recreate the biodiversity in the next generation, various methods of forest management, passive and active nature conservation and other forms of protection must be continued.

- The application for classifying the entire forest as a biosphere reserve with various levels of conservation and various commercial measures constitutes an initiative worthy of support.
- The status of nature reserves in the Białowieża Forest must be exhaustively analysed and revised in order to create a system of a network of objects under nature conservation and to immediately fill gaps in such a system. Hereby, the opinion is expressed that with the right definition of objectives and direction of measures in reserves, the forest districts, as state entities, in cooperation with voivodeship nature conservators, guarantee the proper accomplishment of objectives and the performance of conservation tasks. It concerns also any subjects of research works.
- In reference to the problem of possible change in the borders of the Białowieża National Park and the plan of its buffer zone, there are many controversial opinions presented by exquisite representatives of science and by employees of forest and general administration and of local governments. Therefore, making too quick decisions within this scope seems to be illegitimate. Any misguided organisational changes might disrupt well-functioning systems. It is also not unimportant that the current tense atmosphere created around the issues referred to here is not favourable to establishing target solutions optimal for the conservation of the forest's nature. Phenomena occurring in forest ecosystems are characterised, as we know, with very long multiannual development stages and any sudden and frequent changes in approach and organisational structures are generally harmful for them.
- Decisions related to the forest should be preceded with studies on the objectives, methods and stages of planned works and on the consequences of their performance. In addition, it requires the connection and synchronisation of the network of nature reserves representative for the Białowieża Forest and buffer zones of the biosphere reserve in the Białowieża Forest with the future system referred to in item 3.
- Other forests, not subjected to any special protective regime, should be multifunctional, with the highest possible level of biodiversity.

The body of opinion of the Polish Forest Society on the matter of the Białowieża Forest results from its deep concern about the future of this unique object and from the need for a humble approach to the natural phenomena occurring there. Our standpoint is based on the knowledge and experience of many generations of foresters – co-creators of the concept of homeland nature conservation. The ecosystems of the forest have been formed over centuries and their future cannot depend on quick opportunistic decisions.

Warsaw, October 1994

Polish Forest Society (PTL)

Opinion of the Council of Forestry to the Minister of Environmental Protection, Natural Resources and Forestry on the conservation of the Białowieża Forest

Recently, the efforts of numerous assemblies, movements and social groups related to the nature conservation aiming to extend the Białowieża National Park have become more intense. These activities have even been transferred to other countries, including the countries of North America, and aimed at the encouragement of foreign societies to create pressure on the Polish government in this matter. The basic argument of the implemented actions was the suggestion of a factually inaccurate threat imposed on the forest's future due to the forest management being conducted there. This was particularly strongly emphasised in the opinion of the League of Nature Conservation depreciating the purposefulness and effectiveness of applying to the forest new principles of forest management and undermining the professional credibility of the foresters employed therein ('Opinion of the League of Nature Conservation on the conservation of the Białowieża Forest.', *Przyroda Polska*, 1995, No. 1).

Statements denying the conduction of forest management and tree harvesting in the Białowieża Forest were also expressed by:

- The State Council for Nature Conservation, stating that 'It is high time to interrupt that process of losing inimitable and irreproducible values. The forest cannot continue to be a commercial unit.' ('Opinion of the State Council for Nature Conservation on the conservation of the Białowieża Forest' adopted at its session in Białowieża on 12 and 13 January 1995).
- The Ecological Council to the President of the Republic of Poland that states, among others, that 'Last natural fragments are disappearing at an alarming pace; trees that managed to survive partitioning powers and two world wars will not survive the nearest years. The forest constituting the national sanctity is being turned into a common managed forest'. ('Opinion of the Ecological Council to the President of the Republic of Poland on saving the Białowieża Forest', Zakopane, 18 October 1994).
- The Committee of Nature Conservation, PAS (Polish Academy of Sciences), postulating an 'urgent cessation of exploitation of the last fragments of old stands and

cutting magnificent old trees in the entire Polish part of the forest'. ('Resolution of the PAS Committee of Nature Conservation on the Białowieża National Park extension' adopted on the Session in Białowieża on 12 and 13 January 1995).

- The Scientific Council of the Białowieża National Park, which '… requests the announcement of an immediate moratorium on cutting any stands of primeval origin and old trees in the entire forest'. ('Resolution of the Scientific Council of the Białowieża National Park on the submission of the Polish part of the Białowieża Forest to the conservation in the form of a national park', Białowieża, 12 January 1995).

The above-mentioned standpoints ignore the opinions of forestry-related communities, expressed, among others, by the Polish Forest Society, supporting '(…) a request for classifying the entire forest as a biosphere reserve with various levels of conservation and various commercial measures'. ('Opinion of the Polish Forest Society on the principles of conservation and management of the forest ecosystems of the Białowieża Forest', Warsaw, October 1994), as well as long lasting endeavours of the Polish forestry to protect the homeland nature, in particular the Białowieża Forest. In the recent period, it has been expressed in the Polish Policy of Sustainable Forest Management, being brought into being, establishing instrumental fundaments for reconciling the conservation of forests with their utilisation. It is demonstrated with:

– decision No. 23 of the Minister of Environmental Protection, Natural Resources and Forestry as of 8 November 1994 on the conservation and management of the Białowieża Forest,
– ordinance No. 30 of the Director General of the State Forests as of 19 December 1994 on the Promotional Forest Complexes (LKP).

In that situation, the Council of Forestry, as an opinion-giving and advisory body of the Minister of Environmental Protection, Natural Resources and Forestry – after a discussion held on 9 March 1995 and taking cognisance of standpoints of the Polish Forest Society, Association of Engineers and Technicians of Forestry and Wood Industry, Faculty of Forestry of the AR (Agricultural University) in Poznań, Trade Union of Polish Foresters in the Republic of Poland, Federation of Trade Unions of Employees of Forestry and Wood Industry, Polish Hunting Association and PAS Committee of Nature Conservation, and having consideration for representations of the invited guests, inclusive of statements of the representatives of local governments from areas surrounding the Białowieża Forest – wishes to express its opinion, as follows.

- For many years, the management of forests has been accompanied by foresters' activities for the benefit of the conservation of valuable forest fragments in the form of strict and partial conservation. These were exactly the foresters who established in 1921 firstly a reserve forest subdistrict, and afterwards a forest district with the same name, which became the origin of the present Białowieża National Park with its total area of 5,348 ha (9% of the Polish part of the Białowieża Forest). The remaining part of the Białowieża Forest with a total area of 56,528 ha is managed by three forest districts.

- After World War II, the total area of managed forests in the Białowieża Forest grew from 52,750 to 56,518 ha, i.e. by 7.1%, while the growing stock resources (of merchantable timber) raised from approx. 9.5 to approx. 14.2 million m^3, i.e. by 48.8%; therefore, the mean yield per hectare increased in that period from 189 to 262 m^3, i.e. by 38.6%. Simultaneously, as a result of rational management striving for an enhancement of the forest's species composition, the area-related share of oak stands of younger age classes increased by approx. 20%.

The state of wood resources in the Białowieża Forest still shows a sustainable upward trend and does not justify negative valuation of the forest management conducted therein and of the necessity of '(…) stopping the forest degradation process', as it is described in the already quoted 'Opinion of the Ecological Council to the President of the Republic of Poland'.

- Discerning extraordinary environmental values of the Białowieża Forest, the Minister of Forestry and Wood Industry established in 1975 special principles of forest management to be followed therein, reducing among others the annual norm for timber harvesting from approx. 234,000 to approx. 196,000 m^3 and raising the cutting age for the stands. Then, activities conducted on a large scale contributed to the establishment in the 'managed' part of the forest of 14 reserves with total area of 2,363 ha, to the emergence of 94 protection zones around nests of protected birds covering, inclusive of refuges of western capercaillie, an area of 5,882 ha and to classifying 17,973 ha of forests as protective, including 10,267 ha as water-protecting forests. Moreover, nine reserves with an area of 1,254 ha are in the process of establishment.
- The decision No. 23 of the Minister of Environmental Protection, Natural Resources and Forestry creates more possibilities of maintenance or restoration of the environmental values of the Białowieża Forest. Pursuant to this Decision, three areas with different management systems and different approaches, according to advantages of these areas, were introduced. In the first area (approx. 19,000 ha), the forest management is conducted according to silvicultural and protective needs of stands, which are kept until reaching their physiological old age. In the second area (approx. 37,000 ha), the tree harvesting is adapted to the needs of the stand conversion conducted according to the habitat's properties. The third area

(approx. 35,000 ha) covers lands outside the main complex of the Białowieża Forest. The mentioned Decision ensures a simultaneous maintenance of the oldest trees and of the most valuable parts of woodlands of primeval origin in the entire forest. It is the role of the Scientific-Social Council of the forest to ensure a correct implementation of these solutions.

As a result of the listed projects, the commercial activity of the State Forests is subordinated to an active conservation of the forest. At the same time, the local governments maintain their forest tax income and the local wood processing industry may still operate thanks to the assured, although to a smaller extent, timber purchases. It is of utmost importance for the maintenance and development of the local economy, as the value of final wood products is approx. eight times higher than the timber value. Therefore, the opinion of the State Council of Nature Conservation that '(…) only a national park creates conditions for material and cultural advancement of the local community (…)' is not understandable ('Appeal to the Sejm and Senate of the Republic of Poland concerning the conservation of the Białowieża Forest', Białowieża, 12 and 13 January 1995).

- In the light of the mentioned facts and circumstances and considering the respect for undertaking efforts in favour of the Białowieża Forest's conservation, it is hard to notice stronger and socially correct arguments justifying the opinion of the State Council of Nature Conservation that '(…) the entire Polish part of the Białowieża Forest should become a national park (…)' ('Opinion of the State Council of Nature Conservation (…)'. Because, in the quoted Opinion:
  - the recently established new forms of maintaining the nature in the forest are ignored,
  - the example of national park covering the entire Byelorussian part of the forest is referred to, although its functioning is different than the one of the Białowieża National Park in Poland,
  - socio-economic consequences for local populations inhabiting the Białowieża Forest region are not considered.

Even more far-reaching assessments and conclusions are presented by the General Board of the League for Nature Conservation, stating that 'One cannot believe in the promise that the restitution of "distorted and degenerated parts of natural communities of the forest" will be conducted by the same people who caused that distortion and degeneration (…)' ('Opinion of the League for Nature Conservation […]'). This opinion constitutes an accusation, since the practice of the forest administration was a result of legal solutions in force and adopted management principles and led to an increase in the Białowieża Forest resources.

- Certain organisations and movements reduce the demand for nature conservation to the cessation of tree cutting, which in extreme cases is treated as a sign of barbarism. However, it plays an environmentally significant role, for example in the case of natural disasters (wind- and snow-broken trees, fires, insect gradations, etc.) as it ensures maintaining forest hygiene. Simultaneously, these demands ignore the fact that timber is a precious renewable raw material, a constant element of our civilisation, which creates an ecological environment for human beings, also thanks to its impact on the limitation of carbon accumulation in the atmosphere. A rational timber harvest, counteracting the environment degradation, does not diminish forest resources, but leads to their growth, in the same way in all countries where forest management follows the principle of forest sustainability formulated at the beginning of the 19th century. Moreover, the national parks in Poland also conduct tree harvesting within the framework of 'auxiliary management' – although for other reasons – with an intensity slightly smaller than the harvesting in the State Forests. While the average harvest from 1 ha of woodland in the State Forests came, for example, in 1993 to 2.71 m^3, in national parks, only in relation to the areas under partial protection, it reached 2.06 m^3. Therefore, tree cutting in national parks constitutes an additional source reinforcing their insufficient budget means.

The establishment of the group I protection area for the Białowieża National Park, effected by Decision no. 23 of the Minister of Environmental Protection, Natural Resources and Forestry, is equal to a practical satisfaction of demands aiming at the extension of the area of the Park, carried out by the means of a different legal and organisational solution and with methods relevant for an active conservation.

- The discussion about the Białowieża Forest results from different concepts of nature conservation and forest management. Focusing the attention on the nature conservation only in the form of national parks and nature reserves suggests that foresters' activities are only limited to the exploitation of natural resources, and it simultaneously ennobles in the eyes of society all people who postulate an extension of national parks and demand a prohibition of tree cutting in forests. However, thanks to the foresters' work the most valuable parts of homeland forests have been kept and gradually passed under the administration of national parks. Without them, the Poland's 'ecological' status would be much worse than it is now.

The foresters have never been opponents of introducing various nature conservation forms in forests. However, they mean that the main effort of both, nature conservation and forest management, should be directed to the minimisation of the adverse impact of contaminations on forests and on ensuring the performance by the forests of all functions significant for present and future generations. Thence, the necessity emerges to develop a new paradigm of the forest management and new criteria for the assessment of its condition and of its principles of functioning, which significantly exceed the previous scope of forestry. That is why a strict and constructive cooperation of foresters and environmentalists is necessary, like never before. In the search for new solutions the needs of local, regional and national communities, as well as economic considerations of conservational and non-conservational approach to the nature protection, cannot be forgotten.

While presenting this, the Council of Forestry expresses its belief that its standpoint shall contribute to a properly understood, and resulting from substantive reasons, rationalisation of activities in the Białowieża Forest, which is in historical, natural and commercial terms a priceless object, but in social terms a complicated one, and that it shall usher in a proper cooperation of all people and groups interested in the homeland's nature conservation.

Warsaw, April 1995

President of the Council of Forestry
to the Minister of Environmental Protection, Natural Resources and Forestry
Professor Andrzej Klocek, PhD, DSc

Tadeusz Krajewski

Siemianówka water reservoir and its impact on the Białowieża Forest

Introduction

The concept of construction of Siemianówka water reservoir was defined more than 30 years ago, motivated by the care for the economic activation of the region, including first of all satisfying the constantly increasing water demand for agriculture, municipal needs and industry.

The regional prospective water management plan drawn up in 1964 showed that water deficits amounting 5 to 180 million m^3 of water per year occurred in the upper Narew River basin in the low-flow period. The commencement of studies on the location and determination of parameters of a water reservoir necessary for their coverage (1) dates back to that plan.

Based on large-scale hydrogeological, hydrological and environmental studies, it was established that an optimal variant of the reservoir location was at the section of the Narew River valley near the village of Siemianówka.

According to the approved techno-economic assumptions and the developed plan, the main goals of the reservoir included:

- storage and distribution of 45 million m^3 of water per year to irrigate 31,000 ha of grassland in valleys of upper Narew River and Supraśl River,
- provision of 17 million m^3 of water for municipal needs and industry in Białystok and Łapy,
- increase in low flows in the upper Narew River and Supraśl River in order to improve the biological condition of these rivers,
- organisation of fisheries management,
- creation of conditions for the development of a recreational and water sport centres for the Białystok Industrial District.

The performance of these tasks has become significantly outdated due to the cessation of construction of the Narew-Supraśl transfer canal, change in socio-economic relations in agriculture and a new approach to the ecological development of Poland.

In this situation, the present functions of the reservoir have been significantly limited and are:

- irrigation of grasslands in the Narew River valley and in the area Bagno Wizna with a total area of 13,000 ha,

- water supply to the grounds of the Narew Landscape Park on an area of 20,900 ha in low-flow periods,
- raising the low flows in the Narew River and maintenance of the necessary biological flow in this river,
- reduction of flood risk in the Narew River valley,
- production of electricity of up to 1,100 MWh.

However, it seems that after a temporary stagnation period in Poland, Siemianówka water reservoir will in the future fulfil the majority of functions assumed in the technical plan and contribute to the region's economic activation. The reservoir construction started in May 1977 and lasted 13 years, to 1990, when the preliminary accumulation of water to the ordinate 142.9 m above sea level commenced. The maximal dam level (145.00 m) was reached in April 1994.

The location of the Siemianówka reservoir at the edge of the Białowieża Forest inspired the Forest Research Institute to commence research on its environmental impact. In 1977, at the request of 'Bipromel', C.B.SiP. [Centre for Research, Studies and Planning] the Institute developed a forest-hydrological study and guidelines for a technical plan of water management for woodland areas near the Siemianówka reservoir. That study aimed at the provision of an opinion, formulated from the point of view of forest management concerns, on the water management systems designed at the first stage of the reservoir construction, at the presentation of a proposal of performing additional protective technical solutions and at the determination of optimal ground water levels for particular forest habitat types (1).

The substantive programme of multiannual research in the reservoir area was developed at the Department of Water Management of the IBL [Forest Research Institute], by a team led by Professor F. Białkiewicz, PhD, DSc, and then approved for execution by the investor and the Centre for Scientific Research in Białowieża.

According to the programme, the research consists of two stages:

I – before the water accumulation in the reservoir (1978–1989);

II – after the water accumulation in the reservoir (1990/1991–2000).

The part of research concerning the ground water measurement and other research within the scope of the habitat science is performed in cooperation with the Polish Pedological Society in Warsaw.

General description of the reservoir

Siemianówka water reservoir is situated in the lower Narew River valley, at a distance of only several hundred meters from the state border. It was created as a result of water damming by a cross-river dam at river kilometre 367.4 near the village of Rybaki. The river basin area in this cross-section comes to 1,094 km^2 (Fig.).

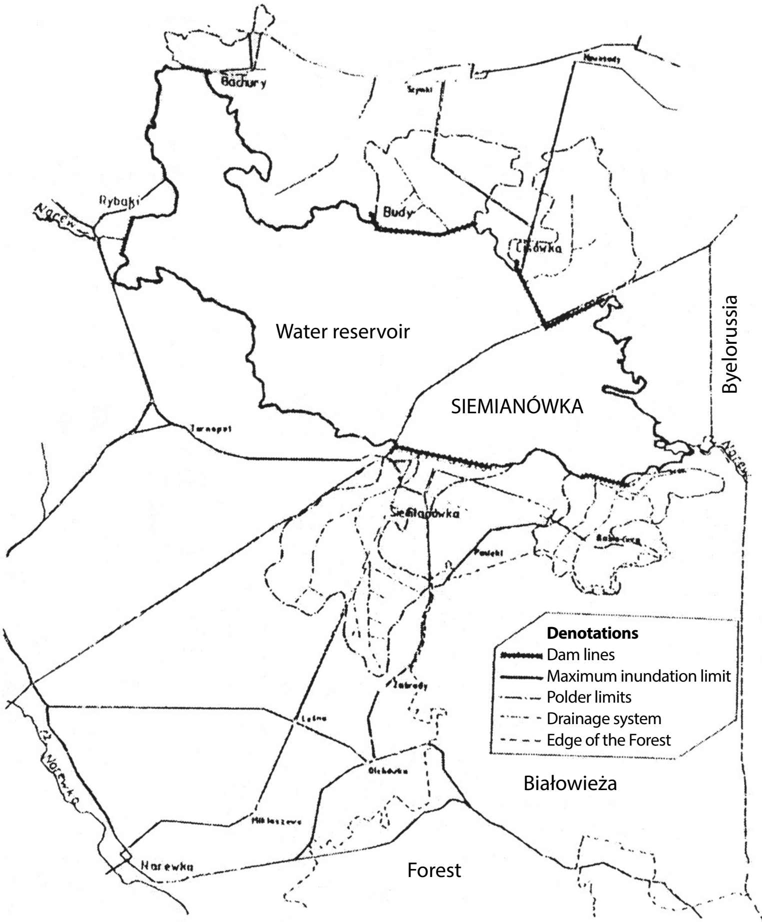

Fig. Overview map of Siemianówka water reservoir

At the maximal accumulation level of 145.00 m above sea level, the water reservoir is 11 km long, 0.8–4.5 km wide, while its area is 3,250 ha. Its total capacity is 79.5 million m^3, while the usable capacity is 62 million m^3 and the average depth 2.5 m (1).

The water reservoir infrastructure comprises:

- cross-river embankment dam, max. height 9.0 m, length 810 m,
- five side embankment dams with an overall length of 825 m,
- five drainage pump houses with a capacity of 0.9–2.8 m^3/s and a total output of 8.87 m^3/s,
- drainage of land near the reservoir of 1,925 ha.

As a result of the construction of side embankment for depression areas, so-called polders, marked by the ordinate 147.00 m above sea level, were created on the plains behind the dams.

The total area of these five polders is 1,890 ha, including 383 ha of forests, i.e. 20.3%. The highest share of forests occurs on three polders: Cisówka (142 ha), Babia Góra (125 ha) and Siemianówka (96 ha). For draining away water from the polder areas, pump houses were built, which drain through the basic drainage network placed along the side dams, construed for the interception of water seeping from the reservoir. High costs of electricity necessary for the reservoir operation encouraged its user to construct in 1996 a waterpower plant using the existing water drop height of 7.0 m. The annual output of the water power plant of 1,100 MWh fully satisfies the needs of the entire reservoir, while the excess is fed into the national grid (5).

Environmental and forestal characteristic of areas near the reservoir

The areas directly adjacent to the reservoir on Babia Góra and Siemianówka polders constitute mostly a belt of grassland, drained and covered with a network of open ditches with head gates. These meadows and drainage installations constructed there create a barrier protecting the Białowieża Forest woods from water seeping from the reservoir.

The Białowieża Forest, covering within the borders of Poland an area of approx. 58 km^2, stretches to the south from the Siemianówka reservoir and includes three forest districts: Browsk, Białowieża, Hajnówka, and the Białowieża National Park. The compact forest management unit Browsk covering an area 9,582 ha is the closest to the reservoir. It is characterised by a relatively poor topographic relief (on average 145–150 m above sea level), a rich mosaic of soils and habitat forest types, and by a strongly differentiated groundwater level. Approx. 60% of the forest management unit area is covered by fertile deciduous forest habitat types of older age classes, with prevailing fresh deciduous forests, fresh mixed deciduous forests, moist deciduous forests, typical alder carrs and alder-ash carrs. The remaining part of the forest management unit consists of fresh mixed coniferous forests and moist coniferous forests. The major forest-forming species include pine, spruce, birch and oak, while the admixture species usually include hornbeam, ash, linden, and elm. A significant part of the forest ecosystems of the Browsk forest management unit is characterised by biodiversity and presents features similar to the ones of a primeval forest.

By July 1996, the Białowieża National Park covered the area of 5,348 ha, while its northern border was delineated by the Hwoźna River, western by the Narewka River, and eastern by the state border. Pursuant to the regulation of the Council of Ministers of 16 July 1996 (Journal of Laws No. 93 item 424), the borders of the Białowieża National Park have been extended and currently its area comes to 10,501.95 ha. Moreover, a buffer zone was established around the park with an area of 3,224.36 ha. Pursuant to the regulation, changes in water relations and regulation of rivers and other watercourses (5) are forbidden in the territory of the Białowieża National Park.

The Białowieża National Park constitutes mostly a strict reserve and is an environmental object of exceptional significance on European scale, and even worldwide. This is evidenced by the fact that in 1977 it was considered the world biosphere reserve and inscribed in 1979 by UNESCO on its World Heritage List. In the light of goals resulting from its international status, the Białowieża National Park is to perform a role of research object within the scope of systemic approaches and to serve modelling of natural processes.

Within its previous borders, the Białowieża National Park was a forest complex similar to a primeval one with a considerable variety of ecosystems, but unfortunately beyond its borders the forest continued to lose the natural forest features, parts of the stands constituting valuable ecotypes were disappearing ever more rapidly, while the list of rare flora and fauna species was shrinking.

When describing the forest and assessing the environmental impact of Siemianówka water reservoir, one should also emphasise the environmental values of this body of water, being appreciated by ornithologists, as it constitutes the largest bird refuge in the Podlasie Lowland. According to the ornithologists, the reservoir and its adjacent areas are home to 164 bird species, including 112 species nesting here and 50 endangered bird species (3).

Moreover, the reservoir and its adjacent areas, thanks to their landscape and ecological values, have already become an attractive place for leisure and recreation for the residents of the towns of the Białystok Voivodeship and from more distant regions of the country.

For a couple of years, the Polish Fishing Association (PFA) has conducted fisheries management on the reservoir and this year it has commenced the construction of nursery ponds covering approx. 60 ha. According to the PFA, in the initial years the average annual output of the waterbody shall be 322 t of various fish species.

Water and climate conditions

The reservoir's catchment area is 1,049 km^2, while the total volume of water flowing there from its catchment area was on average in the years 1964–1986 183.8 million m^3 annually (max. 375.2 and min. 93.6 million m^3). The waters supplying the reservoir come mainly from the upper, source section of the Narew River located in Byelorussia. The length of the Narew River outside the state borders is 44 km, the average depth 1.0 m, while its average flow comes to 0.2–0.3 m/s.

The drainage works conducted in recent decades in the Narew River valley resulted in an excessive unfavourable water outflow and limited the storage character of the valley. Physicochemical and biological monitoring tests of the reservoir's water quality conducted since 1991 by the Voivodeship Inspectorate of Environmental Protection in Białystok have showed that the oxygen conditions (biochemical oxygen demand – BOD5 and chemical oxygen demand – COD) are characterised by a very high seasonal variability, as they fluctuated between class I water and water not matching any standard.

The recorded declines of soluble oxygen content are caused by an unfavourable high water temperature in summer periods, while the seasonally murky colour of the water corresponds to the presence of a larger amount of humic and organic substances being eluted from the peat substrate. Moreover, the elevated content of the biogenic compounds in the water (nitrogen, phosphor) constitutes an important factor affecting the development of algae, in particular the formation of cyanobacterial blooms in the vegetation period. The reservoir's sanitary condition is good, as it corresponds with class I/II.

An unfavourable feature of the reservoir is constituted by periodical fluctuations of the height of the water level and associated changes in the shore line and exposure of large bottom areas. The exposed bottom parts become overgrown with land and wetland vegetation, and after their re-inundation intensive, long-lasting decomposition processes take place, resulting in water contamination and eutrophication of the reservoir.

The negative physicochemical and biological processes discussed here refer in particular to the shallow, periodically inundated south-eastern part of the reservoir, separated from the main basin by a railway embankment with a wide culvert and a bridge. Precipitation and air temperature over the air have a large impact on the formation of hydrological conditions on forest areas near the reservoir.

According to the IMGW [Institute of Meteorology and Water Management] data for the years 1949–1996, the annual sum of precipitation in the climatic station in Białowieża was 630.4 mm, while in that period those sums strongly fluctuated from 434.5 mm in 1964 to 898.0 mm in 1974, with an amplitude of 463.5 mm. There were 16 clearly 'dry' years, when the average annual totals of precipitation did not exceed 550 mm, and 10 clearly wet years (more than 710 mm). In the calendar year 1996, the annual total of precipitation was 518.7mm, 18% lower than the long-term mean. In the summer half-year (May–October), the sum of precipitation was only 288.4 mm and was lower than the long-term mean by 26%, which indicated a very unfavourable distribution of precipitation over the vegetation period.

In the last twenty-year-period, a clear trend in climatic changes has been observed, featured by warm and snowless winters, lack of retention and the occurrence of long periods without precipitation, as well as high air temperatures in the summer half-year.

Previous research and its results

The main objective of the research in the forest areas is the assessment of type, range, and grade of the impact of the reservoir on the environment, and particularly an analysis of changes in hydrological relations. Moreover, the research results obtained at a later stage of reservoir operation should allow the completion of the already constructed drainage systems and adjustment of the operation of the pumping installations to the current needs of the forest habitats (2).

The forest-hydrological research in the vicinity of the Siemianówka reservoir commenced in 1978 is of a comprehensive nature, as it included measurements of ground water by installed piezometers and drain wells, gauge observations, measurements of water flow in the beds of Narewka and Braszcza and periodical pedological, phytosociological and dendrometric-incremental studies on the established sample plots.

The ground water measurements are taken two to four times per month at 67 points along two transects. One transect has a north-south direction, 32 km long, and stretches from the Cisówka polder to the southern borders of the Białowieża National Park, while the other is 5 km long, in the west-east direction, established on the Siemianówka and Babia Góra polders in the Pasieki forest subdistrict.

Detailed results of groundwater measurements from the years 1978–1996 may be found in the archive of the Department of Water Management of the IBL and are regularly developed in annual reports. Since 1985, daily gauge observations and periodical measurements of water flow in the beds of Narewka and Braszcza Rivers have also been conducted.

In 1980, on the areas near to the reservoir, 24 sample plots were established in stands at various distances from the reservoir and representing various forest habitat types. In the years 1980–1987, pedological, phytosociological and dendrometric surveys were conducted to characterise the selected habitats and stands before filling the reservoir. Analogous surveys shall be conducted after ten years from the beginning of the reservoir operation, while comparative materials collected in this way shall allow an objective assessment of habitat alterations.

As the ground water measurements carried out near the reservoir showed, the compact forest complex with an area of 142 ha, located on the Cisówka polder and adjacent to the side dam, is at the highest risk of inundation. However, the area in question featured an unfavourable system of hydrological relations already prior to the reservoir construction. This resulted mainly from the railway embankment impact, which made gravitational water runoff in spring period impossible and resulted in an inundation of stands in the lower locations, in particular of typical alder carr and moist mixed coniferous forest habitats. The forest complex situated on the right northern bank of the reservoir belongs administratively to the Żednia Forest District, Zaleszany forest management unit, and is not related to the Białowieża Forest.

Two enclosed tables have been developed for a pictorial presentation of the previous impact of the Siemianówka reservoir on the Białowieża Forest and to illustrate changes in the set-up of hydrological relations on areas near the reservoir.

Table 1 shows characteristic groundwater table values at 15 measuring points located on the area of the Białowieża Forest, in the periods before and after damming of the water. As the table shows, groundwater levels in forests areas, depending on local habitat conditions, are characterised by considerable variety. Before the damming their mean values fluctuated from 8 cm beneath the ground level at point no. 4 up to 325 cm beneath the ground level at point no. 25. After the water damming, the mean ground water level dropped at 13 points (within the range from 2 to 46 cm), which testifies to the lack of significant impact of the reservoir on the forest environment.

Table 2 shows more detailed example data concerning the average monthly ground water levels, measured by piezometer 9, in the moist coniferous forest [habitat] on the Siemianówka polder, 4,500 m away from the reservoir. The results of measurements provided in the table show that before the reservoir filling in the years 1985–1989 the ground water was at a depth of 2–86 cm beneath the ground level, while after water damming in the years 1990–1994 at a depth of 45–133 cm beneath the ground level, hence, the water table dropped significantly. This phenomenon confirms the previously formulated thesis about the absence of an impact of the reservoir on the forests surrounding it to the south.

The discussed areas of the forest near the reservoir have been so far sufficiently protected by the constructed drainage systems and do not show permanent and significant changes in hydrological relations. The observed bidirectional fluctuations in ground water level, both before and after damming the water in the reservoir, are mainly caused by climatic conditions, and not by the impact of the reservoir. However, it cannot be excluded that the reservoir's impact in forest habitats may become noticeable after its longer operation.

Summary

Siemianówka water reservoir, constituting one of the largest hydrotechnical investments in the lowland of Poland, was constructed in the years 1977–1990 at the edge of the Białowieża Forest, therefore it is an object of thorough observations by foresters and environmentalists, as well as an object of interest to broad public opinion.

This is evidenced by comprehensive studies on the reservoir's impact on the forest environment, and particularly with regard to changes in hydrological conditions on the areas near the reservoir, initiated by the employees of the Forest Research Institute and other research institutes.

TABLE 1 Characterstic levels of groundwater table at measuring points on the area of the Białowieża Forest, in periods before and after water damming in the reservoir

Point (piezo-meter no.)	Terrain ordinate (a.s.l.)	Com part-ment no.	Before damming				After damming				Differences* in cm			
			depth fr. ground level (cm)				depth fr. ground level (cm)							
			max.	avg.	min.	amplitude	max.	avg.	min.	amplitude	max.	avg.	min.	amplitude
4	146.84	5-C-i	123	8	+31	154	146	23	+29	**175**	-23	**-15**	-2	**+21**
5	146.93	5-D-a	114	14	+23	137	122	23	+29	**151**	**-8**	-9	**+6+**	**14**
6	149.55	6-C-f	299	207	144	155	310	213	**146**	**164**	**-11**	-6	+2	+9
9	146.67	7-A-b	121	47	+9	130	**151**	93	38	113	-30	-46	-47	-17
10	147.42	7-B-h	108	44	4	104	103	27	+20	**123**	+5	+17	+24	**+19**
15	147.24	8-C-a	183	34	+23	206	123	32	+27	**150**	+60	+2	+4	+23
16	147.45	16-B-b	109	38	+4	113	123	45	**00**	123	**-14**	-7	-4	+10
19	147.48	5-C-g	235	119	40	195	193	124	65	**128**	+42	-5	-25	-67
21	147.39	**5-A-d**	136	78	5	**131**	183	94	32	**151**	-47	-16	-27	+20
23	146.31	1-A-g	160	79	15	165	**165**	91	28	137	-5	-12	**-13**	**-28**
24	150.97	6-D-i	331	278	221	107	335	285	244	91	-4	-7	-20	**-16**
25	151.77	6-D-c	391	325	245	146	446	327	247	199	-55	-2	-2	53
26	147.76	2-C-a	205	98	23	**182**	173	114	60	113	+32	-16	-37	**-69**
27	149.90	2-d-A	365	295	225	140	405	317	264	141	-40	-22	-39	+1
28	146.61	1-a-C	218	91	10	208	177	109	57	120	+41	**-18**	-47	**-88**

* A minus sign (-) preceding the calculated values indicates a decrease and a plus sign (+) an increase in ground water level in the period after water damming in the reservoir, while in the case of amplitude – its increase or decrease.

TABLE 2 Average monthly heights of ground water (in cm beneath the surface) in the years 1985–1994

Siemianówka polder
Drain well no. 9
Browsk Forest District
Pasieki Forest Subdistrict, compartment 7-A-c
Habitat type: moist coniferous forest
Topographic relief – 146.67 m a.s.l.
Distance from the reservoir – 4,500 m
Dominant species – pine
Age in 1985 – 60 years

Year of measurement	Month no.												Amplitude [cm]
	XI	XII		II	III	IV	V	VI	VII	VIII	IX	X	
Before the reservoir filling													
1985	64	57	63	72	57	26	23	33	34	50	54	58	49
1986	62	57	30	11	11	15	45	44	77	66	50	47	66
1987	44	40	50	53	46	20	16	32	51	64	75	64	59
1988	50	45	30	29	11	2	14	21	31	38	24	32	48
1989	28	22	7	17	28	40	54	63	65	75	86	50	79
Avg. 1985–89	*50*	44	36	36	31	21	30	39	52	59	58	*50*	*60*
During the reservoir filling													
1990	59	55	86	106	87	113	114	127	121	102	82	108	72
1991	81	86	91	113	79	73	63	81	90	107	109	106	46
1992	107	103	83	51	45	57	59	75	111	133	116	121	88
1993	103	79	109	123	84	49	66	76	100	108	104	112	74
1994	114	84	65	53	73	63	72	86	125	133	125	102	80
Avg. 1990–94	93	81	87	89	74	71	75	89	109	117	107	110	72

On the base of stationary measurements of ground water before and after water damming in the reservoir, conducted in a period of over a dozen years, no significant negative alterations were observed in the forest habitats in question or in the system of hydrological conditions.

Relatively large fluctuations in the groundwater level noticed in the last ten-year-period in the territory of the forest do not feature any permanent upward trend and have a bidirectional nature. They result mainly from the intensity of precipitation and air temperature in particular 'dry' and 'wet' years, and not of infiltration of water from the reservoir.

The water accumulation in the reservoir, which has lasted for several years, causes a change in the underground water regime. The Narew River no longer performs its primary draining function and it has become an element supplying the areas near the reservoir with water, in particular the polders located in a depression.

The violation of the natural system of hydrological relations and the predicted change in underground water regime may require necessary adjustments and modifications of already constructed drainage systems at a later stage of reservoir operation.

Due to the buffer capacities of forest habitats and the resistance of the woodlands of the forests to the pace and course of changes in hydrological conditions, the reservoir's environmental impact may become apparent with a large delay, which is why it would be advisable to continue the forest-hydrological research on the areas near the reservoir, which is a unique biosphere reserve.

From the Department of Water Management of the IBL
[Forest Research Institute]

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Piotr Paschalis

Selected issues on the use of old trees in the territory of the Promotional Forest Complex 'Białowieża Forest'*

Introduction

A widespread belief in the necessity of treating the forest's productional function as the most important and primary one, and often as the only one, has led for a very long time in the history of Europe to the management of forests being essentially reduced to the exploitation of forest resources. Forests were treated as a never-exhaustible source of wood raw material, which resulted in the continued deforestation of Europe in the last 2,500 years. The changes in the forest area and resources of Poland suffered the same fate as other European forests, in some periods lagging behind the pace of changes in the Western Europe, sometimes ahead of them. The entire period of civilizational development of Europe has been dependent on forest resources, and this development can be divided into nine distinctly separated phases, which in effect are not only the history of civilizational changes, but also of changes in vegetation cover, forest area and their distribution (6).

Unfortunately, any documents based on which we would be able to recreate in any detail maps of Poland's forests across the centuries have not survived. Based on historical analyses, Jasienica notes that in the beginning of the statehood, in the 10th and 11th centuries, forests covered approx. 60–70% of the present territory of Poland. Computer simulations carried out on the base of historical records, attempts at reconstruction of vegetation cover, colonisation, and communication routes have allowed, to a large extent, the reliable reconstruction of a forest cover map for part of Central Europe.

Poland's forest cover in the 10th century on that basis was approx. 90% (3). It is estimated that at the beginning of the 13th century approx. 60% of the area within the present borders of Poland were covered by forests, while by the beginning of the 14th century this was approx. 43–45%. The forest cover of Poland slowly changed from the 14th until the mid-20th century, gradually reducing. At the beginning of the 20th century it was approx. 30–32%, while the practices of the partitioning powers and two world wars led to

* This paper was developed as a part of the study titled *Zasady ochrony starych drzew z uwzględnieniem ciągłości pokoleń na terenie LKP Puszcza Białowieska* [Principles of Old Trees Protection with Consideration of the Continuity of Generations in the Territory of the PFC 'Białowieża Forest'], drawn up by the order of the Directorate General of the State Forests.

the situation where by 1945 the forest cover in Poland was approx. 21%. The current forest cover in Poland is 28%.

Few forest complexes in Europe have survived relatively intact. The woodland complex of the Białowieża Forest is one of these, and it is an example of the way that an exceptional combination of historical events, in connection with the natural inaccessibility of these forests, has allowed the maintenance of fragments of natural forest ecosystems with centuries-old stands and trees.

This paper presents certain issues of forest utilisation related to some functions performed by old trees, and a proposal for the application of special methods for removing old trees when necessary.

The first issue was analysed by adopting the assumption that **old trees perform different functions than raw material-related ones**, while the solution of the second issue assumes that **the necessity of removing an old tree should not result in damage to the remaining old trees, but should protect younger tree generations, shrubs, groundcover and forest soil.**

Performance of other functions by the old trees than the raw-material function

The art of using a found or broken branch, later on the processing with ever improved tools, and finally becoming convinced that our entire material and spiritual culture could not do without wood is imprinted in our history.

It is estimated that the first phase of the non-substitutability of wood as a raw material lasted for very long time, from the Neanderthal period to the early 19th century. Of course, that phase continues to exist in many regions of the world and it is featured by the important role of wood as a non-substitutable raw material in the field of construction, transport, as an energy source, household equipment, in defence, religious practice, for the construction of musical instruments and thousands of other products which humans find indispensable. On many continents, the long and uncontrolled period of wood utilisation has resulted in irreversible damage to forests. The demand for timber and its harvesting on a large scale have led to the eradication of forests over huge territories in many countries all over the world, including Europe. The construction of entire towns and communication routes, temples, ships, and fortifications resulted in deforestation of a large part of the Mediterranean coast, as well as in floods, droughts, and erosion, collapses of huge ancient towns and human migration. Such events happened not only in ancient history. The power of the fleet of Elizabethan England grew on cutting down millions of the most beautiful trees in countries bordering the Baltic Sea, mainly Poland and Russia. The extensive buildings of medieval Poland were also a huge tribute paid by our forests. The sources quote that for several decades several million cubic metres of the best oak wood were harvested in the

Niepołomice Forest for the development of Kraków. The increased demand for glass products also led to the largest destruction of forests in Central Europe, in particular in Poland. Wood burning to obtain potash for the production of glass, textiles and soap reached such scale that throughout the 19th century forests were at risk of complete perdition. The steel industry, prior to the invention of coke, also consumed very large volume of timber for charcoal production, but before it was done – the forests of today's England, the Netherlands, Belgium and Germany had paid a very high price for that.

The very rapid development of science and technology in the 19th century eliminated wood from many fields to a large extent. At the time it even seemed that the achievements in metallurgy, chemical and extractive industries, processing of other raw materials, and the progress in the use of other materials in the construction industry would lead to the replacement of wood. That period of our civilizational development lasted more or less to the first half of 1950s and ended with the third phase of a repeated non-substitutability of wood.

Approx. 30,000 different products are nowadays manufactured from wood. We continue to turn to those features of wood that were appreciated, often intuitively, by previous generations, and now we are able to prove their exceptionality scientifically.

The presented outline of the continuous utilisation of wood and its treatment as a renewable resource still lies deep in our awareness. I think that an important rectification to such an understanding of the issue is the necessity of realising the fact that wood is a renewable raw material only if the forest is renewable. This is a confirmation and an acknowledgement of the concept of the permanent and sustainable management of natural resources, enabling us and future generations to develop and survive further.

The forest utilisation defined by the forest sciences refers to learning about the properties of products and raw materials originating from forests, determining methods and principles of their rational harvesting, as well as – to a limited extent – converting them into specific semi-finished and ready products.

To a broader extent, forest utilisation comes down to the satisfaction of our material and spiritual needs. It means that the withdrawal from the direct utilisation of goods originating from forests and restricting oneself to emotional experiences, consisting of the pleasure of looking at the forest or at a single tree, or only from the fact of having experiences and dreams that such a forest or tree exists – means also its utilisation (6). **The exceptionality of the Białowieża Forest arises from its association with deep spiritual values, important not only for Polish people but also perceived from the global perspective.**

These aspects of the forest utilisation concerning raw material harvesting have a particularly deep reference to old trees in the Białowieża Forest. For the time being, I ignore such issues as whether or not a 200-year-old common oak is yet an old tree, or whether it becomes an old tree at the age of 250 years or more. It should be added that tree ageing is one of the least researched and least understood processes of tree physiology.

Under a GEF [Global Environment Facility] grant, original research was conducted on the diversity of ageing symptoms in the structure and physiology of the vascular cambium of *Pinus sylvestris* L. in stand populations of the Białowieża Forest, led by Professor S. Zajączkowski (8). That research is referred to here mainly to emphasise actual complications and difficulties in answering the question: when can we consider a given tree to be old? From the point of view of its technical maturity – the matter is much simpler. However, it does not solve the problems of the actual value of old trees in the Białowieża Forest. From the economic point of view – the value of these trees is equal to the price that society / a single person / 'ecological' organisation is willing to pay. I hope that someday society will consider that this price should be paid and is worth of paying.

Therefore, it may be assumed that the issue of utilisation of old trees in the Białowieża Forest is based on two lines of thought (in my opinion) only apparently opposing each other.

The first one, resulting from long-term practical observations and supported by scientific evidence, is that that the possibility of ensuring forest sustainability in these areas is possible only when a specific number of trees is cut down in order to make space for a new forest generation. These are actually verified, detailed solutions that may very precisely describe and allow the performance of all operations of forest utilisation, regeneration, maintenance and protection; all these procedures formed by forestry over several centuries of development of forest science and practice, which are based on the even longer acquired experience of foresters, dating back many centuries.

There is also no doubt that the present 'primeval' nature of this forest complex has been maintained in such a form thanks to the huge contribution of the work, skills and often civil and moral courage of foresters managing the woodlands of the Białowieża Forest. Keeping the existing order of things – i.e. conducting forest management compliant with assumptions of sustainable and balanced development, guarantee the continuity of the Białowieża Forest.

The second line of thought, adopting without any reservations the catastrophic visions of threats to environmental systems on various scales, from local to regional and global destruction, means that we have to deal with a huge increase in ecological sensitivity. This sensitivity affects the creation of various concepts of saving the Earth, the formation of a vision of the world and modification of human behaviours (9). The issue of preservation of old trees in the Białowieża Forest is in this line often treated existentially: the cutting down of old trees irreversibly destroys our here and now, so that the future seems to be catastrophic, filled with concern. It should be admitted that we have a sufficient number of examples proving the possibility of such a final result.

As a matter of fact, both directions of thinking are based on the same motivation for actions leading to the maintenance of a certain status quo. I am not able to foresee whether leaving the woods of the Białowieża Forest without human conservation and intervention may assure the sustainable existence of oak or linden trees for several generations. I am not able to foresee it mainly because the existence of forests and human being is so interdependent that any attempts to separate them from each other (and we have much evidence for this) have always ended tragically: both for the forests and the humans.

However, we may certainly prove the close relation of maintaining forest sustainability through conducting proper forest management. The prior emphasis on those aspects of forest utilisation that did not consist of the direct harvesting of raw materials, semi-finished or ready products and on the exceptionality of the existence of the Białowieża Forest in its unique form has led to the statement that:

Old trees in the Białowieża Forest should be put under a special conservation regime that relates to every tree species and every single tree.

Practically, this means assigning a number of functions to every old tree, while only some of these functions can be subjected now to a measurable valuation, **the necessity of their existence is for society more important than any interim economic benefits.** It is also equal to a negative appraisal of applying, as a criterion for the old age of a tree, its diameter at the height of 1.3 m above the ground. Mainly because the tree diameter at breast height depends on many factors and tree age is only one among them, and not really the most significant one.

In those cases justified by the necessity of forest sustainability that can be justified related to leaving an old tree, which is thought to happen sporadically, such a tree should be removed.

At the same time, I want to clearly emphasise that the removal of an old tree from the LKP [Promotional Forest Complex] 'Białowieża Forest' is considered in categories of a reasonable approach by the person entrusted with the management of natural resources.

The matter of determining the real number of old trees is complicated in this area not only due to the lack of data due to incomplete records. Despite very numerous non-governmental groups, scientific institutions, forest administrations, voivodeship and community administrations actively involved in the so-called issue of old trees in the LKP 'Białowieża Forest', there are no results illustrating the full quantitative status of old trees in the Białowieża Forest. There are data demonstrating that old trees such as the natural monument 'Car-dąb' [Tsar-oak] located in the Hajnówka Forest District, Starzyna Forest Management Unit, Forest Subdistrict Łozice, compartment 513d, classified as a natural monument in 1954, was erased from the register of natural monuments in 1984, which does not alter the fact that this tree still exists (2). The scientific works performed under the GEF Grant (headed by the author of this paper) covered many research topics within that scope and formed a start of works dedicated to the issue of old trees in the Białowieża Forest. An inventory of monumental trees showed that in the Białowieża Forest there exists a very abundant group of trees older than 200 years which are not recorded in any official register. These are usually old seed trees originating from natural regeneration. These trees certainly deserve special forms of conservation, also because they are relicts of native populations. An analysis carried out by Korczyk, PhD, of all trees considered natural monuments recorded at the end of 1994 in the Voivodeship Department of Nature Conservator indicated that among 827 trees, oak constituted 71.4%, common pine 7.4%, ash 7.4%, common spruce 6.4%, small-leaved linden 2.9%, with 4.5% maples, hornbeams, birches, alders, firs, and aspens. While comparing the above percentage distribution of monumental trees to the actual share of these species in the forest, a significant asymmetry is stated, particularly significant for two species: pine and spruce. That is why the works performed by Korczyk were oriented mainly.

On seeking pines and spruces that could be considered monumental trees. The works ended in 1995 by registering 200 monumental trees, including 139 pines and 61 spruce. The largest number of monumental trees was found in the territory of the Białowieża Forest District – 98 – and the Hajnówka Forest District – 89. A total of 13 trees were found in the Browsk Forest District. Moreover, it was found that a significant number of old trees that should be considered natural monuments [but were not covered by this study] still exists in the area of the forest. This concerns particularly deciduous species (2).

A team led by J. Zajączkowski, MSc, from SGGW [Warsaw University of Life Sciences], did a similar undertaking under a GEF grant. It made a survey of 100 monumental trees in the Białowieża Forest District and provided full documentation to the Voivodeship Nature Conservator in Białystok. During the 14 days of work, the team found 100 trees meeting the criteria defined for monumental trees, including: 58 oak, 10 ash, 9 linden, 8 spruce, 8 pine, 2 alder, 2 aspen, 1 maple, one group of neighbouring two spruces, and spruce and maple connate with each other (7).

Hence we have to deal with an unknown number of old monumental trees, trees that deserve being regarded as natural monuments, and an unknown number of old trees.

Will the implementation of an administrative provision ordering the cessation of felling trees with a diameter at breast height X and permitting the felling of trees with a diameter at breast height X–1, separately indicating the dimension X for every tree species – solve the problem of the necessity of leaving old trees in the Białowieża Forest?

I think no, and striving for the implementation of such a provision would be contrary to the theoretical principles of forest utilisation guaranteeing the factual conservation of trees, stands and forest ecosystems. It would be inconsistent with fundamental imperatives of maintaining forest sustainability, its ability to self-regenerate and biodiversity (including dimensional and age diversity).

Therefore, the assumption about subjecting old trees to the special conservation regime formulated in the beginning of this paper requires the development of such a conservation regime. It requires that every old tree in the Białowieża Forest is approached by the (forest, park, and the like) administration, so that a decision on felling it is dictated not only by the knowledge of forest craftsmanship, but also by a thorough understanding of nature and reasonable human operation.

Principles of removing old trees

In order to meet the imposed conditions concerning the protection of the remaining old trees, younger tree generation, shrubs, groundcover and soil, the removal of a single tree should be executed in connection with meeting special terms (4):

- every tree should be described and measured, whereby the measurements should be conducted both before (e.g. diameter at breast height, crown projection) and after felling (among others: total length, age of tree, height of the first living branch, etc.),
- a register of all felled old trees should be conducted.

These records shall constitute a valuable testimony for further scientific research. It should be clearly emphasised that the proposed methods and technologies of work described below will be significantly different from those applied by forest workers to final and intermediate cutting. The differences concern both the equipment and the work method used while performing specific operations.

Tree topping

In some cases, prior to the felling of a tree, boughs should be removed, and in very rare cases a part of the apex must be cut away.

The work is performed with use of chain saws, and when cutting boughs and the apex, relevant occupational safety requirements must be met:

– properly trained workers (working at heights),
– proper protection (special belts, ropes, handles, rope ladders, etc.),
– proper professional supervision.

Tree felling

Tree felling is done with chain saws. A tree free of boughs (or spreading branches and possibly apex) is cut according to the commonly accepted principles described in detail in relevant training materials within this scope.

In the cases when the tree felling direction resulting from the distribution of static and dynamic forces affecting the tree, properly evaluated by the supervising person(s) and the worker is unacceptable – lanyards ensuring a specific tree felling direction should be applied. After the tree felling, the stump and each log should be properly marked.

Tree delimbing and bucking

The delimbing and bucking are executed with the use of chain saws. Both operations are performed while obeying the rules binding for a forest worker executing this kind of work. The bucking must be preceded with a very clear presentation of the further objective:

- timber is treated as a material for further processing.

In such a case, the bucking is done at places allowing for a maximal utilisation of the raw material value, considering further limitations resulting from the applied extraction means.

- timber is left on site.

The bucking is conducted in a way enabling workers to turn particular sections and mark them properly. It is believed that the whole tree should not be left in its entire length, without bucking. A bucked trunk shall more quickly undergo natural decomposition.

Extraction and transport of wood raw material

It should be assumed that we will have to do with wood raw material of large dimensions and great weight. Horse skidding is recommended only in strictly specified cases (exceptionally inaccessible terrain, very swampy, large distance from the closest road or compartment division line). Contrary to the wide belief (often also among foresters), horse skidding causes more significant damage (of remaining stand, groundcover, soil) than skidding with a forwarder. Definitely, it is not recommended to use agricultural tractors or skidders for extraction.

The removal of wood raw material should be executed with use of a forwarder or, after reloading from the forwarder – with a truck.

All operations mentioned must be performed by properly trained operators. It should be assumed that the cost of performing these operations shall be high and in numerous cases the value of wood raw material harvested with use of described methods and technologies of work will not cover the costs of its harvesting.

From the Department of Forest Utilisation
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SGGW (Warsaw University of Life Sciences)

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Resolution of the General Board of PTL [Polish Forest Society] on the inscription of the entire Białowieża Forest on the UNESCO World List of Biosphere Reserves

In recognition of the exceptional, particularly important role performed by the Białowieża Forest in the system of natural resources in Poland and Europe, the General Board of the Polish Forest Association applies for the need of undertaking by the Government of the Republic of Poland endeavours aimed at the inscription of the entire part of the forest belonging to our country on the UNESCO list of biosphere reserves under the programme 'Man and Biosphere' (MaB) of the UNEP.

The inscription of an object on the UNESCO World List of Biosphere Reserves proves a very high recognition of its environmental values by the UNEP independent experts. Currently, seven recognised biosphere reserves exist in Poland (including the Białowieża National Park), while in Europe there are approx. 130 of them and more than 350 worldwide. In a biosphere reserve, the nature conservation should have various forms, starting from strict conservation for the so-called centre, through partial and landscape protection for developed lands. The submission by the Government of an object to be included in the 'Man and Biosphere' (MaB) programme constitutes a simultaneous obligation of the Government subject this natural site to special care.

In the case of the Białowieża Forest, the General Board of the Polish Forest Society proposes that the so-called central zone should be created of the Białowieża National Park in its existing size (sites of strict and partial conservation), and the remaining zone should consist of the established landscape park composed of the Promotional Forest Complex with the forest districts Białowieża, Browsk and Hajnówka, where a properly dimensioned landscape conservation, as well as strict and partial nature conservation should be conducted.

In the opinion of the General Board of the PTL, this proposal shall meet the demand for granting to the entire Białowieża Forest the special status of an object under conservation, and simultaneously it shall not have any financial consequence for the state budget.

It does not exclude the possibility of creating in the future, circumstances permitting, the Białowieża Forest National Park from the entire area of the Polish part of the forest.

Warsaw, 3 February 2000

President of the General Board
of the Polish Forest Society
Professor *Andrzej Grzywacz*, PhD, DSc

List of recipients:

1. Prime Minister of the Government of the Republic of Poland,
2. Minister of Environment,
3. Podlasie Voivode,
4. MaB Committee of Poland at the Polish Academy of Sciences,
5. Director-General of the State Forests,
6. Director of the National Board of National Parks,
7. Director of RDLP [Regional Board of State Forests] in Białystok,
8. Director of the Białowieża National Park,
9. Forest Districts: Białowieża, Browsk, Hajnówka.
10. Committee of Nature Conservation, Polish Academy of Sciences,
11. Committee of Forest Sciences, Polish Academy of Sciences,
12. League for Nature Conservation,
13. Environmental and forest press,
14. Branch offices of the Polish Forest Society.

Conference: Approach to 'temporary' stands in forest districts of the Promotional Forest Complex 'Białowieża Forest'

Conclusions and arrangements

An important issue in 'temporary' stands covering approx. 15% of the Białowieża Forest area is constituted by the determination of the silvicultural and conservational approach to these stands.

'Temporary' stands emerged as a result of strong anthropopressure and the renaturation of them should be conducted in accordance with forest management methods. One should not count on the self-regulating impact of nature. At the end of 2001, the forest management plans for the districts of he Białowieża Forest will expire, thus the preparation of new plans should be commenced, whereby they should contain the following silvicultural directions and guidelines for the consideration of the techno-economic commissions.

- 'Temporary' means 70–80-year-old coppice stands of aspen, birch and alder, formed on extensive clear cuts made during World War I and in the years 1924–1929, as well as stands being older than 100–120 years with impoverished and habitat non-compliant species composition, including stands with dominance of expansive hornbeam.
- Stands with species composition non-compliant with habitat conditions should be inventoried with consideration of their distortion level and of the advancement of the development stage of their renewal, natural one or carried out with maintenance treatments. The inventory should allow a comparison in subsequent forest management planning cycles.
- A conversion of these stands is deemed purposeful depending on the forest habitat type and the present species composition of a stand. Such conversion should be oriented towards the accomplishment of goals included in the valid soil and habitat documentation (1998), i.e. renaturation of stands and formation of mixed-species stands with complex stratification. The conversion of aspen, birch, and alder coppice stands is deemed the most urgent.
- The cessation of final cutting results in an emergence of disruptions in the forest renewal and maintenance processes, which in consequence leads to a reduction

of the stability and interrupts the sustainability of functions performed by the forest. Temporary stands at the maturity age and close to the maturity age should be considered while balancing the planned regulation of harvesting volume and in their schedule for the next twenty-year-period. Cuts should be intensive, oriented towards the conversion and renewal of stands, while the cutting system should be adapted to the species and to the forest habitat type.

- For communities indicating features of commenced self-regeneration a partial conversion or adjusted maintenance treatments should be planned, in order to give direction to these processes and to accelerate them.
- The principle valid in the forestry should be the accurate imitating of nature, thus a certain part of 'temporary' stands is to be left without any treatment, in order to conduct observations and scientific research related to the natural succession, although the effectiveness of large-area natural processes may appear to be doubtful.
- The distinguished parts of the forest constituting primeval or close-to-primeval forests should be left, if possible, completely without any direct human interference or limiting such interference to the unavoidable minimum, in particular, in cases of a threat to the forest's sanitary condition.
- In the 'Białowieża Forest' Promotional Forest Complex, it is necessary to develop scientific research supporting reinforcement of the sustainability and naturalness of forests, and improvement of their condition, health, viability and ability of performing all their functions.
- The 'Białowieża Forest' Promotional Forest Complex, a forest ecosystem developed mainly due to purposeful forest management operations, should still be submitted to already verified methods of forest management, ensuring the maintenance and development of their social, cultural and environmental-creative values. The previously applied specific ways and methods of renewal process initiation and stand protection are deemed appropriate.
- For the accomplishment of basic silvicultural and protective objectives it is necessary to amend selected previously binding orders on the management and protection of the Białowieża Forest and to withdraw or change the Order of the Director-General of the State Forests No. 48 dated 16 July 1998. Ad-hoc orders and decisions concerning the practice in specific cases should be of systemic nature and include legal principles enabling the forest district manager to act in a way allowing the performance of the obligation to maintain a proper forest condition.
- When working out the principles of drawing up a forest management plan, the terms 'forest management plan' and 'management guidelines' should be precisely defined, and then incorporated into the effective legal regulations. The goal

accomplishment method specified in the forest management plan should not be treated as obligatory for the forest district manager.

- The conversion of temporary stands should be accelerated in order not to allow standing timber depreciation.

Commission for applications consisting of:
Wojciech Fonder, MSc, BEng – chairman
and members:
Stanisław Kułak, MSc, BEng
Jerzy Tołwiński, BEng
Professor Jan Zajączkowski, PhD, BEng
Włodzimierz Poskrobko, PhD,
Bogdan Brzeziecki, PhD, DSc
Jerzy Ługowoj, MSc, BEng

Tomasz Borecki, Bogdan Brzeziecki

Silvicultural and forest management analysis of *post-Century* stands in the Białowieża Forest[1]

The problems of management of the so-called *post-Century* stands, formed in the course of natural or artificial regeneration on sites of clear-cutting conducted in the years 1924–1929 by the English company The Century have been attracting great interest for a long time on the part of forest practice and theory (Kutrzeba, 1979; Sokołowski, 1996; Chyra, 2000). The complexity of this matter is determined, firstly, by the total area covered by these stands, which is currently estimated at approx. six thousand hectares, and, secondly, by the distorted (from the point of view of forest management) species composition of *post-Century* stands, in which aspen, birch, alder and hornbeam frequently occur as dominant species. The high share of these species results from natural, spontaneous regeneration processes having the nature of secondary succession and only marginally affected by maintenance and protective stand treatment measures.

The subject of this study is an attempt of an advanced, silvicultural and forest management planning oriented, analysis of *post-Century* stands, encompassing the determination of optimal treatment methods for these stands and the forecasting of their further development resulting from the planned silvicultural and protective treatments. As a research tool, the BWINPro software (Nagel, 1999; Brzeziecki, 2000) was applied. It allows the analysis, graphical visualisation and forecasting of the development of mixed-species and uneven-aged stands.

General description of *post-Century* stands

Table 1 presents current data concerning the structure of habitats occupied by *post-Century* stands, with consideration of the dominant species. The total area of *post-Century* stands is currently estimated at almost 6,000 hectares (data compiled by the staff of forest districts of the Białowieża Forest). In total, 1,019 sub-compartments were rated as *post-Century* stands, which means that an average stand area comes to approx. 6 ha. The

[1] The study was developed partially (B.B.) within the KZL 50603020012 job 'Directions of naturation of distorted and degraded forest communities'. The project titled 'Fundamentals of sustainable and balanced forest management in the Promotional Forest Complexes', funded by the National Fund for Environmental Protection and Water Management.

most frequent dominant species is birch (almost 50% of the area of stands), spruce and alder (approx. 20% each). The remaining species (aspen, hornbeam, pine, linden, oak, and ash) account for approx. 10%. The share of habitat types is similarly unevenly distributed. The highest part of the *post-Century* stands occurs in the habitat type of fresh deciduous forest and fresh mixed deciduous forest. The moist deciduous forest, alder-ash carr and fresh mixed coniferous forest also cover relatively large areas. The share of other habitat types is low. Compared to an analogous summary prepared 20 years ago by Kutrzeba (1979), a significant decrease in the total area of *post-Century* stands (by approx. 2,000 ha) and shifts within the structure of forest habitat types, consisting mainly in an increased share of fertile and very fertile sites, can be noticed.

TABLE 1

Area distribution (ha) of forest habitat types of *post-Century* stand by dominant species (Chyra 2000) STL: forest habitat type

Tree species Pine Spruce Birch Aspen Oak Hornbeam Linden Ash Alder Total

STL	**Moist coniferous forest**									
	Fresh mixed coniferous forest	**Moist mixed coniferous forest**	**Fresh mixed deciduous forest**	**Moist mixed deciduous forest**	**Mixed deciduous bog forest**	**Fresh deciduous forest**	**Moist deciduous forest**	**Alder carr**	**Alder-ash carr**	**Total**
Bw			3						1	4
BMśw	5	73	157	5						240
BMw		12	32	0					4	48
LMśw	72	560	1161	70	12	10			6	1891
LMw		41	41	8					16	106
LMb			7						4	11
Lśw	5	561	1282	130	12	88	60	2	52	2192
Lw		68	101	28		32	10	13	640	892
Ol			13						51	64
OlJ		7			18			11	441	477
Total	82	1322	2797	241	42	130	70	26	1215	5925
5	1,4	22,3	47,2	4,1	0,7	2,2	1,2	0,4	20,5	100,0

The data shown in Table 1 illustrate well the scale of the problem concerning the *post-Century* stands. However, due to the synthetic and superficial nature of these data, it is hard to accept them as a basis for silvicultural and forest management planning analysis of *post-Century* stands and in forecasting their further development. For example, the creation of such synthetic categories as stands with birch as the dominant species leads to the inclusion of stands with highly diverse species compositions in one group. From point of view of planning of further measures to be applied to *post-Century* stands, the most complete possible information on these stands is needed, including data about their quantitative structure (in terms of the number of trees of individual species). For this reason, data from eighteen 25-are sample plots established in *post-Century* stands by Professor A. Sokołowski (1996) is used. These plots represent the full scope of variability of habitat conditions of the *post-Century* stands and present the most characteristic structural types of these stands.

Species composition of *post-Century* stands

Table 2 shows data representing the variability of species composition of *post-Century* stands. This composition was specified by two methods (these and further calculations were performed with use of the BWINPro software): based on the share of species by volume and the number of boles. With regard to volume, birch is very often dominant, while hornbeam with regard to the number of boles. Table 2 shows the total share of target species (such as pine, spruce, oak, alder, ash, maple, linden) and other species (birch, aspen, and hornbeam). The division of species into these two groups, applied also in further analyses, is fully arbitrary and considers mainly the economic point of view. Based on the combined share of target species, two stand groups may be distinguished. The first one is constituted by stands where the target species are in a majority. These stands usually occupy extreme sites on the gradient of habitat conditions (forest stands 1 to 6 occur in the forest habitat type of fresh mixed coniferous forest and in on the poorer variant of the fresh mixed deciduous forest, as well as stands 13 and 16–18, which occupy the forest habitat types of fresh deciduous forest, moist deciduous forest and alder-ash carr). The second group consists of stands 7–12 and 14–15, dominated by other species (birch, aspen and hornbeam). These stands occur mostly in the fresh mixed deciduous forest and fresh deciduous forest habitat type.

Quantitative structure of *post-Century* stands

The quantitative structure of *post-Century* stands is characterised by the data presented in Table 3. For reasons of simplicity, less numerously represented species have been combined in two categories: biocenotic and valuable deciduous species. Quantity-wise, spruce, birch, oak and hornbeam dominate. These species occur almost in the entire scope of habitat conditions. Pine, alder and ash are also numerously represented here.

TABLE 2

Species composition of stands on sample plots researched by Professor A. Sokołowski (1996) ($d_{1.3}$ >7 cm): D: target species; P: other species;

Plot no.	STL*	Species composition by volume	by number of trees	Total share of species D	p
	BMśw	8 pine 1 spruce 1 birch	4 pine 3 oak 2 spruce 1 birch		
2	BMśw	5 pine, 3 spruce, 2 birch	5 spruce, 3 pine, 2 birch		
3	LMśw	5 pine, 3 spruce, 2 birch	6 spruce, 3 pine, 1 birch		
4	LMśw	3 spruce, 2 birch, 1 oak, 1 aspen	3 spruce, 2 birch, 2 pine, 1 oak, 1 hornbeam		
5	LMśw	5 pine, 2 spruce, 2 birch, 1 hornbeam	4 spruce, 2 pine, 2 hornbeam, 1 birch, 1 oak		
6	LMśw	5 birch, 3 pine, 1 hornbeam, 1 spruce	5 hornbeam, 2 birch, 2 pine, 1 spruce		
7	LMśw	5 birch, 2 hornbeam, 1 spruce, 1 aspen, 1 linden	5 hornbeam, 2 birch, 2 spruce, 1 linden		
8	LMśw	4 birch, 3 spruce, 1 aspen, 1 hornbeam, 1 oak	3 spruce, 3 hornbeam, 3 birch, 1 oak		
9	LMśw	7 birch, 2 spruce, 1 hornbeam	4 hornbeam, 3 birch, 2 spruce, 1 oak		
10	LMśw	6 birch, 2 spruce, 1 hornbeam, 1 oak	3 birch, 3 hornbeam, 2 spruce, 1 oak, 1 pine		
11	LMśw	6 birch, 2 oak, 2 spruce	4 oak, 2 birch, 2 spruce, 2 hornbeam		
12	LMśw	7 birch, 1 spruce, 1 hornbeam, 1 aspen	4 birch, 3 hornbeam, 1 spruce, 1 oak, 1 aspen		
13	Lśw	5 birch, 3 spruce, 1 oak, 1 hornbeam	3 spruce, 2 birch, 2 oak, 2 hornbeam		
14	Lśw	5 birch, 2 spruce, 2 hornbeam, 1 oak	5 hornbeam, 2 spruce, 2 birch, 1 oak		
15	Lśw	6 spruce, 2 birch, 1 alder, 1 pine	6 spruce, 2 birch, 1 alder, 1 hornbeam		
16	Lw	5 alder, 3 spruce, 1 ashes, 1 maple	4 spruce, 3 alder, 2 hornbeam, 1 maple		
17	Lw	4 aspen, 3 alder, 1 spruce, 1 birch, 1 linden	3 alder, 2 spruce, 2 linden, 2 hornbeam, 1 aspen		
18	OlJ	9 alder, 1 ashes	7 alder, 2 ash, 1 spruce		

An analysis of the tree count representing target species allows the distinguishing of five groups of stands. The first one includes stands 1–3, where this role may be performed by pine and spruce. The second one consists of stands 4–6, where pine, spruce and oak are the target species. The third and largest group is constituted by stands 7–12 and 14–15, where spruce and oak are the most important species. The fourth group is composed of stands 13 and 16–17, where alder and spruce occur as target species. In the last stand (18), alder and ash are the most important target species. Apart from the above-mentioned, valuable deciduous admixtures (maple, linden, elm) may also perform the role of target species, particularly considering their relative shortage in the analysed stands.

In table 4, the total number of trees of target species in each analysed stand is presented and compared to the approximately determined (based on yield and stand increment tables) number of trees of target species, assuming a class I site index, full stocking and that only target species appear in the stand composition. The comparison of the actual and table-based number of target species trees demonstrates that in the majority of stands this number represents more than 70% of the values given in the tables. As suggested by Professor E. Bernadzki (oral information), such a tree count coefficient for target species is sufficient to make a decision on further maintenance of stands and the gradual conversion of their species composition by the elimination of undesired or excess species and supporting target species. In several cases (stands 6, 7, 9, 10, 12 and 15), the share of target species is lower than the assumed value of 70%, which may, but does not have to, justify the need to apply stronger methods for the conversion of these stands, in the form of initiation of regeneration cutting.

Changes in volume of *post-Century* stands as a result of planned silvicultural and protective treatments

The forecast of changes in the yield of the analysed stands as a result of planned silvicultural and protective treatments is shown in Table 5. For the planning of the mentioned treatments and forecasting alterations in stands resulting from these treatments, the BWINPro software (Nagel, 1999) was applied.

For the planning of treatments a general assumption was made, that due to overrun or approaching cutting maturity age, all or most aspen and birch trees should be removed from the majority of the analysed stands in the next ten years. Moreover, it was assumed that in many stands a reduction of expansive hornbeam would also be necessary not to allow its domination over the desired species (mainly oak and spruce).

[*] Forest habitat types: BMŚw – fresh mixed coniferous forest, LMŚw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, Lw – moist deciduous forest, OlJ – alder-ash carr

TABLE 3
Number of trees (N/ha) on sample plots ($d_{1.3}$ >7 cm)

Plot no.	STL*	Tree species									Target species
		Pine	Spruce	Birch Aspen	B	Oak	Horn-beam	CL	Ash	Alder	
	BMśw	336	168	16	12	**236**					Pine, spruce
2	BMśw	196	380	116	4						Pine, spruce
3	LMśw	184	392	108			8	12			Pine, spruce
4	LMśw	144	232	172	84		48				Oak, pine, spruce
5	LMśw	164	232	68	4	32	160		4		Oak, pine, spruce
6	LMśw	152	68	224		16	544	36			(Oak), pine, spruce
7	LMśw	4	224	172	16	36	432	40			Spruce, oak
8	LMśw		372	304			84	280	12	4	Spruce, oak
9	LMśw		252	344	96		532	12			Spruce, oak
10	LMśw	12	204	316	4	80	288				Spruce, oak
11	LMśw		200	212	388	132					Spruce, oak
12	LMśw	8	100	280	4	92	164	16			Spruce, oak
13	Lśw		296	244	8	236	156	20	8		Spruce, oak
14	Lśw		164	156	32		336	40	24		Spruce, (oak)
15	Lśw	16	336	128	4	12	40			48	(Alder), spruce
16	Lw		236	16	8		96	32	8	200	Alder, spruce
17	Lw		196	148			100	160	20	320	CL, alder, spruce
18	OlJ		48	8	4		8	152	480		Alder, ash

B – biocenotic species (pear tree, apple tree, rowan, goat willow); CL – precious deciduous (maple, elm, linden)

* Forest habitat types: BMŚw – fresh mixed coniferous forest, LMŚw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, Lw – moist deciduous forest, OlJ – alder-ash carr

As a consequence, high coefficients of utilisation (thinning) intensity of up to 70% were required for many of the stands. Assuming two treatments within ten years, this would mean the necessity of carrying out a thinning exceeding in some cases 30% of the stand volume. The increment in stands within ten ten-year-periods would not fully balance the volume reduction caused by the planned treatments, and consequently the average yield of stands at the end of the period would be slightly smaller (by approx. 10%) compared to the state at the beginning of the analysed period (Table 5).

TABLE 4

Comparison of actual and model (table-based) number of trees in the analysed stands Class I site index

Plot no.	STL*	Number of trees of target species		
		actual	table-based	%
	BMśw	504	650	77
2	BMśw	576	650	89
3	LMśw	576	650	89
4	LMśw	460	600	77
5	LMśw	432	600	72
6	LMśw	272	600	45
7	LMśw	304	550	55
8	LMśw	472	550	86
9	LMśw	360	550	65
10	LMśw	296	550	54
11	LMśw	588	550	107
12	LMśw	216	550	39
13	Lśw	560	550	102
14	Lśw	260	550	47
15	Lśw	412	550	75
16	Lw	484	550	88
17	Lw	696	550	126
18	OlJ	692	550	126
	Mean	453		79

* Forest habitat types: BMŚw – fresh mixed coniferous forest, LMŚw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, Lw – moist deciduous forest, OlJ – alder-ash carr

However, it should be emphasised that these results are obtained in office work conditions, not on the basis of actual silvicultural needs specified in the field. Therefore, they should be treated as only one of many possible scenarios. The simulative experiment aims to present a general approach to *post-Century* stands, rather than gathering accurate quantitative data illustrating the development of these stands in the near term. Accomplishment of the latter objective would require, among other things, establishing an appropriate number of sample plots and increasing the scope of measured properties and parameters.

TABLE 5

Changes in volume of merchantable timber of forest stands as a result of planned silvicultural procedures

Plot no.	STL*	Cur growing stock (m^3/ha)	Harvesting in ten-year-period (m^3/ha)	Harvesting in ten-year-period (%)	Tree species	Net increment (forecast) (m^3/ha)	Growing stock '2010' (m^3/ha)
	BMśw	227	26	11	Pine, spruce, aspen, birch	+45	272
2	BMśw	311	79	25	Birch	-4	307
3	LMśw	298	58	19	Birch	+25	323
4	LMśw	347	87	25	Birch, aspen	+14	361
5	LMśw	264	54	20	Birch, hornbeam	+29	293
6	LMśw	251	125	50	Birch, hornbeam	-44	207
7	LMśw	277	185	67	Birch, aspen, hornbeam	-98	179
8	LMśw	267	147	55	Birch, aspen, hornbeam	-76	191
9	LMśw	288	190	66	Birch, hornbeam	-120	168
10	LMśw	289	163	56	Birch, hornbeam	-80	209
11	LMśw	227	115	51	Birch, aspen, hornbeam, oak	-32	195
12	LMśw	271	150	55	Birch, aspen	-65	206
13	Lśw	228	59	26	Birch, aspen	+14	242
14	Lśw	262	120	46	Birch	-45	217
15	Lśw	279	146	52	Birch, hornbeam	-52	227
16	Lw	307	33	11	Spruce	+87	394
17	Lw	379	141	37	Aspen	-71	308
18	0IJ	393	78	20	Alder	+10	403
	On average	287	109	38		-26	261

* Forest habitat types: BMŚw – fresh mixed coniferous forest, LMŚw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, Lw – moist deciduous forest, OlJ – alder-ash carr

High intensity of harvesting focused on species that have achieved their cutting maturity age or are represented excessively allows achieving within a short period a relatively significant improvement in species composition of the researched stands (Table 6). As a result of the planned treatments, the combined share of the target species increases practically in each stand. At the end of the analysed period, the combined share of target species is lower only in one case (stand 12), while in three cases (stands 9–11) it is equal to the share of remaining species. This result emphasises the dynamic nature of species composition of mixed stands and the possibility of its alteration in a direction desired generally through appropriately planned and conducted operations.

TABLE 6

Species composition of stands prior to and after the planned silvicultural and protective treatments

Plot no.	STL*	Species composition		Combined share of target species	
		present	10 years after planned silvicultural and protective treatments	currently	forecast
	BMśw	8 pine, 1 spruce, 1 birch	9 pine, 1 spruce	9	10
2	BMśw	5 pine, 3 spruce, 2 birch	6 pine, 4 spruce	8	10
3	LMśw	5 pine, 3 spruce, 2 birch	6 pine, 4 spruce	8	10
4	LMśw	3 spruce, 3 pine, 2 birch, 1 oak, 1 aspen	5 spruce, 4 pine, 1 oak	7	10
5	LMśw	5 pine, 2 spruce, 2 birch, 1 hornbeam	3 spruce, 6 pine, 1 hornbeam	7	9
6	LMśw	5 birch, 3 pine, 1 hornbeam, 1 spruce	5 pine, 2 hornbeam, 1 spruce, 1 birch	4	7
7	LMśw	5 birch, 2 hornbeam, 1 spruce, 1 aspen, 1 linden	4 hornbeam, 3 spruce, 1 linden, 1 oak	2	6
8	LMśw	4 birch, 3 spruce, 1 aspen, 1 hornbeam, 1 oak	6 spruce, 2 hornbeam, 1 oak, 1 birch	4	7
9	LMśw	7 birch, 2 spruce, 1 hornbeam	4 spruce, 3 hornbeam, 2 birch, 1 oak	2	5
10	LMśw	6 birch, 2 spruce, 1 hornbeam, 1 oak	3 spruce, 3 birch, 2 hornbeam, 1 oak, 1 pine	3	5
11	LMśw	6 birch, 2 oak, 2 spruce	3 spruce, 3 birch, 2 oak, 2 hornbeam	4	5
12	LMśw	7 birch, 1 spruce, 1 hornbeam, 1 aspen	4 birch, 2 hornbeam, 2 spruce, 1 oak, 1 linden		4
13	Lśw	5 birch, 3 spruce, 1 oak, 1 hornbeam	6 spruce, 2 oak, 1 birch, 1 hornbeam	4	8

* Forest habitat types: BMŚw – fresh mixed coniferous forest, LMŚw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, Lw – moist deciduous forest, OlJ – alder-ash carr

Plot no.	STL*	Species composition		Combined share of target species	
		present	10 years after planned silvicultural and protective treatments	currently	forecast
14	Lśw	5 birch, 2 spruce, 2 hornbeam, 1 oak	3 spruce, 2 hornbeam, 2 linden Maple 1 birch, 1 oak, 1 ash	3	7
15	Lśw	6 spruce, 2 birch, 1 alder, 1 pine	3 spruce, 2 alder, 1 pine	8	10
16	Lw	5 alder, 3 spruce, 1 ash, 1 maple	6 alder, 2 spruce, 1 ash, 1 maple	10	10
17	Lw	4 aspen, 3 alder, 1 spruce, 1 birch, 1 linden	4 alder, 2 spruce, 2 linden, 2 birch	5	8
18	OlJ	9 alder, 1 ash, 9	alder, 1 ash	10	10

* Forest habitat types: BMŚw – fresh mixed coniferous forest, LMŚw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, Lw – moist deciduous forest, OlJ – alder-ash carr

Discussion and conclusions

The approximate nature of the data included in standard inventory descriptions makes the successful planning of silvicultural and protective treatments virtually impossible. Therefore, the silvicultural and forest management planning-oriented analysis of *post-Century* stands conducted within the framework of this study is based on data from a publication by Professor A. Sokołowski (1996). The fundamental advantage of these data consists of the information on the quantitative structure of trees that should perform an essential role in any considerations concerning the selection of the optimal methods for stand conversion. It is unknown to what extent the data collected a few years ago describe the present status of *post-Century* stands, which might have changed significantly for many reasons in the meantime. The representativeness of the data is also an issue here. There is no doubt that they reflect well the range of variability of habitats occupied by *post-Century* stands and their main structure types. However, on their basis it is impossible to define the relative frequency of occurrence of particular stand categories. Finding an answer to this significant question would require the establishment of a systematic trial. The value of analyses with use of the mentioned data is limited also by their incomplete character (among other, missing information on the height and spatial coordinates of trees, quality of the trees representing target species).

The adequacy of the BWINPro model (Nagel, 1999) under the Białowieża Forest conditions is also the great unknown. Taking into account possible advantages of this model, it seems that it deserves greater interest not only by forest science, but also forest practice.

When recapitulating, the formulation of the following conclusions may be attempted:

- efficient planning of silvicultural and protective treatments in stands with diversified structure requires the development of an extended database on these stands;
- standard data included in inventory records of stands do not allow, among other things, for the assessment of a quantitative share (in terms of number of boles) of particular species, spatial structure of stand, quality and silvicultural usefulness of trees of target species;
- the problem complexity of the management of *post-Century* stands indicates the necessity of applying appropriate stand inventory methods that use circular plot sampling, with an extended scope of inventoried properties, such as the number and silvicultural quality of trees of the target species;
- the development of optimal handling methods and variants for *post-Century* stands would require the establishment of an appropriate number of model (standard) sample plots (in terms of form and assumptions similar to thinning sample plots), on which detailed measurements would be conducted and treatments compatible with the current silvicultural and protective needs of various *post-Century* stand categories would be planned. The data collected from the mentioned sample plots would also allow a more credible assessment and forecasting of the further development of *post-Century* stands in the near term, including changes in yield and species structure of these stands, harvesting volume and structure, etc.;
- taking into account:
    1. the specificity of stands in the Promotional Forest Complex 'Białowieża Forest',
    2. total size of *post-Century* stands,
    3. current problems with obtaining valuable renewal, a decision on conversion of stands in the form of initiation of regeneration treatments should be made only as a last resort;
- making the decision on the commencement of the conversion of a specific stand, in the form of initiating regeneration cutting, does not have to imply that regeneration cutting must cover the entire stand area. These fragments of stands under conversion process, in which an appropriate number of trees of the target species exists (e.g. 60–80 crop oaks per hectare) should be kept for further silvicultural processes;
- the analysis of more than a dozen exemplarily selected *post-Century* stands shows that in many of them the number of trees of the target species is sufficient to allow further silvicultural processing of these stands in the next 30 (alder), 50 (pine, spruce, ash) and even 100 years (oak);

- in all these stands or in their appropriately large fragments (e.g. 1 ha), where a sufficient number of trees (min. 70% of the value indicated in tables) of the target species (pine, spruce, oak, alder, ash, precious deciduous species) is present, the conversion should not consist of initiating regeneration cutting, but in a gradual change of species composition of the stand, according to its natural development rhythm and with consideration of the cutting maturity age of particular species.

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Changes in plant communities and habitat types in natural stands of the Białowieża National Park

Signals about a strong acceleration in the pace of change in flora come from various regions of Poland (3, 4, 9, 13, 16, 17). Over the last few decades, directional transformations of plant communities have been observed, which – as shown by many examples – have their source not only from the natural succession processes. Spectacular changes in plant communities occurring in industrial regions in the very short period of the last 20–30 years (9, 10) have been particularly noticeable. The increasing fertility of habitats is observed more clearly in managed forests. The data from forest management planning show a decline in the area of poor habitats. However, in this case, the existence of the human factor related to the improvement of classification and of field work related to soils and habitats (2) cannot be excluded. Against this background, the Białowieża National Park, where no forest management activities have been conducted for more than 80 years and human penetration has been very limited, constitutes an excellent subject for research on changes persisting in forest ecosystems. In its entire history, it has also been kept under special care, so that the least distorted forest ecosystems have been preserved there.

The main objectives of this study include the comprehension of the alterations in the flora effected over the last 40 years and an attempt to explain the reasons for the observed changes and to verify the boundaries of plant communities.

Research subject and methodology

The study was conducted on a sample plot of the Department of Silviculture, SGGW [Warsaw University of Life Sciences] situated in the territory of the strict reserve of the Białowieża National Park in compartment 284/285. It has the form of an elongated rectangle, with the dimensions 780 m × 40 m (with a 40 m × 40 m side branch). Its total area comes to 3.28 ha. In June 1959, 23 phytosociological relevés were made on the sample plot by Zaręba (19) with the Braun-Blaquet method. The mean relevé area was approx. 200 m^2. Then they were grouped into tables of plant associations with use of taxonomy principles for forest communities developed in 1952 by Matuszkiewicz (8). In 1998, the phytosociological surveys were repeated, with 80 evenly distributed sample plots being established. All of them had a square shape with sides of 10 m. The distances between the sample squares were fixed and was 10 m. The phytosociological classification developed by Sokołowski (15) was applied. For each association, the systematic value of the group of coniferous forest and oak-hornbeam forest species was calculated as of 1959 and 1998. The coniferous forest species comprised species from the *Vaccinio-Piceetea* class, *Vaccinio-Piceetalia* order and *Dicrano-Pinion* alliance, while the oak-hornbeam forest species included species from the *Querco-Fagetea* class, *Fagetalia* order and *Carpinion betuli* alliance.

Research results

In 1959, on a large part of the research plot, the fresh coniferous forest *Vaccinio myrtilli-Pinetum* Kobendza 1930 (Fig.) was present. While using the present taxonomy of forest communities developed by Sokołowski (15), the phytosociological relevé made on the sample plot adjacent to oak-hornbeam forests was rated as small reed-spruce fresh mixed coniferous forest *Calamagrostio arundinaceae-Piceetum* Sokoł. 1968. The other phytosociological relevés represented the association of cowberry fresh coniferous forest *Vaccinium vitis-ideae-Pinetum* Sokoł. 1980.

Since then, very large changes have occurred in the composition and structure of these communities. Pine is under a process of gradual stem exclusion. Spruce plays an increasingly important role in the stand, as it appears in its overstorey on all plots. Sometimes it is the major component of the stand. However, in the lower layers of the stand and in the shrub layer, a strong reduction of this species is noticed. Birch is clearly retreating from the stand. Hornbeam is highly expansive, and in some plots it forms compact groups in the understoreys of the stand. It shades the forest floor and causes an almost complete decline of the moss cover. In addition, a significant increase in the share of hornbeam in the shrub layer is noticeable.

Highly oligotrophic species are disappearing from the ground cover: *Solidago virga aurea, Antennaria dioica, Calluna vulgaris, Anthericum ramosum, Amica montana.* The significance of other species that prefer poor and acidic soils also decreases: *Vaccinium vitis-idaea, Dieranum undulatum, Scorzanera humilis.* Coniferous forest species with higher habitat-related requirements are increasing their [canopy] coverage and extending their range: *Pteridium aquilinum, Ptilium crista-castrensis, Trientalis europaea.* Similar trends are demonstrated by species with a wide ecological amplitude: *Calamagrostis arundinacea, Oxalis acetosella, Maianthemum bifolium.* New mesotrophic species: *Rubus idaeus, Dryopteris carthusiana* as well as eutrophic ones: *Urtica dioica, Stellaria nemorum, Circace alpine* have appeared. The group from the *Querco-Fagetea* class has grown by new species: *Milium effusum, Mycelis muralis, Corylus avellana.* In general, a small increase in the systematic value of the oak-hornbeam forest species group occurred over the 40 year period. In the case of the coniferous forest species group, an opposite tendency was noticed.

Similarly, very large changes in the flora have occurred on the area of the former *Pino-Quercetum serratuletosum* Mat. 1955 association, in its poorer variant. According to the present classification by Sokołowski (15), phytosociological relevés representing the mentioned association correspond with the small reed-pine fresh mixed coniferous forest

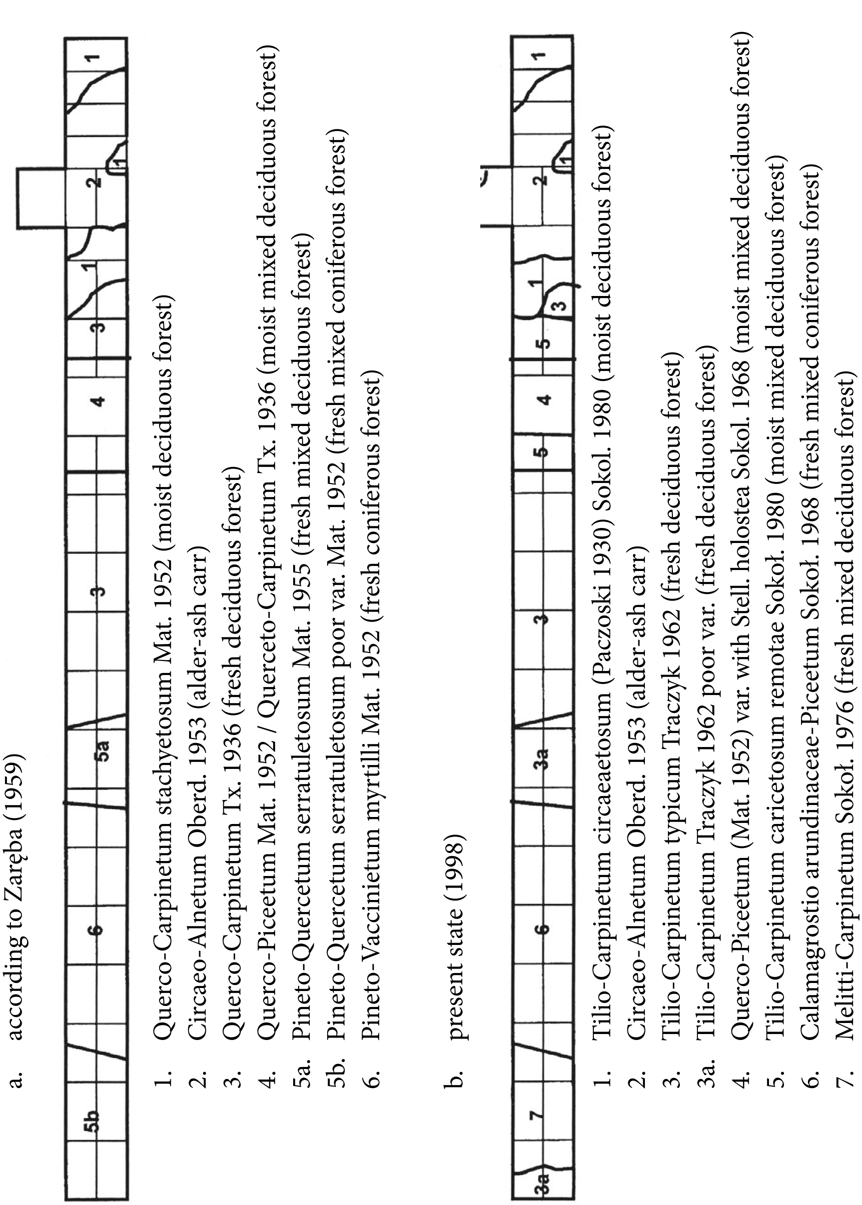

Fig. Forest associations and habitat types on the research plot in compartments 284–285 of the Białowieża National Park

Calamagrostio arundinaceae-Piceetum Sokoł. 1968 sub-association, variant with *Polygonatum odoratum*. The tree overstorey underwent significant depletion. Early successional species: pine and birch retreat as they do not find conditions for natural regeneration. Hornbeam and linden enter intensively; on the majority of plots they dominate clearly in all strata of the understorey. Special attention should be paid to a very large decrease in share of spruce in all stand layers, particularly in its bottom layers. However, this species has completely disappeared from the shrub layer. Due to the occurrence of various stand development phases on a given area, the conditions for development of the ground cover vegetation are different. The bastard balm-hornbeam deciduous forest *Melitti-Carpinetum* Sokoł 1976 association, variant with *Vaccinium vitis-idaea* is dominant. A typical oak-hornbeam forest *Tilio-Carpinetum typicum* Traczyk 1962 in its poor variant (Fig.) exists on a small area. On one of plots, it is impossible to ascertain the association name due to large flora distortions resulting from almost full light access to the forest floor and a significant quantity of well-decomposed wood. Eutrophic species occur numerously: *U. dioica, S. nemorum, C. alpina*. The systematic value coefficient of the coniferous forest species group has significantly decreased on the analysed area, i.e. from 22% to 6.7%. The coniferous forest mosses: *Hylocomium splendens* and *Pleurozium schreberi* are subject to a significant reduction. Certain oligotrophic herbaceous plants: *S. humilis, Chimaphila umbellata, O. secunda* completely disappear. On the other hand, oak-hornbeam forest species from the *Fagetalia* order appear: *Lamiastrum galeobdolon, Carex pilosa, Mnium undulatum, Dentaria bulbifera,* belonging to the *Querco-Fagetea* class: *Moehringia trinervia, Dryopterisfilix-mas*. The share of the oak-hornbeam forest species group in the formation of the association increases. Moreover, species typical for bright oak forest from the *Quercetalia pubescentis* order: *Carex montana, Melittis melisophyllum* exist sparsely. However, the systematic value coefficient of this species group has significantly reduced, from 7.3% to 1.3%.

The former *Pino-Quercetum serratuletosum* Mat. 1995 sub-association, in its more fertile variant, corresponds in the present phytosociological classification with the bastard balm-hornbeam deciduous forest *Melitti-Carpinetum* Sokoł. 1976 *variant with Hepatica nobilis*. In the analysed period, the structure and species composition of the phytocenosis have changed drastically. It is mainly associated with the maturing process of species characteristic for the oak-hornbeam deciduous forest, namely hornbeam and linden, which strongly modify the microclimatic conditions of the forest interior. The composition of the overstorey of the stand has basically remained unchanged. Old oaks are still dominant. Spruce is a co-dominant species. Pine occurs individually. The lower layers of the stand have strongly developed over 40 years. These layers consist mainly of hornbeam and linden. 40 years ago, Zaręba observed the occurrence of a large quantity of self-sown seedlings, mainly of hornbeam. These seedlings together with the then already well-developed linden in the second growth layer initiated the development of lower stand layers on that site.

Currently, the layer of self-sown seedlings consists of hornbeam, linden, maple and oak. Also, because of the small quantity of light reaching the forest floor, the ground coverage has significantly decreased, coming in the early spring stage to 30 to 40%, while in the summer stage to only 0 to 10%. Substantial changes are observed in the ground cover species composition. Almost all coniferous forest species from the *Vaccinio-Piceetea* class disappear, including: *P. aquilinum, Vaccinium myrtillus, O. secunda, S. humilis* and heliophilous species: *C. arundinacea, P. odoratum, Serratula tinctoria,* and *Convallaria majalis.* The systematic values of the coniferous forest species group and from the *Quercetalia pubescentis* class dropped to zero. However, species have appeared occurring in oak-hornbeam forests from the *Fagetalia* order*: L. galeobdolon, Galium odoratum, Lathyrus vernus, Dryopteris-filix-mas* and from the *Querco-Fagetea* class*: M. muralis, Thelypteris phegopteris, Corylus avellana* as well as eutrophic species: *U. dioica.* The significance of an important, typically oak-hornbeam forest species – *Stellaria holostea* increases. In addition, the systematic value of an entire oak-hornbeam forest species group significantly increased.

Due to the described changes in species composition and structure of the *Pino-Quercetum serratuletosum* Mat. 1955 community, it is necessary to update the phytosociological diagnosis formulated 40 years ago. According to the present classification of forest communities (15), it is a typical oak-hornbeam forest *Tilio-Carpinetum typicum* Traczyk 1962 *poor variant*. The boundary of typical oak-hornbeam forests (fresh deciduous forest) moved, covering areas formerly rated as fresh mixed deciduous forest (Fig.).

In the phytosociological *Querco-Carpinetum medioeuropaeum* Tx. 1926 association, equal, according to the present phytosociological classification (15), to the typical oak-hornbeam *Tilio-Carpinetum typicum* Traczyk 1962 association, *variant with Hepatica nobilis*, changes in the flora were not large. The community structure stabilised. Multi-storey stands were formed. The stand composition basically did not change. Hornbeam and linden dominate in each stand layer. Oak-hornbeam forest species are still dominant in the ground cover. Many species have appeared recently: species distinguishing the *variant with Hepatica nobilis: Polygonatum multijlorum, Lathyrus vernus, Lathrea squamaria,* from the *Fagetalia* order*: Brachypodium sylvaticum, S. nemorum, Catharinaea undulata, Scrophularia nodosa;* from the *Querco-Fagetea* class*: C. digitata, M. muralis.* Therefore, there is an observable completion of plant composition with new species, important from the diagnostic point of view. Rare coniferous forest species, present 40 years ago, have completely disappeared.

The area formerly covered by the spruce-oak wet mixed coniferous forest association with elements of the oak-hornbeam forest: *Querco-Piceetum* Mat. 1952 / *Querco-Carpinetum mediaoeuropaeum* was rated as moist deciduous forest. In the light of the present classification of forest associations, the phytosociological material was divided into two parts corresponding with the associations: sedge oak-hornbeam forest – *Tilio-Carpinetum caricetosum remotae* Sokoł. 1980, *poorer variant with Dicranum scoparium,* and oak-spruce moist mixed coniferous forest *Querco-Piceetum* Mat. 1952 em. Sokoł. 1968, *variant with Stellaria holostea*. In the first-mentioned association, an increase in share of hornbeam was observed, while in the latter one a reduction of birch and spruce in the bottom strata of the stand. The share of spruce in the overstorey grows, which is associated with small changes in the ground cover vegetation. The systematic value of the coniferous forest species group did not change, while for oak-hornbeam forest species it slightly increased.

Also, in the sapric oak-hornbeam forest association – *Tilio-Carpinetum circaeaetosum alpine* (Paczoski 1930) Sokoł. 1980 (moist deciduous forest) and ash-alder riparian forest association *Circaeo-Alnetum* Oberd. 1953 (alder-ash carr), changes in flora are small. In the alder-ash carr habitat, an increased share of hornbeam and linden in the stand is observed, resulting in a modest increase in the significance of ground cover species typical for oak-hornbeam forest. Simultaneously, a small shift of the borderline of the ash-alder riparian forest to the area of the former moist deciduous forest is noticed, probably associated with a change in the inundation area of the stream (Fig.).

Summary and discussion

Over the last few decades, a clear reduction in the oligotrophic and heliophilous species in the composition of forest communities may be observed (3, 4, 13, 14, 15, 16, 20). Also, on the scale of the entire sample plot, a decline in ground cover species, with a majority of them belonging to the above-mentioned groups of species, was noticed over the last 40 years. In parallel, the phenomenon of increase of eutrophic species share in the composition of many forest communities occurs. Despite that, the number of species arriving does not compensate for the number of species disappearing. It is clearly noticeable in communities described with a rich variety of flora and the presence of xerothermic species typical for mesotrophic habitats. On the sample plot, such a situation happened for two variants of the *Pino-Quercetum serratuletosum* Mat. 1995 association, corresponding with habitat types of mixed coniferous forest and fresh mixed deciduous forest. Respectively, 25 and 13 species declined there.

The above-mentioned changes in vegetation constitute a common phenomenon, observed also at other sites: in nature reserves of the Białowieża Forest (14, 15) and in other areas of north-eastern Poland (13, 16, 17), as well as in the central (3, 10, 11) and the southern part of the country (4, 9). In many cases, changes in species composition of forest communities are so clearly marked that they justify the necessity of a modification of previous phytosociological and habitat-typological diagnoses (3, 6, 11, 14, 15, 16, 17, 18). In that period, the cowberry fresh coniferous forest association, *Vaccinium vitis-ideae-Pinetum* Sokoł. 1980, showed a tendency for changes towards the small reed-spruce fresh mixed coniferous forest *Calamagrostio arundinaceae-Piceetum* Sokoł. 1968 association.

The latter transforms into the bastard balm-hornbeam deciduous forest *Melitti-Carpinetum* Sokoł. 1976, while particularly fertile variants of this association become similar to a typical oak-hornbeam forest *Tilio-Carpinetum* Traczyk 1962 (15, 16, 18). It is expressed in significant floristic changes, a reduced systematic value of the coniferous forest and heliophilous species group from the *Quercetalia pubescentis* class, with a simultaneous increase in the significance of the oak-hornbeam species groups. The above-mentioned directions of changes in the flora occur also in associations being present on the research plot. In the typological approach, the following trends may be noticed: the habitat type of fresh coniferous forest becomes similar to the mixed coniferous forest, which in turn becomes similar to the mixed deciduous forest, and the latter to the fresh deciduous forest (18). The mentioned forest habitat types are characterised, on the one hand, with high susceptibility to degradation, while on the other hand with the quickest regeneration, but simultaneously they are described with the strongest response to extraneous eutrophication changes. The phenomenon of an increase in fertility of fresh habitats becomes more and more common. In the case of moist habitats, the floristic changes are significantly smaller (15, 18). The specificity of moist habitats consists in their formation on semi-hydrogenic or hydrogenic soils, where water is the major soil-forming factor. The communities present there have climax nature, as the high level of ground water allows existence of few tree species, which are best adapted to such conditions. Moreover, the mentioned habitats develop usually on fertile soils with large buffer capacity.

It seems that the observed changes in vegetation are caused not only by one reason. Many researchers lean towards the opinion that it is difficult to separate the impact of particular factors. The regeneration of plant communities of the Białowieża National Park after their former anthropogenic distortions (game overabundance, livestock grazing, litter raking, clear-cuts) overlaps the eutrophication of habitats caused by air pollution and climatic changes (1, 2, 5, 7, 16, 17, 18). In natural forests, these phenomena may be reinforced with the impact of windthrows and dead wood. It seems that the alterations occurring in communities existing on the sample plot are of directional nature and may indicate the habitat eutrophication process observed the most clearly on fresh habitats. It should be assumed that it will be increasingly important in the dynamics of the vegetation of the Białowieża National Park.

An attempt to explain reasons for changes occurring over the last 40 years in the composition of communities existing on the sample plot indicates that they occurred as a result of two overlapping processes: regeneration of communities and eutrophication of habitats. As a result of their coaction, significant changes, not foreseen in earlier forecasts, occurred in a relatively short time (8, 12). The hornbeam expansion has not ended yet (1). Therefore, it should be assumed that tendencies of various habitats to gain a deciduous forest character shall deepen.

Conclusions

- Over the last 40 years, the largest changes in vegetation have been observed in the poor fresh coniferous forest habitat and medium fertile habitats of fresh mixed coniferous forest and fresh mixed deciduous forest. The fresh coniferous forest habitat has completely disappeared. In moist habitats represented on the sample plot: moist mixed deciduous forest, moist deciduous forest and alder-ash carr, changes in vegetation are minor.
- An increase in fertility of fresh habitats by one fertility class has been observed. The fresh coniferous forest habitat has become similar to the fresh mixed coniferous forest, while the fresh mixed coniferous forest habitat transformed into mixed deciduous forest, and the latter into fresh deciduous forest.
- The largest changes in species composition and structure of stands on the scale of sample plot are accompanied by large changes in the ground cover species composition. The most intensive spruce stem exclusion in the lower strata of the stand concern, in particular, poor and medium fertile fresh habitats. In fertile habitats, the share of this species reduces in the entire stand. Simultaneously, an expansion of deciduous species (hornbeam, linden) has been observed, the most clearly in the fresh mixed coniferous forest, fresh mixed deciduous forest and fresh coniferous forest habitats.
- The entrance of tree species typical for oak-hornbeam forest into the stand results in changes in the ground cover vegetation towards the oak-hornbeam forest character. This is expressed in the elimination of oligotrophic and heliophilous species, as well as in the appearance of ground cover species distinctive for the oak-hornbeam forest.

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Małgorzata Krasuska, Stanisław Miścicki

Large-scale inventory of stands in the Białowieża National Park*

Introduction and research purpose

The national park conservation plan is developed in accordance with an appropriate instruction (NFOS, Instruction 1994). It is composed of a number of partial plans and a general plan. Due to a very high share of forest area in the majority of Polish national parks, a forest ecosystem protection plan is usually the most important component of a general plan.

For more than a dozen years, the method of drawing up forest ecosystems conservation plans for a national park has been criticised in the forestry scientific community, as demonstrated by discussions at scientific conferences in Prądnik (1990) and Kudowa Zdrój (2000). The invoked instruction and, consequently, the ready-made plans are negatively evaluated for their schematic approach. The information contained in the plan is usually insufficient and does not reflect the specificity of the object. The application of solutions foreseen for maintenance forests (collection of data with application of relascopic samples, describing uneven-aged stands with use of age-classes, site index and stocking tables) does not reflect the complexity of national park forests, their environmental and geographical disparities.

A change in the present methodological solutions applied for the development of forest ecosystem conservation plans is necessary. Information on forests in a given national park should concern the entire unit and few or more than a dozen of smaller, aggregate units subjected to interpretation, composed of distinguished stands e.g. due to their natural development stage (Miścicki 1994), dominant tree species and ecological process (Faliński 1991). Detailed data, multilaterally characterising the stands and capturing the object's specificity (e.g. renewal state, shrub quantity, quantity of woody debris, tree damage, structure of tree dimensions, species composition) should be gathered as a result of measurement of other sample plots than the relascopic ones. Permanent sample plots, developed in Switzerland (Schmid-Haas 1991) and verified under Polish conditions on

* Study developed under the statutory activity funded by the State Committee for Scientific Research

numerous occasions (Przybylska 1977), are considered the best. Due to their measurement cost (especially for the first turn), their number should be relatively small (usually not higher than 1,000) (Miścicki 2000b). However, a larger number of properties is considered in the measurements. In forests of national parks, it is not necessary to have accurate information available on every stand (no regulation of utilisation exists), but it is necessary to understand many properties and to track the development of the entire forest. Successive measurements on permanent control plots allow, apart from revealing the present state, for an estimation of the intensity and direction of changes happening in the forest, together with an evaluation of the characteristics of the dynamics – learning the scale of ingrowth and decline of trees, and the current volume increment.

The goal of this research consisted in a large-scale survey of stands in the strict protection area of the Białowieża National Park. It contains a presentation of the most important properties featured by the stands of this domain:

- yield of merchantable timber,
- stand density,
- species composition,
- structure of dimensions,
- mean diameter at breast height of dominant trees,
- maximal diameter at breast height of tree species,
- level of crown projection area,
- level of area coverage by woody debris,
- share of stands classified by natural development stages,
- share of stands by dominant species,
- share of stands by number of tree storeys.

Under the discussion, own results were compared to the most important data collected for the purposes of the forest management plan for the Białowieża National Park (BULiGL 1992).

Research object

The Białowieża National Park – the oldest object of its type in Poland – was established in 1921. In 1977, it was considered the World Biosphere Reserve, while in 1979 it was inscribed on the World Heritage Site list. The strict protection area covers a small, best preserved part of the Białowieża Forest. The forest area covered by inventory was 4,584 ha. The last forest management planning works were performed at the turn of 1980s and 1990s, assessing the forest state as of 1 January 1991 (BULiGL 1992).

Methodology

Measurement work

The measurement work was performed in June 1995 on 460 sample plots systematically distributed on a rectangular 1000x1000 m grid. The shorter side of the grid had an azimuth orientation 330°. A sample plot consisted of four concentric circles with the following sizes: 5.31 m^2 (measurement of all trees including seedlings $h<0.3$ m and aged ≥ 2 years), 20 m^2 (measurement of trees $h\geq0.3$ m), 50 m^2 (measurement of trees $d_{1.3}\geq2$ cm), 200 m^2 (measurement of trees $d_{1.3}\geq12$ cm), 500 m^2 (measurement of trees $d_{1.3}\geq36$ cm). The species was defined and the diameter at breast height (or height if $h\leq1.3$ m) was measured for all trees included in the sample. Specimens for height measurement were selected from every species and in every stand layer. In the case of trees with a diameter at breast height $d_{1.3}\geq60$cm, the height was always measured.

Within each sample plot, the properties describing the forest stand were estimated: the natural development stage according to the modified classification by Leibundgut (Miścicki 1994), the aggregated plot coverage by crowns (%), dominant species, vertical structure (number of stand storeys, crown projection for each layer; %), plot coverage by woody debris (%).

The measurement works were executed by Ryszard Kocieliński, Stanisław Miścicki, Andrzej Szerszenowicz and Krzysztof Szerszenowicz.

Calculation work

The height curve was calculated according to the Naslund formula, separately for each tree species. The volume of merchantable timber for a single tree of particular species was calculated with use of the volume function (Bruchwald et al. 2000). Due to the division into size classes, it was assumed that merchantable timber meant trees with a diameter at breast height $d_{1.3}>8$ cm. The yield of trees on the sample plot converted per hectare was calculated according to the principles applied on concentric plots – as a sum of products of tree volumes and coefficients depending on tree size (Miścicki 2000a). The stand density on the sample plot converted per hectare was calculated as a sum of tree coefficients on the sample plot.

The diameter at breast height for dominant trees (d_{250}) was calculated as the mean of the 250 thickest trees per hectare. For each tree species, the maximal diameter at breast height (d_{10ha}) was calculated, i.e. the diameter exceeded by an average of 1 tree per 10 ha. The tree survival coefficient *q* was calculated in diameter classes, and on that basis the development stages were assessed for the stands treated cumulatively (Poznański and Rutkowska 1997).

It was assumed that in the distinguished unit (a total of stands on the strict protection area of the Białowieża National Park) an error of estimation of the mean value of measurable properties (e.g. yield) is approximately same as at the calculation specific for the simple sampling scheme. In the case of qualitative properties (e.g. share of stands rated by the natural development stages), the fraction and the fractional error were calculated based on the number of sample plots with the given property in relation to the total number of sample plots (Zöhrer 1980). The assessment of the accuracy of results was provided with statistical significance α=0.05.

Results

The average merchantable timber yield of trees in the Białowieża National Park was 383 m^3/ha (Table 1). That result was estimated with an error of ±20 m^3/ha, i.e. ±5%.

The average stand density with regard to trees featuring merchantable timber volume ($d_{1.3}$≥8 cm) was 515±29 pcs/ha, i.e. ±6% (Table 1). The average stand density with regard to all trees, including self-sown seedlings (h<0.3 m) and ticket (h=0.3–1.3 m or $d_{1.3}$<8 cm) was 12,910±1,804 pcs/ha (Table 2).

The tree frequency curve had the form of a one-sided curve (Fig. 1). The tree survival rate in diameter levels was q=0.86. On that basis, stands of the Białowieża National Park were rated as a crop development stage. The most numerous were self-sown seedlings – 8,074 pcs/ha (Table 2). The second numerous were saplings – 4,321 pcs/ha. The diameter at breast height of dominant trees was d_{250}=38 cm. The largest diameter at breast height measured on sample plots was d_m=154.5 cm. The yield curve in diameter classes had a different form than the frequency curve (Fig. 2). Trees from medium size classes dominated.

In the stands of the Białowieża National Park, 13 tree species occurred (Table 3). Norway spruce *Picea abies* L. had the highest share in the total yield. A high share (over 5%) was also observed in the case of common oak *Quercus robur* L., European hornbeam *Carpinus betulus* L., black alder *Alnus glutinosa* Gaertn., small-leaved linden *Tilia cordata* Mill., European ash *Fraxinus excelsior* L. and Scots pine *Pinus sylvestris* L. The group of species with low share (1–5%) was composed of birch species *(Betula pendula.* Roth., *Betula pubescens* Ehrh.), Norway maple *Acer platanoides* L. and aspen *Populus tremula* L. The remaining tree species with a share lower than 1% were classified as sporadic. They were represented by wych elm *Ulmus glabra* Huds., willow species *Salix sp.* and rowan *Sorbus aucuparia* L. Crantz. The species composition calculated on the base of the stand density was slightly different (Table 3). Spruce had the highest share in the total number of trees. Hornbeam and linden had a significant share (much higher than the one calculated based on yield). The share of oak in the total number of trees was very low. The species composition calculated on the base of the fraction of sample plots with the given dominant species was also different (Table 3). The share of spruce and oak stands was high. Pine, alder and hornbeam stands had a similar, high share.

TABLE 1

Yield and density of trees featuring merchantable timber volume (in breast-height size classes) in the Białowieża National Park

Species	Unit	Yield and density of trees in breast-height diameter classes – $d_{1.3}$ (cm)												Total	Share
		8–11.9	12–19.9	20–27.9	28–35.6	36–47.9	48–59.9	60–71.9	72–87.9	88–103.9	104–119.9	120–139.9	140–159.9		(%)
Spruce	m³/ha	1.1	4.9	10.2	16.8	21.8	18.3	14.1	4.5	0.4				**92.2**	**24.1**
	pcs/ha	38.3	41.1	25.8	19.3	13.1	5.9	2.7	0.6	0.04				**146.8**	**28.5**
Oak	m³/ha		0.1	0.3	1.2	4.8	7.4	8.0	10.7	9.4	17.0	11.1	2.9	**73.0**	**19.1**
	pcs/ha		1.2	0.8	1.2	2.3	2.0	1.3	1.2	0.7	0.9	0.5	0.1	**12.2**	**2.4**
Horn-beam	m³/ha		1.2	3.6	5.3	10.9	14.7	9.3	2.5	0.5				**47.9**	**12.5**
	pcs/ha		45.6	31.7	13.6	14.4	10.1	3.6	0.6	0.1				**119.4**	**23.2**
Alder	m³/ha	0.5	1.3	2.9	6.1	11.6	8.9	7.3	0.4	1.0				**40.0**	**10.4**
	pcs/ha	13.9	10.2	6.6	6.8	6.6	2.8	1.4	0.04	0.1				**48.4**	**9.4**
Linden	m³/ha	0.5	3.0	6.0	7.3	3.5	1.7	2.5	7.6	4.3	3.3			**39.7**	**10.4**
	pcs/ha	30.9	27.2	16.3	8.6	2.4	0.5	0.5	0.9	0.4	0.2			**87.9**	**17.1**
Ash	m³/ha	0.03	0.5	0.9	1.4	5.2	8.4	7.9	4.9	0.5	0.7			**30.4**	**7.9**
	pcs/ha	1.3	3.7	1.9	1.4	2.5	2.4	1.3	0.6	0.04	0.04			**15.2**	**2.9**
Pine	m³/ha	0.05	0.2	1.6	4.1	5.9	8.7	4.6	1.5	0.9				**27.6**	**7.2**
	pcs/ha	2.2	1.5	5.0	6.0	3.8	2.9	0.9	0.2	0.1				**22.6**	**4.4**
Birch	m³/ha	0.4	2.0	2.8	2.2	2.8	1.8	0.6						**12.6**	**3.3**
	pcs/ha	13.9	20.2	8.6	2.7	1.8	0.6	0.1						**47.9**	**9.3**
Maple	m³/ha	0.01	0.01	0.1	1.2	2.7	2.7	2.3	1.9					**10.9**	**2.8**
	pcs/ha	0.4	0.2	0.3	1.1	1.4	0.9	0.4	0.2					**4.9**	**0.9**

Species	Unit	Yield and density of trees in breast-height diameter classes – $d_{1.3}$ (cm)												Total	Share
		8–11.9	12–19.9	20–27.9	28–35.6	36–47.9	48–59.9	60–71.9	72–87.9	88–103.9	104–119.9	120–139.9	140–159.9		(%)
Aspen	m³/ha		0.01	0.3	0.4	1.3	2.6	1.2	0.8	0.7				**7.2**	**1.9**
	pcs/ha		0.1	0.8	0.4	0.6	0.7	0.2	0.1	0.1				**3.0**	**0.6**
Wych elm	m³/ha		0.05	0.1	0.4	0.2	0.2							**0.95**	**0.2**
	pcs/ha	1.7	1.2	1.2	0.2	0.1								**4.4**	**0.9**
Willow	m³/ha	0.1	0.1	0.1										**0.3**	**0.1**
	pcs/ha	1.0	0.6	0.2										**1.8**	**0.3**
Rowan	m³/ha	0.01												**0.01**	**0.1**
	pcs/ha	0.1												**0.1**	**0.1**
Total	**m³/ha**	**3.8**	**15.9**	**30.9**	**51.9**	**74.5**	**69.6**	**51.2**	**32.8**	**17.2**	**21.0**	**11.1**	**2.9**	**3,112.8**	**100**
	pcs/ha	**148.3**	**139.3**	**81.3**	**62.1**	**44.8**	**22.3**	**9.4**	**3.9**	**1.5**	**1.2**	**0.5**	**0.1**	**514.7**	**100**

TABLE 2

Density of trees ascribed to layers of stands of the Białowieża National Park and maximal diameter at breast height per species

Species	Density					Maximal breast height diam. d_{10ha}
	seedlings (h<0.3 m)	saplings (h≥0.3 m and $d_{1.3}$<8 cm)	trees $d_{1.3}$≥8 cm	all trees	share	
	pcs/ha				%	cm
Spruce	958	222	146.8	1327	10.3	87
Oak	86	56	12.2	154	1.2	139
Hornbeam	4275	1786	119.4	6180	47.9	72
Alder	20	146	48.4	215	1.7	82
Linden	127	384	87,9	599	4.6	110
Ash	950	710	15.2	1675	13.0	92
Pine			22.6	23	0.2	86
Birch	90	188	47.9	326	2.5	64
Maple	1146	125	4.9	1276	9.9	79
Aspen	131	295	3.0	429	3.3	79
Wych elm	70	73	4.4	147	1.1	37
Willow		62	1.8	64	0.5	37
Rowan	221	273	0.1	494	3.8	
Total	8074	4321	514.7	12910	100	

The interpretation of the species composition by share in size classes is difficult. This is caused by differences in maximal dimensions achieved by particular species (Table 2), their different growth paces and the development strategies. The properties of species are overlaid by the impact of many external factors, both with the ecosystemic (selective game browsing, natural ecological processes) and global (climate changes) range. Spruce had a relatively uniform share in the class of very thin ($d_{1.3}$=8.0–19.9 cm), thin ($d_{1.3}$=20.0–35.9 cm) and medium ($d_{1.3}$=36.0–71.9 cm) trees (Fig. 3). In the class of thick ($d_{1.3}$=72.0–87.9 cm) and very thick ($d_{1.3}$=88.0–160.0 cm) trees, its share was decreasing. In the layer of self-sown seedlings and in the saplings, there was a relatively small number of spruces. The share of oak in size classes was atypical – the higher the diameter at breast height the higher the share was, accompanied by nearly complete absence in the layers of self-sown seedlings and saplings, and in the classes of very thin and thin trees. The expansion of hornbeam in the recent period was evidenced by its share that was increasing simultaneously with decreasing tree dimensions. Linden and ash were species featuring a significant split into two generations. Pine was absent in the layers of self-sown seedlings and in the saplings layer. That species had also a low share in the class of very thin trees, which proved its declining. The share of alder in size classes took a similar shape. The decline from stands, after a short period of numerous renewal, may also be assumed in the case of birch, maple, and aspen. Only a small part of wych elm trees grew to medium dimensions.

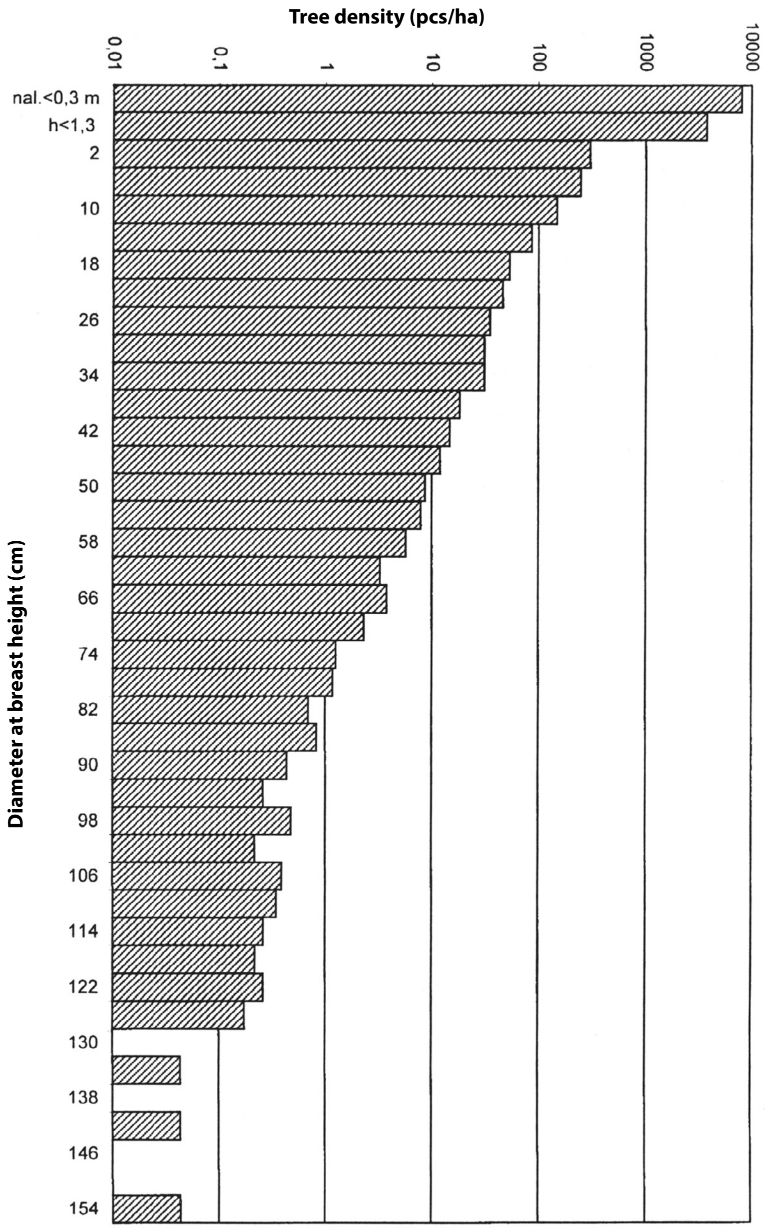

Fig. 1.
Tree density in size classes in the Białowieża National Park (self-sown seedlings h<0.3 m, saplings h=0.3–1.3 m; for trees featuring diameter at breast height the tree density was provided for 4 cm wide classes)

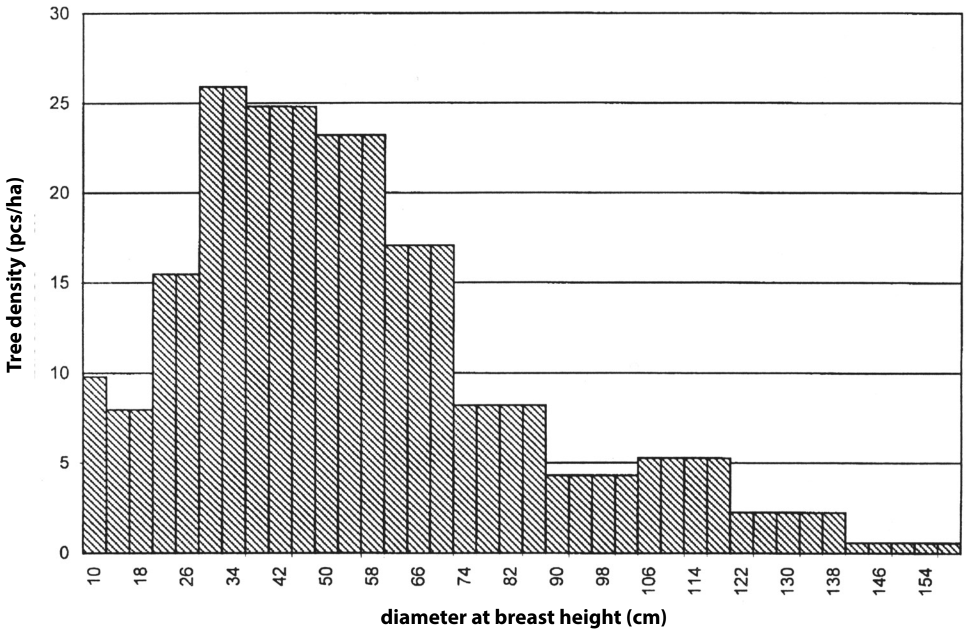

Fig. 2.
Yield of merchantable timber in breast-height size classes in the Białowieża National Park

In the Białowieża National Park, all natural development stages of stands were distinguished (Fig. 4). The ageing early stage was the most numerous, which accounted for 22.4±2.0% of the area, while the selection stage was the least numerous, at 0.4±0.3%.

The mean aggregate crown projection was 73%, while the most stands had a crown projection of 80%. A large span of the latter feature occurred: from 10 to 100% (Fig. 5). With regard to the stand stratification, single-, two- and three-layered stands were distinguished. The highest share was accounted for by two-layered stands – 56.1±2.3%, the share of three-layered stands amounted for almost a half of it – 26.7±2.1%, while single-layered stands had the lowest share – 17.2±1.8%. The greater the number of layers in a stand, the lower the crown projection of the overstorey (Fig. 6). As an example of adoption of inventory data to explain environmental principles, the calculation of the relation between the crown projection of the first layer [overstorey] and the crown projection of the second and third layer can be used (Fig. 7).

The mean coverage of woody debris in stands of the Białowieża National Park was 10.7% and most frequently up to 5% (Fig. 8). Almost 90% of stands had a cover of woody debris, but to an extent not exceeding 55%.

TABLE 3

Species composition by volume, tree density and area of dominant species in stands of the Białowieża National Park and comparison of the results obtained in this study (state as of 1995) to the results obtained during forest management planning works (state as of 1991)

Species	Species composition							
	by volume of actual species			by area of dominant species			by density	
	in 1991 share (%)	in 1995 share (%)	in 1995 error in share	in 1991 share (%)	in 1995 share (%)	in 1995 error in share	in 1995 share (%)	in 1995 error in share (%)
Spruce	24.2	24.1	±2.4	16.6	23.9	±2.0	28.5	±3.3
Oak	17.9	19.1	±3.4	19.6	17.4	±1.8	2.4	**±0.4**
Hornbeam	10.9	12.5	±1.5	18.9	10.0	±1.4	23.2	**±2.9**
Alder	12.6	10.4	±2.3	11.6	10.0	±1.4	9.4	±2.2
Linden	7.9	10.3	±1.9	4.5	8.5	±1.3	17.1	±2.6
Ash	8.2	7.9	±2.4	6.0	7.2	±1.2	2.9	±0.7
Pine	9.1	7.2	±2.0	11.3	11.1	±1.5	4.4	±1.3
Birch	4.0	3.2	±0.8	6.0	7.2	±1.2	9.3	±2.6
Maple	3.8	2.8	±0.9	4.0	2.4	±0.7	0.9	±0.3
Aspen	1.4	1.9	±1.0	1.5	2.2	±0.7	0.3	±0.3
Wych elm		0.2	±0.1				0.9	±0.4
Willow	0.002	0.08	±0.08		0.2	±0.2	0.3	±0.3
Rowan		0.002	±0.004				0.02	±0.04

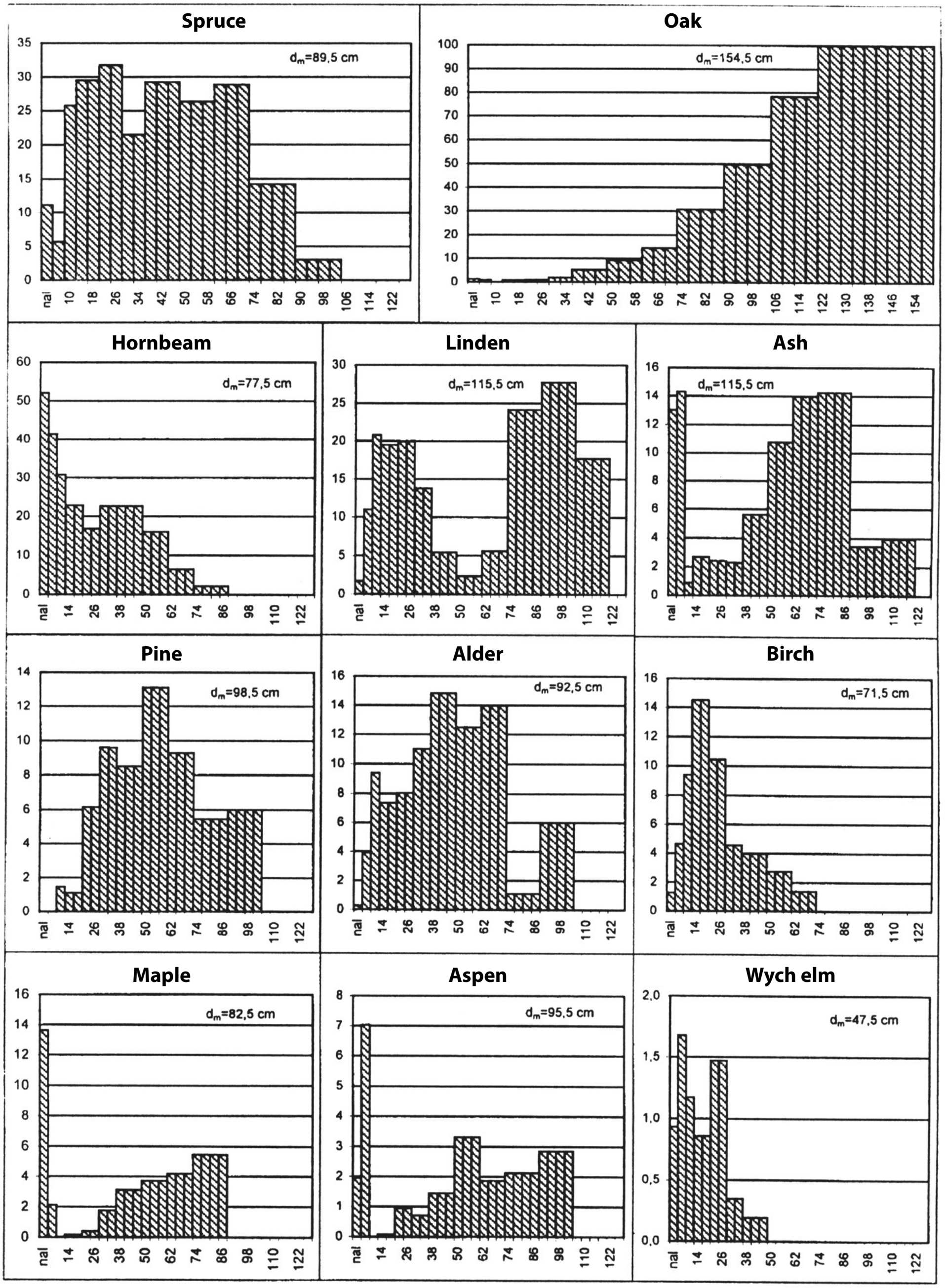

Fig. 3.
Share of trees of particular species in size classes in the Białowieża National Park (indications of size classes: self-sown seedlings h<0.3 m, saplings h=0.3–1.3 m or $d_{1.3}$<8 cm, and further on breast-height size classes 4 cm wide; the OY axis shows the share of a species in a given dimension class, d_m – maximal diameter at breast height measured on sample plots; for all species, except of oak, the share is given for breast-height diameter range up to 128 cm)

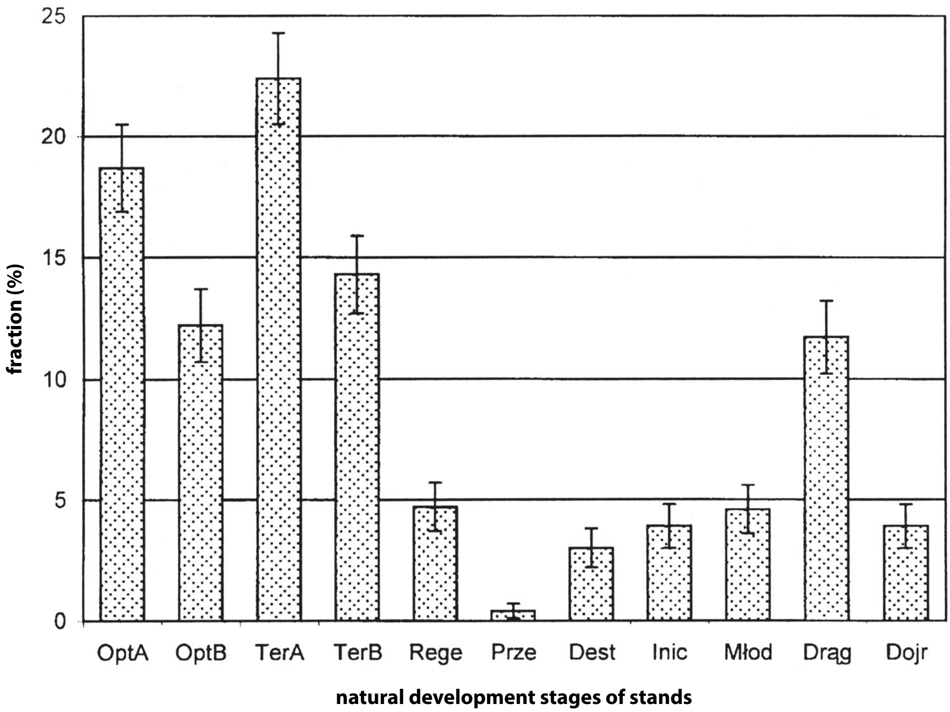

Fig. 4.
Fractions of stands ascribed to the particular natural development stages in the Białowieża National Park. (explanation of symbols: OptA – optimal early, OptB – optimal late, TerA – ageing early, TerB – ageing late, Rege – regeneration, Prze – selection, Dest – destruction, Inie – initiational, Młod – young, Drąg – even-aged pole stand, Dojr – even-aged pre-mature stand; error values given for α=0.05)

Discussion

The importance of the results obtained in this study may be considered as:

- proposal of a thematic scope and method of collecting necessary data or data desired for a forest ecosystem protection plan of a national park,
- presentation of original, or to certain extent even acquired for the first time, data characterising the strict protection area of the Białowieża National Park.

A large-scale survey of national park forests as one large unit, at most divided into more than a dozen interpretative units, has already been known from studies for other ranges – the Bieszczady National Park (Przybylska, Kucharzyk 1999) and the Gorce National Park (Chwistek 2000). In the Białowieża National Park, just like in the mentioned ranges, the measurement works were limited to several hundred sample plots for the benefit of a larger number of measured features. That allowed a multilateral interpretation of the state

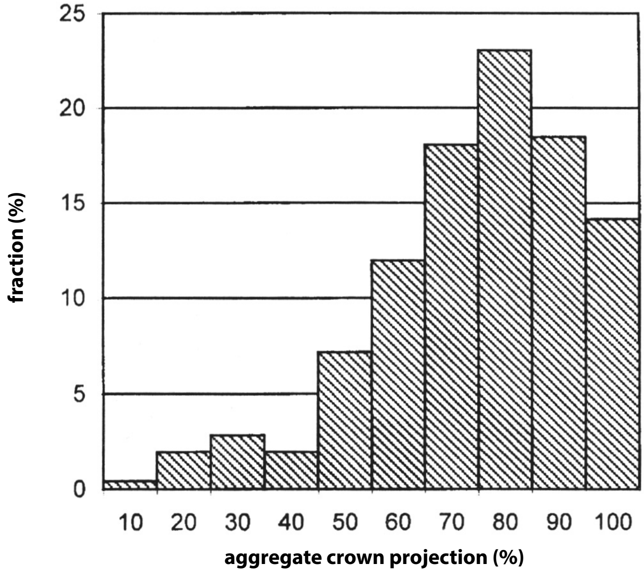

Fig. 5.
Fractions of stands in classes of aggregate crown projection in the Białowieża National Park

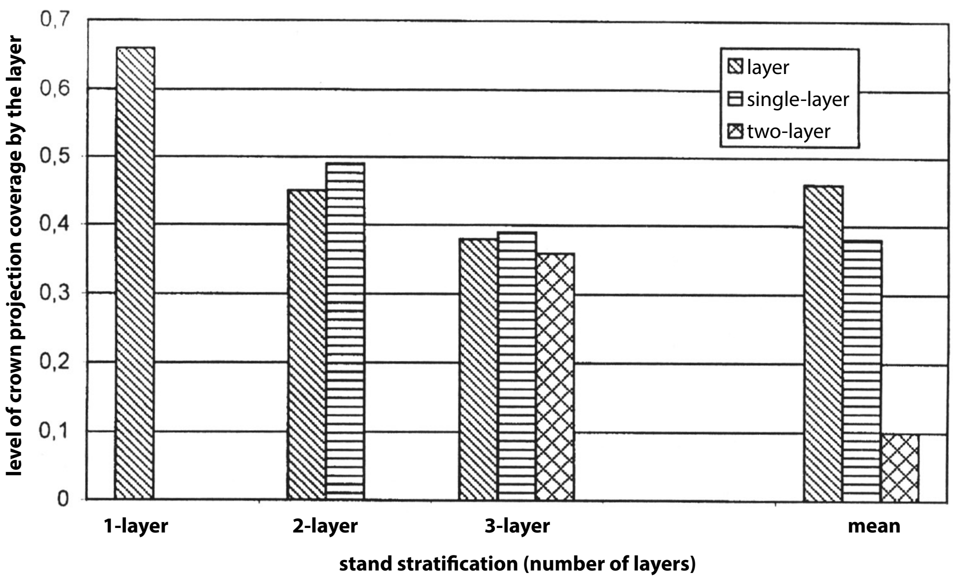

Fig. 6.
Mean coverage by particular tree layers depending on the stand stratification in the Białowieża National Park

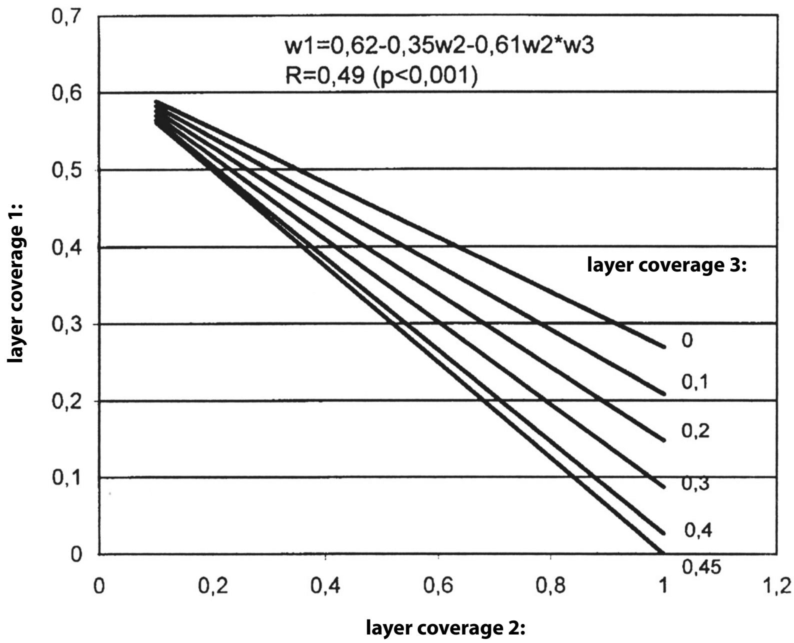

Fig. 7.
Relation between the coverage of the first tree layer (w1) and the level of coverage of the second (w2) and third (w3) layer in stands of the Białowieża National Park

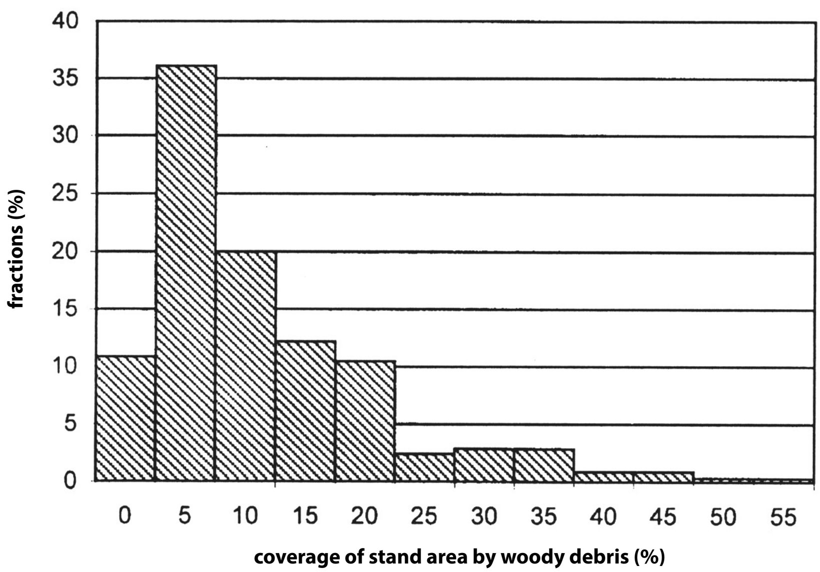

Fig. 8.
Fractions of stands in classes of area coverage by woody debris in stands of the Białowieża National Park

of the park's forest – apart from the traditionally distinguished parts of trees due to the merchantable timber criterion, also concerning trees ascribed to the renewal. Due to the experimental nature of the works, the sample plots were not established as permanent control plots. However, the obtained results are identical to those collected at the first attempt at measurements for a permanent inventory.

In terms of results completely new for the Białowieża National Park were those concerning tree density (including self-sown seedlings and saplings), dimension structure of trees (including maximal dimensions), species composition with consideration of tree dimensions, coverage of stand area by woody debris, vertical and horizontal structure of stands (number of layers, level of coverage), and share of stands ascribed to particular development stages. Due to the large number of new results, it seems interesting to compare the yield and species composition by the volume or share in area of the stands of the Białowieża National Park obtained in this study to the data collected under forest management planning works according to their state as of 1991 (BULiGL, 1992).

During those works, according to the Forest Management Planning Instruction (MLiPD, NZLP 1980), 5,460 relascopic sample plots were established, randomly and by choice. It was calculated that the yield in the then strict reserve was 410 m^3/ha (determined with a mean percentage error of ±0.60%). Thus, the accuracy of estimation was higher than in this study, which resulted from the number of sample plots being more than ten times larger. Both results concerning the yield differ from each other (t=2.54*). The reasons for this discrepancy may be divided into two categories. The first of them is the use of other yield tables (the assumption of a different threshold of diameter at breast height for the calculation of merchantable timber changes the result sparsely – moving this threshold from 8 to 7 cm increases yield by 0.43 m^3/ha). The second reason is probably a decrease in growing stock in the period 1991–1995, in particular as a result of spruce dieback after infestation by European spruce bark beetle in 1994.

A comparison of species composition (by volume) calculated in this study with the species composition established during the forest management planning works indicates that in the latter no rare species were distinguished: wych elm and rowan (Table 3). However, differences in the share of particular species were small and did not exceed 2.5%. While calculating the species composition by areas occupied by dominant species in a stand, willow (apart from wych elm and rowan) was not distinguished during the forest management planning works (Table 3). A comparison of that species composition with the composition established by fractions of dominant species (in that research) displayed large differences, which were largest for the share of spruce and hornbeam. The reason was a different method to determine the dominant species – in the entire stand (in forest management planning works) or at the location of the established sample plot (in that research). In the second case, in a mosaic forest structure, a higher share was estimated for species occurring in the form of a grove mixture.

Some results obtained here may be compared with the results of studies on permanent sample plots (Bernadzki et al. 1998). After many years of successive measurements, an expansion of deciduous species (linden, hornbeam, ash), a decline of spruce and heliophilous species (pine, alder, birch), and a stabilisation of the position of oak were observed. It mostly corresponds with the interpretation of the species composition with consideration of the tree dimensions performed here. The discovery of a 'linden-less period' – expressed as a very low share of trees of medium thickness, is attention-grabbing. The results concerning the retreat of pine are convincing – this species is absent in the self-sown seedlings and in the saplings layer. The oak situation should be interpreted differently than in the paper by Bernadzki et al. (Bernadzki et al. 1998). A very low share in the renewal and in the classes of very thin, thin, and medium thick trees may appear to be insufficient for the maintenance of this species' population.

It should be emphasised that this paper presents only a part of the results concerning the large-scale survey of stands of the Białowieża National Park. The remaining results concerning, for example, a detailed assessment of the forest renewal, means that stands classified by natural development stage require separate preparation.

Conclusions

- For the assessment of the state of forest in a national park it is recommended to perform measurements on several hundred sample plots. It permits basic results to be obtained (growing stock, species composition), being equivalent, with respect to the interpretation, to the results previously gathered in a stand-based data collection system.
- The measurement of multiple features on sample plots significantly increases the scope of information on national park stands. Apart from features concerning the trees rated as merchantable timber, features concerning the forest structure, state of renewal, tree damage and forest dynamics are also referenced.
- The measurements performed on 460 sample plots in the Białowieża National Park allowed the gathering of many results describing the strict protection area, so far unknown in the literature. It is recommended that such a number of sample plots should be established as permanent sample plots. It would enable to successively follow the development of the forests in the Białowieża National Park and would extend the knowledge about this domain.

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The use of the Białowieża Forest during the Jagiellonian dynasty and its traces in the contemporary forest environment

Introduction

The form of the modern environment is a resultant of two factors – natural and abiotic environmental processes and the history of human impact on the environment. Historical data may have great significance to achieve a full understanding of the state of environment observed today. This is particularly clearly visible based on the example of a unique natural monument – the Białowieża Forest, where fragments of the primeval forest have survived thanks to centuries of planned conservation.

This paper aims at the collection and analysis of available source data concerning the utilisation of the Białowieża Forest in the Jagiellonian era, i.e. the almost 200 years of reign by that dynasty in Poland (1386–1572) and at the discussion on the impact of their conduct on the present state of the forest. This period is the first one for which we have written sources concerning the protection and conservation of the Białowieża Forest. It is also a period of the formation of a general forest policy in the Grand Duchy of Lithuania. The forest entered the sphere of influence of the great dukes of Lithuania in the 13th century. A settlement was present there even earlier, which was evidenced by several Slavic burial sites from the 10th–12th century (Samojlik, Jędrzejewska 2003).

Throughout the entire rule of the Jagiellonian dynasty, the Białowieża Forest continued to be a constituent part of the Grand Duchy of Lithuania and only its affiliation with voivodeships changed. In the age of the Jagiellonian dynasty, it belonged to the royal domains, which then also meant the sovereign's and the state's treasury. Only after 1589 were the public and the king's treasury separated from each other. Then the Białowieża Forest was incorporated into the king's private estate, thus becoming the source of income to the private treasury of subsequent monarchs. In the 16th century, the Grand-Ducal properties constituted approx. 30% of the entire land property in the Grand Duchy of Lithuania (Sahanowicz 2002).

The forms of management of the Białowieża Forest in the Jagiellonian times can be divided into: 1) royal hunting, 2) gentry's *wchody* [access rights – Ed.], and 3) non-timber utilisation by royal servants. The issue of hunting and of conservation of the Białowieża

Forest during the Jagiellonian dynasty shall be the subject of a separate study. This paper focuses on the gentry's *wchody* rights and on the non-timber utilisation of the forest by 'royal people', attempting to answer the following questions: What were the non-hunting forms of exploitation of the Białowieża Forest in the 15th and 16th centuries? How did the utilisation affect the form of the Białowieża Forest environment? Is it possible to see remnants of the 15th- and 16th-century economy in the forest ecosystems today?

Material and methods

An analysis of the forest's environmental state in the times of the Jagiellonian dynasty was conducted on the base of a reconstruction of Central Poland's climate over the last millennium (Maruszczak 1999) and palynological studies conducted in the Białowieża National Park (Borowik-Dąbrowska, Dąbrowski 1973; Borowik-Dąbrowska 1976; Mitchell, Cole 1998). The research by Mitchell and Cole (1998), due to the sufficiently numerous dating of profile samples by the ^{14}C method, allowed the plotting of changes in the forest cover on a time scale. The geographical range of the Białowieża Forest in the 15th and 16th centuries was reconstructed thanks to the data from the work by Hedemann (1939), with papers by Michaluk (1997) and Kołodziejczyk et al. (2001) also were used.

For the reconstruction of the methods of utilisation of the Białowieża Forest, the document *Revizya pushch i perehodov zverinyh v byvshem Velikom Knyazhestve Litovskom* written in 1559 by G. Wołowicz (published in Vilnius in 1867, further referred to as *Revizya pushch… 1559*) and historical documents quoted by Łowmiański (1923–1924), Kolankowski (1927) and Hedemann (1936, 1939) were used. The *wchody* [access rights] to the forest were subject to a detailed analysis. According to Łowmiański (1923), 'the right of entry to the woods, fishery, hunting and beekeeping was generally known as *wchody* in Lithuania, with the same term being applied to the objects of use'. Granting a *wchód* [singular form of *wchody*] to someone meant that the primeval forest owner waived his rights to strictly specified areas of forest utilisation and to the income resulting from that utilisation. Simultaneously, the ownership right to the primeval forest being the object of use did not change, thus '*wchody* take a specific form of a [possession] right over somebody else's ownership' (Łowmiański 1923). The *wchody* constituted a hereditary right, while the *wstępnik* [user] might have been a nobleman, town, or the Orthodox or Catholic Church.

The legal force of *wchody* to royal primeval forests and lakes underwent verification during the agrarian reform ('*volok* [land] measurement'), which was the fullest expressed in the Act on Voloks of 1557. The Act on Voloks stated: 'the gentry and their subjects have *wstępy* and *wchody* [entry and utilisation rights] together with the subjects of ourselves' (Hedemann 1939). In 1559, the *wchody* to the Białowieża Forest were subjected to a verification by Grzegorz Wołowicz, the Mścibogów staroste. In general, based on

Revizya pushch… and sources quoted by Hedemann (1939), 44 *wchody* were identified in the 16th-century Białowieża Forest, of which 40 could be located on a map (91%). In the case of 33 *wchody* (75%), the sources included information on the type of activities conducted there. For 28 *wchody* (64%), it was possible to locate the estate possessing the entry right to the forest.

The remaining documents do not reflect the full state of *wchody* of the royal servants to the forest – they are mentioned only when they overlap with the *wchody* [rights] of the gentry or bourgeoisie and are used together (*suderew*) by *wstępnicy* [users] and the forest service.

Results

Climate and spatial range of the Białowieża Forest in the 15th and 16th centuries. After the medieval warming period with its optimum in the years 1100–1200, the climate started to cool. The mean temperature for central Poland in the period of interest, i.e. the 15th and 16th centuries – was 7.1°C, which was approx. 0.5–1°C less than the contemporary mean. The early Middle Ages were also described with a high climate humidity, which rapidly decreased in the years 1250–1300. All Białowieża-related palynological studies show that throughout the second millennium the share of forest tree and shrub pollens did not decrease below 85–95% of all pollens, which indicated a very high level of forest cover (Borowik-Dąbrowska, Dąbrowski 1973; Mitchell, Cole 1998).

In the 15th and 16th centuries, the Białowieża Forest was connected with the territories of neighbouring primeval forests: Jałówka, Świsłocz, Szereszów, Kamieniec, Tokary, Bielsk and Narewka (Fig. 1). Among all of them, only the Białowieża Forest and the Kamieniec Forest had the status of a royal forest, while the others were in private hands or constituted the object of exploitation exercised by towns, and by the 15th and 16th centuries already their afforested areas were quickly declining. When comparing the reconstructed range of the Białowieża Forest in the 16th century with the present state (Fig. 1), it may be stated that the present borders of the forest have moved significantly to the north due to the administrative incorporation of the Świsłocz Forest (in the 19th century) and the Ladzka Forest (the remainder of the Bielsk Forest, in the 20th century) into its boundaries. Due to deforestation, the present forest is reduced in its southern areas (by the Rivers Sipora and Biała). In the 15th and 16th centuries, the Białowieża Forest covered an area of approx. 1,800 km^2. The overlapping part of the former and present forest constitutes 62% of its area in the 16th century. Within its modern administrative borders, the Białowieża Forest covers approx. 1,500 km^2 (Jędrzejewska, Jędrzejewski 2001).

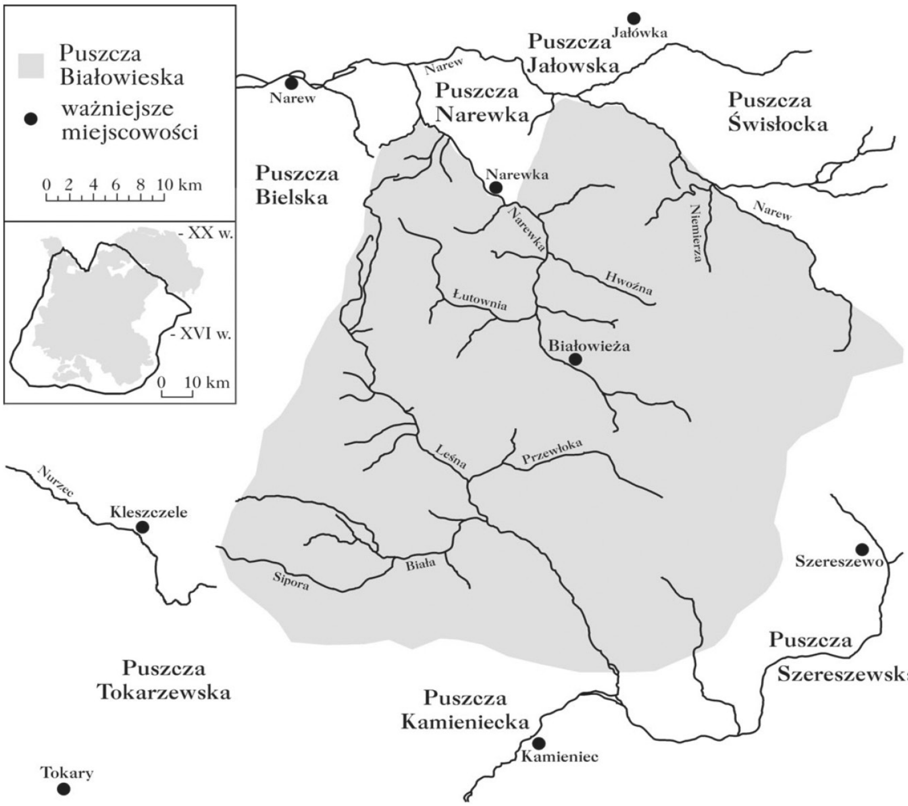

Fig. 1.
The Białowieża Forest in the 15th and 16th centuries and primeval forests neighbouring. An outline of the modern borders of the Białowieża Forest is presented in a smaller scale against its range in the 15th and 16th centuries
[*Puszcza Białowieska* – Białowieża Forest; *ważniejsze miejscowości* – major localities; *XX w.* – 20th century; *XVI w.* – 16th century; *Narew* – Narew River; *Puszcza Bielska* – Bielsk Forest; *Puszcza Narewka* – Narewka Forest; *Puszcza Jałowska* – Jałówka Forest; *Puszcza Świsłocka* – Świsłocz Forest; *Puszcza Tokarzewska* – Tokary Forest; *Puszcza Kamieniecka* – Kamieniec Forest; *Puszcza Szereszewska* – Szereszów Forest]

Methods and scope of utilisation of the Białowieża Forest. In the times of the Jagiellonian dynasty, haymaking appearing in 27 *wchody (*82% of the total number of identified *wchody* – Table 1) was the most important *wchody* privilege concerning the Białowieża Forest. It enabled a user to periodically gather hay from the primeval forest meadows. The hay was often stored in the form of large haystacks left on the mown meadows until winter or even spring. Two types of haymaking *wchody* were identified: *błotne* [muddy] – i.e. by rivers and in river valleys and *dubrowne* [oak wood] – in oak woods, i.e. in the forests of oak-hornbeam type with a high share of old oak trees. By rivers haymaking occupied the largest areas. It usually covered several voloks (i.e. several dozen hectares), and sometimes its volume was estimated by the number of haystacks (usually 30–50). Files from the mid-16th century (e.g. 1557–1567, Hedemann 1939) document process of establishing and/or extending the hay meadows. The royal commissioners were conducting *wymorgowanie* [derived from the term *morga*, a historical area unit in the medieval Poland equal to 0.5755 ha], i.e. the demarcation and measurement of lands overgrown with grey willow and birch in river valleys and lands in oak woods for future meadows.

On some haymaking *wchody* (on 8 sites in total, 15% of *wchody*, only haymaking), the *wstępnicy* [users] were entitled to construct *izby* [shelters] or keep livestock on hayed meadows in winter (Table 1). The shelters were probably small wooden cottages raised as temporary place to stay for people working on *wchody*. The need for having such type of shelter resulted from the straight-line distance of a *wchody*-estate from the *wchód* [entry] into the forest of 5 km to 55 km, an average of 27 km.

TABLE 1
Different kinds of access rights to the Białowieża Forest in the 16th century at 33 locations with a known scope of activity

Permitted activity	Number of *wchody*	Percentage of *wchody*
Haymaking	27	82
Honey trees	24	73
Construction of weirs and fishing in rivers	13	39
Construction of shelters in *wchody*	5	15
Construction of ponds ('lakes') by rivers	4	12
Keeping livestock on hayed meadows in winter	4	12
Farmsteads	2	6
Tree cutting for own requirements[1]	2	6
Hunting[2]	1	3
Settling down of peasant population[2]	1	3

The hay-making *wchody* with the right to establish sites for livestock, i.e. keeping the livestock on the *wchody*-estate in winter accounted for 12% of the total number of *wchody* (Table 1). From today's perspective it is hard to determine the motivation of *wchodnicy* [users] to keep their livestock on the *wchody* in the forest. Maybe the costs and technical

[1] The right granted by Sigismund I the Old and Bona Sforza d'Aragona only to the Orthodox and Catholic Church in Szereszów;

[2] The right for beaver chasing and hunting within their access areas (however with the exception for bison and red deer) and settlement of people was the competition of the Bracaw castle governor Andrzej Kapusta, however they possibly were not executed, but rather served as an argument during the 1571 action. Formally – Act on Voloks of 1557 cancelled the both rights.

difficulties related to the transport of several dozen haystacks to the estate or farmstead were higher than driving a cattle herd and leaving it for the winter on the *wchody*.

The wild beekeeping *wchody*, products of which included honey and wax, were the second most important ones (73% of all *wchody*, 24 sites in the forest – Table 1). Pines were commonly used as honey trees, oak trees less often, while spruce and linden only sporadically (Karpiński 1948).

The rivers and streams creating a complicated water system in the forest also constituted an important object of use. The right to construct weirs and to fish in the rivers of the forest appeared at 13 *wchody* locations (39% of the total number of *wchody* – Table 1). The weir was a dam on a river raised by ramming stakes into the river bottom across its entire width, entwined with branches to allow the free movement of the fish. Such a dam had a small gap in the middle, covered with a special net, called *norot* (Hedemann 1939). Sometimes, the weir construction was associated with the right to 'build lakes' by rivers, i.e. to create artificial, probably small-sized ponds (12% of *wchody*, 4 sites – Table 1). In the 16th century, weirs existed on the Biała, Narewka, Narew, Leśna, Przewłoka and Niemierza Rivers, while ponds on the Biała, Narewka, Narew and Leśna Rivers (Fig. 2 and Table 2).

Dworzyszcza [farmsteads], found on two *wchody* (6% of all *wchody* rights – Table 1), were small, single-building settlements, also referred to as *sieliszcze* [derived from *sioło* – settlement]. They were a remnant of 'wild' colonisation on the so-called *żerebia* [singular: *żerebie*, derived from the early-medieval term *źreb* meaning grounds belonging to one homestead] from the period prior to the Volok Reform (Hedemann 1939).

It should be emphasised that the right to cut down trees in the Białowieża Forest was granted only in two cases, by Sigismund I the Old in 1521 to the Orthodox Church in Szereszów and in 1537 by Queen Bona Sforza to the Szereszów Catholic Church. Both churches were provided with the right to cut down trees for their own needs (Table 1). In 1559, no *wstępnik* [user] had the right to hunt or to settle a peasant population on *wchody*. Still, in 1571, Andrzej Kapusta, the Bracław chatelaine, possessed the right to hunt beaver and game on his *wchody* (except deer and bison) (Hedemann 1939), thus this type of activity was included in Table 1.

A comparison of the number of activity types on 33 *wchody* with the known scope of rights (Table 3) demonstrates that only in 24% of *wchody* were the *wchodnik's* rights limited to one form of forest use. On more than three-quarters of *wchody*, two or more forms of the forest use were combined. Usually haymaking, wild beehive keeping and freshwater fishery were connected. The entitled *wstępnik* (n=16 natural or legal persons) had from one to four *wchody*, while exceptionally one person (chatelaine Kapusta) had nine *wchody*. On average, one *wstępnik* had 2.8 *wchody* (SD 2.0).

The rights granted to royal subjects constitute a separate group. The estimation of the scope and number of 'royal people's' *wchody* is difficult due to missing data – no registers of them have been left, apart from cases of a record of the joint use of the same *wchody* (defined in the source as *suderew* use) by *wstępnicy* testifying in 1559 before Wołowicz and by the forest service. It occurred on eight *wchody* (marked on Fig. 2), while on two of them haymaking and beehive-keeping were jointly used, on six only beehives, and on the two other only haymaking.

TABLE 2

Anthropogenic utilisation of river valleys in the Białowieża Forest in the 16th century

River (or swamp area)	Haymaking	Number of known sites		Cattle	Chambers
		Weirs	Ponds		
Biała	9	4	4	–	–
Narewka	7	4	1	2	1
Narew	6	4	1	3	1
Leśna (formerly Lsna, Lsnica)	3	2	2	–	–
Przewłoka	3	1	–	–	–
Niemierza	2	2	–	–	–
Tuszemla	1	–	–	–	–
Policzna	1	–	–	–	–
Sipora	1	–	–	–	-
Błota Nikor, Dikoje, Głęboki Kąt	5	–	–	1	1

TABLE 3

Number of activity types (see list in Table 1) allowable in one *wchód*, based on 33 *wchody* with a known scope of access rights

Number of various activity types	Number of *wchody*	Percentage of *wchody*
1	8	24
2	9	28
3	7	21
4	7	21
5	1	3
6	1	3

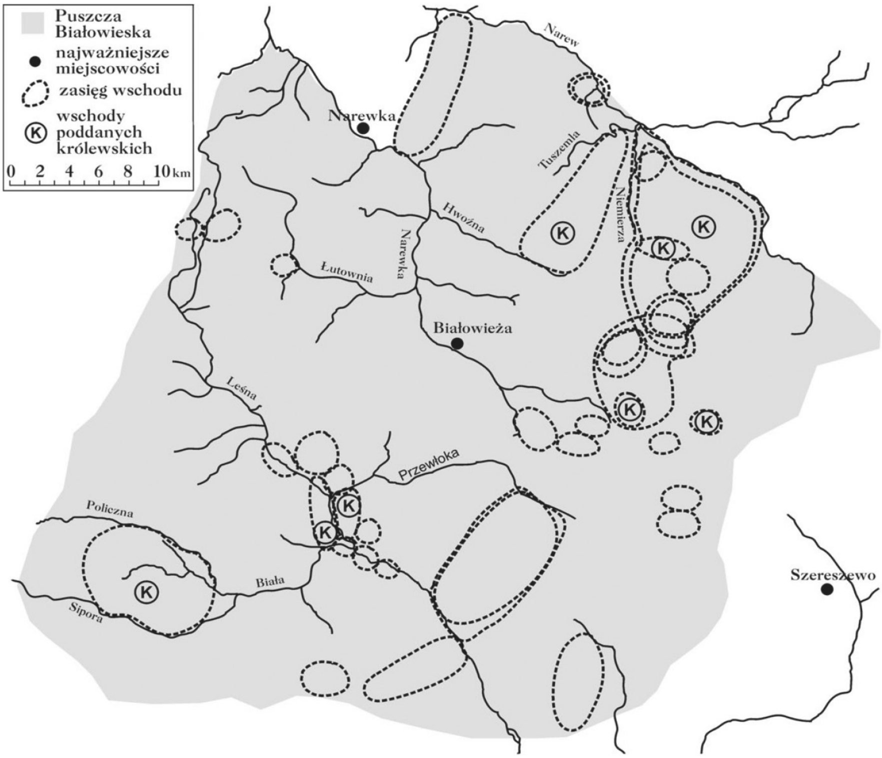

Fig. 2.
Distribution and approximate area of 40 *wchody* in the Białowieża Forest in the 15th and 16th centuries (from the total of 44 documented *wchody*), the rights to which were possessed by the gentry, and the Catholic and Orthodox Church, against the range of the forest. The marked *wchody* of royal subjects (only location, no size-related data) come from an unknown total number of this group of *wchody*
[*Puszcza Białowieska* – Białowieża Forest; *najważniejsze miejscowości* – major localities; *zasięg wchodu* – range of a *wchód; wchody poddanych królewskich* – *wchody* of royal subjects]

The 'royal people' used the forest in two ways: firstly, they were permitted to use its resources as an in-kind benefit for their service, secondly royal subjects were allowed to use forests to a limited extent, provided that they paid fees to the treasury. The forest service members had a guaranteed right to harvest timber for their own needs (without a trading right), collecting woody debris and snags to be used as fuel, and branch wood for fences, tearing bast (primitive shoes were made from linden inner bark), making woodsplint (for weaving baskets, boxes, sowers or even carts), torchwood, picking forest fruit, including blueberries, edible plants, medicinal (e.g. hogweed *Heracleum sphondylium* used also as leafy vegetable and a component of eau de vie bootlegged then), and farming (like hop) plants, as well as nuts, edible mushrooms and bracket fungi (Hedemann 1939).

It should be emphasised that in the 15th and 16th centuries in the Białowieża Forest, apart from the mentioned *wchody* right of the Catholic and Orthodox Church in Szereszów, no tree cutting or timber trade took place. A timber trade could not exist as there were no appropriate river transport routes. In the light of the analysed documents, in Hartmann's opinion that '(…) transport conditions were excellent as there were many floatable rivers, with the Narewka River system ahead' (Hartmann 1938). A number of weirs on the rivers of the forest (Table 2) shows that timber floating down the Narewka River was impossible in the forest, and more so by the Leśna River. There are also no data on the production of potash, birch tar and pine tar in the Białowieża Forest in the 15th and 16th centuries. Karcov's (1903) statement that the first pine tar manufactures [smokehouses] were already operating in the forest in 1567 was not reflected in the sources. That activity type, which was then illegal, was mentioned for the first time in 1591. Sigismund III Vasa complained about a forest warden from the Bielsk Forest that 'by crossing the ancient border between the Bielsk and the Białowieża Forest, '(…) he devastates this [Białowieża – TS and BJ] forest by the burning of forest products without our permission' (Hedemann 1939). The exploitation of bog iron did not cover the Białowieża Forest in the Jagiellonian times. The first reference to bog iron factories in the Białowieża Forest appeared in sources only in the year 1639 (Hedemann 1939).

The first information on mills on the forest's rivers come from the beginning of the 16th century. In the years 1527–1544, trouble occurred around the mills of the Kopeć family on the Sipora River (south-western edge of the forest). As a result of a report by the forest warden Tyszkiewicz and gamekeeper Pac, stating that that due to those millers 'zweru szkoda u Puszczy Karola Jeho Miłosty wełykaja se dejała' (Hedemann 1939), Sigismund I the Old ordered the burning down of the millers' settlements and the mills on the Sipora River. In 1559, none of the *wstępnicy* [users] presented a legitimation to set up and operate mills. This resulted probably from the lack of agricultural lands (cultivation of cereals) in the primeval forest areas. In 1639 there were already 11 mills in the forest (Hedemann 1939).

Impact of forms and scope of utilisation on the natural environment of the Białowieża Forest. The map of location of 40 out of 44 *wchody* possessed by the gentry, the Catholic Church, and the Orthodox Church and of 8 of an unknown number of *wchody* possessed by royal subjects and servants demonstrates that the use of the Forest in the 15th and 16th centuries was concentrated mainly in its southern and eastern part (Fig. 2). This results largely from the fact that *wchody* estates tended to be located towards the south and east Forest borders. In the northern, western and central part of the forest only a few *wchody* were located. Many of *wchody* on the fringes of the forest were located outside of today's administrative borders (Fig. 1).

In the natural landscape of the Forest, characteristic forest communities were distinguished by the populace already in the 16th century: *bory* (pine forests), *jełosmycz* (spruce forests), *grudy* (oak-hornbeam forests, oak forests), *olesy* (alder carrs and riparian forests)

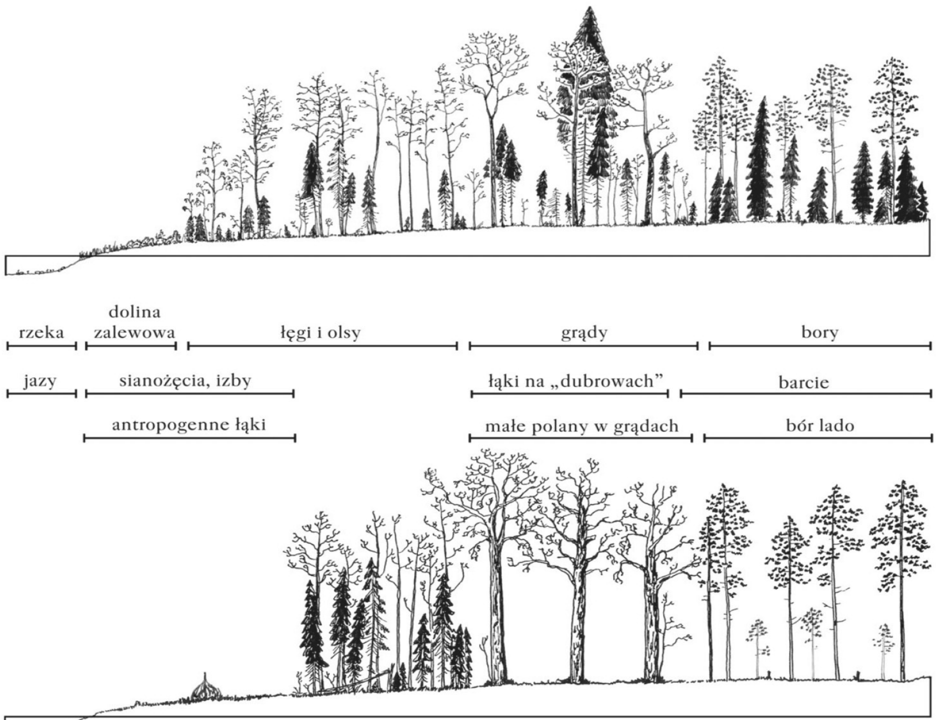

Fig. 3.
Types of utilisation of the *wchody* in the forest in the 15th and 16th centuries against the background of catena of forest communities and their potential impact on the environment of the Białowieża Forest
[*rzeka* – river; *dolina zalewowa* – floodplain; *łęgi i olsy* – riparian forests and alder carrs; *grądy* – oak-hornbeam forests; *bory* – coniferous forests; *jazy* – weirs; *sianożęcia, izby* – haymaking, *izby*; *łąki na 'dubrowach'* – meadows in oak forests; *barcie* – beehives; *antropogenne łąki* – anthropogenic meadows; *małe polany w grądach* – small glades in oak-hornbeam forests; *bór lado* – *lado* coniferous forest]

(*Revizya pushch… 1559*), and those names were often referred to in descriptions of rights to use the forest. On that basis, the environmental distribution of *wchody* could be reconstructed.

A natural catena of forest communities in the Białowieża Forest (according to Faliński 1974), occurring in the cross-section of the terrain from the river or stream valley to the highest locations of the local watershed, covered narrow non-forested floodplains overgrown with low boggy vegetation and willows, moor birch and alders, riparian forests and alder carrs *Circaeo-Alnetum*, oak-hornbeam forests *Tilio-Carpinetum*, further mixed coniferous forests *Pino-Quercetum* and coniferous forests *Peucedano-Pinetum* (Fig. 3). The *wchody*-type use in Jagiellonian times was concentrated basically in the river valleys (weirs and haymaking), coniferous and mixed coniferous forests (beekeeping), and to a smaller extent in oak-hornbeam forests with a high share of oak (meadows in oak forest). A significant number of *wchody* (approx. 15) was situated in such a way that they covered parts of the valleys of two rivers (haymaking) and coniferous forests situated on the watershed (for wild beehives) (see Fig. 2).

Written documents indicate that in the 15th and 16th centuries the area of riverine meadows in the forest significantly increased to the detriment of riparian forests and alder carrs (Fig. 3). The source data are confirmed by the palynological material. Borowik-Dąbrowska and Dąbrowski (1973) stated that in the territory of today's Białowieża National Park, in a phase corresponding with the beginning of the Jagiellonian reign, the area of alder carrs decreased, while the share of meadows increased. An identical conclusion results from the research by Mitchell and Cole (1998): the percentage share of anthropogenic plant pollens (meadows and beaten sites) in the total quantity of pollens doubled: from 4–5% in the early medieval period to 9% at the end of the 16th century (Fig. 4).

An increase in the area of open meadows with low vegetation was beneficial for a forest penetrated by many non-forest and ecotonal animal species, e.g. common vole *Microtus arvalis*, northern lapwing *Vanellus vanellus*, and lesser spotted eagle *Aquila pomarina*. Interestingly, it was beneficial also for the bison *Bison bonasus*. They could find an excellent feeding area and favoured the grass and herbs found on hayed meadows by rivers and in oak forest glades (Gębczyńska, Krasińska 1972; Gębczyńska et al. 1991). Moreover, haystacks left for winter on the meadows offered an easily accessible winter food source. The forest protection services probably quickly noticed that bison benefited from the hay. Over time, a system for the regular winter feeding of bison on hayed meadows managed by the forest administration was developed on that basis. The oldest known record of the bison feeding as an obligation of the forest protection service dates back to 1700. A royal commission inspecting the Białowieża Forest recommended to mark out additional hayed meadows in some backwoods, where a part of them was to be leased for a rent and the rest of them left for 'animal feeding' (Hedemann, 1939). It may be supposed that this method of active protection of the bison population, developed on the base of traditional haymaking, has contributed to the conservation of free roaming bison in the Białowieża Forest, and the basic forms of bison population management (winter feeding with hay, feeding glades) continue to date (Krasiński et al. 1999).

The use of riverine meadows for hay survived several centuries. Its largest spatial range was noted in the 19th century (Fig. 4 and source data in: Karcov 1903). In the Polish part of the Białowieża Forest, since the second half of the 20th century, a decline in the traditional use of riverine meadows has been observed, making them subject to rapid secondary forest succession (Falińska 1991). In the Byelorussian part, riverine meadows, edges of not drained bogs (*Dikoje*) and entire areas of dried bogs (Wild Nikor) are still regularly mowed and even fertilised and refilled by the sowing of grass mixes (A. N. Bunevich, oral information).

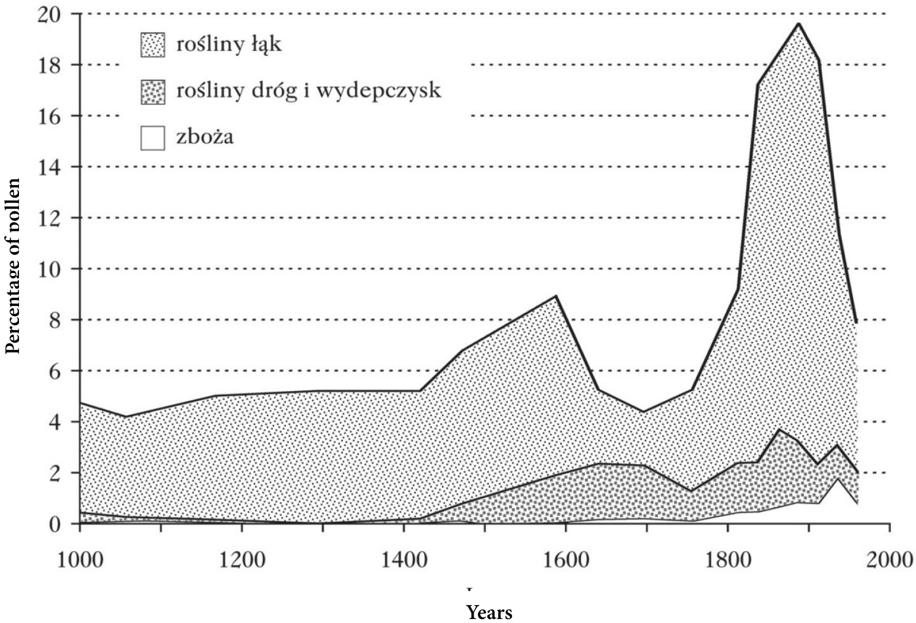

Fig. 4.
Percentage of pollens of anthropogenic plants in the years 1000–2000 from palynological studies in compartment 256 (site 1) in the Białowieża National Park. Data from a [soil] profile 0–70 cm deep were converted to calendar years based on dating with the ^{14}C method (data from: Mitchell and Cole 1998]
[*rośliny łąk* – plants from meadow sites; *rośliny dróg i wydepczysk* – plants from road and beaten sites; *zboża* – cereals]

The wild beekeeping situated in coniferous forest, mixed coniferous forests and sometimes in oak-hornbeam forests (Fig. 3) survived in the Białowieża Forest to the first half of the 19th century, both in the form of scattered wild beehives on single trees and – less frequently – as bee yard glades with a larger number of log hives placed in tree crowns (Brincken 1826; Karpiński 1948; Samojlik et al. 2003). In 1792, 936 wild beehives and beehives with bees, and 6,219 empty wild beehives were counted in the entire forest (Hedemann 1939). However, from the point of view of the environmental impact, the fact the beekeepers' activities were inherently linked to introducing fire to the forest seems to be more important than making wild beehives and promoting honeybees *Apis mellifera*. Numerous documents from the last centuries have emphasised regular forest fires being caused by working beekeepers. It was, however, expressed in the most explicit way in 1764 by G. Harnak (quoted from Hedemann 1939): 'Fires in the forest occur frequently due to the recklessness of beekeepers, as they walk to wild beehives from one wilderness to another wilderness, with burning firebrands and cause burning even if they do not intend to do so.' Brincken (1826) was also emphasising that the beekeeper's work 'requiring fire-making may easily cause a fire' and recommended replacing the primeval forest beekeeping with homestead beekeeping.

The beekeeping was not the only anthropogenic source of fire in the forest. In the later centuries (17th to 19th), together with the development of livestock grazing in the forest, the activity of shepherds ensued, who attempted to improve the feeding ground for the livestock by burning the forest floor. In the 17th and 18th centuries, charcoal making was an additional source of fire in the forest. It should be emphasised that natural fires (caused by lightning bolts) happen in the Białowieża Forest – just like in all forests in the Central Europe – very rarely (data from the Białowieża Forest District and the Browsk Forest District – oral information).

The source data can be confirmed by the palaeoecological material. Since about the year 1400, the ratio of charcoal microparticles to plant pollens in palynological samples from the Białowieża National Park has been increasing, reaching its peak values in the years 1400–1750 (Fig. 5). This ratio is a good indicator of the relative frequency of burns (F. G. Mitchell, PhD, information by letter). Interestingly, after the year 1800 the ratio of charcoal microparticles to pollens rapidly decreases to stay at a very low level to date (Fig. 5). Genko (1902–1903) states that after a devastating fire in 1811, it was strictly forbidden to burn the forest floor, and the forest service was ordered to increase its protection from arson. In the 19th century, primeval forest wild beekeeping declined, while slightly before that (end of the 18th century) the making of charcoal, potash and tar started to lose its importance or to decline (Brincken 1826; Genko 1902–1903; Hedemann 1939).

Frequent forest floor fires in coniferous forests and mixed coniferous forests resulted in a reinforcement of the domination of pine *Pinus sylvestris* and in the elimination of admixtures of spruce *Picea abies* and deciduous trees. Pure pine forests, locally referred to as *lado* coniferous forests, existed in the Białowieża Forest already in the 16th century (Genko 1902–1903). The etymology of the word *lado* (Rus. *lado*, *lada*, Pol. *lędo)* – a forest glade cleared by using fire from plant cover and prepared for cultivation (see Hensel 1951) – also indicates the role of intentionally started fires in the formation of this forest community. The *lado* coniferous forest survived in the Białowieża Forest to the end of the 19th century. Eliza Orzeszkowa left behind an interesting description in her novel *Ad Astra*: '*Lada* coniferous forest, the most precious jewel of the forest, the immemorial heritage of giants. Only pines live here, the most ancient of all, strongly defending their homeland from the attack of other tribes. As it is undignified for giants, they do not crowd, but raise their wide crowns to the heights under the clouds on straight and smooth trunks' (Orzeszkowa 1904).

Therefore, a hypothesis may be formulated that the *lado* coniferous forest was a degenerative stage of mixed coniferous forest (in some cases maybe even of fresh oak-hornbeam forest), maintained due to frequent forest floor fires. The Russian forest inventory

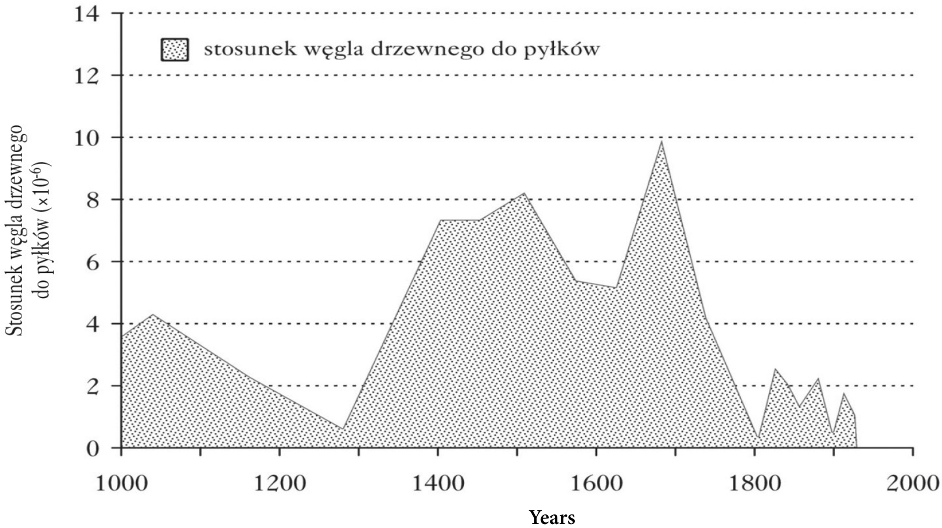

Fig. 5.
Ratio of charcoal microparticles to plant pollens in the years 1000−2000 according to palynological studies in the Białowieża National Park. Source of data and time axis scaling – as in Fig. 4
[*stosunek węgla drzewnego do pyłków* – ratio of charcoal to pollen;
Stosunek węgla drzewnego do pyłków (×10^{-6}) – Ratio of charcoal to pollen (x10^{-6})]

of 1889 indicated that the *lado* coniferous forest covered in total 39% of the area of the forest (Genko 1902−1903) and was situated mainly in its southern part, which was at the earliest characterised by wild beehive utilisation (see Fig. 2). Already at the end of the 19th century, (Genko 1902−1903) observed overgrowing of the *lado* coniferous forest with spruce, whereby he dated that process back to the 1820s (by counting the annual rings of spruce). Nowadays, the *lado* coniferous forest has almost completely disappeared from the forest's floristic landscapes, and for decades a very weak natural renewal of pine has been observed in the natural stands of the Białowieża Forest (Bernadzki et al. 1998).

In the 15th and 16th centuries, together with the exercising of relatively numerous and extensive *wchody* rights, a system of roads and paths for people, carts and livestock must have developed. Although in the documents only the 'Great Białowieża Road' from Kamieniec Litewski through Królowy Most (on the Leśna River) to Białowieża (*Revizya pushch … 1559*) is referred to, many more roads must have been there. The palynological data (Fig. 4) display an increase in share of pollen from plants typical for roads and beaten sites, from the year 1400 throughout the entire analysed period.

In the face of the currently low water level in the larger rivers of the forest and of a periodical summer drying up of smaller rivers, such a great significance of freshwater fishery among the *wchody* rights in the 15th and 16th centuries may seem strange. Undoubtedly, the water level in the Białowieża Forest rivers was much higher then, especially considering that the previous historical period (Middle Ages) had been characterised with a more humid climate, while the straightening of river beds and the drainage of the Białowieża Forest bogs began only in the 19th century and was conducted on a large scale in the 20th century. The 16th century weirs and ponds on rivers played an ecological role, which now is referred to as small water retention. They were slowing down the rivers and were retaining water in the forest.

The freshwater fishery in the Białowieża Forest was still gaining importance in the 17th and 18th centuries, while fish species present in the rivers of the forest were recorded during animal inventories, e.g. in 1796 [Hedemann 1939). In the 19th century and even more so in the 20th century, freshwater fishery lost its importance after large-scale drainage in the forest and its vicinity. However, it is interesting that in the second half of the 20th century, in the Belarussian part of the forest, several large water reservoirs were built with the river damming method (e.g. Lyackoe), in which an extensive breeding of freshwater fish has been conducted.

It is hard to assess the size of the forest use by royal subjects, but with the scarce development of settlement in the Białowieża Forest area in the 15th and 16th centuries (Hedemann 1939), it may be assumed that it did not cause any significant changes in the forest environment. However, there should be emphasised the initiation of such forms of use that would become problematic 200 years later, e.g. tearing linden bast. In the 18th and 19th centuries, it was commonly believed that such a practice led to a significant decrease in the share of linden (*Tilia cordata*) in the Białowieża Forest stands (Brinken 1826).

Summary and conclusions

During the period of the Jagiellonian dynasty, the Białowieża Forest had an area of approx. 1,800 km^2 with more than 90% forest coverage, of which a significant part was not subjected to any permanent utilisation form. *Wchody*, i.e. the right to use specific renewable resources of the forest on the royal property's area, constituted the dominant method of exploitation in the 15th and 16th centuries. The *wchody* rights usually covered haymaking on riverine meadows, beekeeping in coniferous and mixed coniferous forests, and freshwater fishery. Moreover, many edible or usable plants and mushrooms were being picked. The timber harvesting was limited to the use of snags and woody debris, and felling for the own needs of few *wstępnicy* [users] and royal servants.

The forms of the forest utilisation, commenced and developed in the 15th and 16th centuries, appeared to be very durable. Their most important ecological impacts include:

- formation of 0.1–2 km wide deforested river valleys,
- introduction of fire as a method of maintaining pine forests (*lado* coniferous forest).

In the Belarussian part of the Białowieża Forest, the mowing of meadows continues, while in the Polish part the return of abandoned meadows to forests has been observed since the second half of the 20th century. A decline in the role of fires in the formation of the forest's landscape has taken place since the first half of the 19th century. The Jagiellonian era initiated the active conservation of free ranging bison by providing additional winter food (haystacks on meadows).

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Rafał Paluch

Natural regeneration of oak in the Promotional Forest Complex 'Białowieża Forest' – state, conditions, prospects*

One of the major tasks in establishing promotional forest complexes consist in the possibility of testing binding and new silvicultural methods with a view to their eventual use in other forests. In the new *Silvicultural Principles* (2003), for the first time separate principles of silviculture for this type of domain have been considered. Most of these principles have been previously valid in the Białowieża Forest. The inventory of forests similar to natural ones (Sokołowski 1999b) and the determination of directions for the natural dynamics of forest communities (Bernadzki et al. 1998; Sokołowski 1999a; Paluch 2001) contribute to a better understanding of the environmental conditions of the Białowieża Forest, allowing better silvicultural and forest-related decisions to be made. To this end, optimal conditions for the natural renewal of an important forest-forming species – i.e. oak – were determined.

The necessity of developing separate management guidelines for the Białowieża Forest has been emphasised many times (Mierzejewski 1960; Graniczny 1969). Zajączkowski (2003) provided that already in the first, post-war edition of *Silvicultural Principles* concerning distinct rules for forest management in the Białowieża Forest. An important moment was the implementation of the *Basic Principles of the Forest Management in the Białowieża Forest* in 1975, limiting the harvesting and emphasising the protective objectives of the forest. Shortly afterwards, the forest habitat type was adopted as the basic criterion of management, to which the [methods of] regeneration cutting were adjusted. Graniczny (1969) underlined that the target species composition should be maintained at a level similar to the natural one, treating endangered species, i.e. oak, ash and sometimes pine, advantageously in the course of renewal, as well as to apply to them an appropriate time advantage when introducing regenerations'. These species currently face problems with their natural renewal (Paluch 2003). Important forest-forming species (pine, oak, ash) shaping the environmental conditions of many forest communities are highly heliophilous. For several decades, a clear expansion of shade-tolerant species (hornbeam, linden) has been observed

* The paper was developed on the base of the document *Formation of conditions for the development of the natural regeneration of pine and oak in the Promotional Forest Complex 'Białowieża Forest'*, developed by the order of the Directorate General of the State Forests in Warsaw.

in the Białowieża Forest; currently, under natural conditions, these species outcompete the heliophilous species (Bernadzki et al. 1998; Sokołowski 1999a; Paluch 2001). Will oak still remain the symbol of the Białowieża Forest, or will it be outcompeted by more expansive species, like hornbeam and birch, from the species composition of the primeval forest communities? Due to the difficulty with obtaining a natural renewal of oak in this exceptional range, detailed, systematic studies on oak renewal methods were initiated in the Department of Natural Forests of the IBL [Forest Research Institute] in 1998.

In the managed part of the Białowieża Forest, a significant share is occupied by fertile deciduous forest (30%) and mixed deciduous forest (27%) habitats, where oak should be the dominant or co-dominant species in the stand. Its largest area-related share in the stands is 11.2% (Michalczuk 2001), definitely too low with regard to the potential of the habitats.

Research objectives and methodology

The research was conducted in the years 1999–2003 in theBiałowieża Forest in its commercial timberland and in selected nature reserves in the managed part of the forest, and in the Białowieża National Park in its part subjected to strict and partial protection. The main research objectives included the determination of the conditions for the natural regeneration of oak in the Białowieża Forest and the changes in the size of the regeneration on permanent plots in the period 1999–2003, as well as of probable reasons for those changes. The analysis of oak natural regeneration was conducted in the following site groups:

- In natural stands, with a share of oak, plots with dimensions of 50 m × 50 m (2,500 m^2) were established and the composition and structure of the overstorey defined. In the particular research years, self-sown oak seedlings were counted and their height was measured with consideration of their age.
- In oak stands, in which the regeneration process was initiated by preparatory cutting to open the canopy closure, three sample plots with dimensions of 10 m × 10 m were established.
- In pine stands of age class IV, originating from artificial regeneration with abundant oak undergrowth and saplings originating from natural regeneration, plots with dimensions of 50 m × 50 m (2,500 m^2) were established.

Research results

Oak regeneration in conditions similar to the natural ones, without human interference.

Fresh coniferous forest. In fresh coniferous forest habitats, self-sowing oak is quite common. Intensively browsed by game, it survives in the undergrowth layer up to an age of more than dozen years and in some areas it enters the second-growth forest, enriching the species composition of the plant community and entire biocenosis.

Fresh mixed coniferous forest. Studies conducted in the Starzyna nature reserve since 1975 have demonstrated a permanent presence of self-sown oak in the small reed-spruce fresh mixed coniferous forest (*Calamagrostio-Piceetum* Sokoł. 1968), but only few specimens advance into the stand (Fig. 1). In the years 1999–2003, the density of the oak renewal in the mixed coniferous forest habitat was low, but the largest in comparison to the other habitat types (Table). But, the constantly present oak second-growth was browsed by game, and the older specimens entering the second-growth layer were largely eliminated by the crown snow load. However, in some places, single oak trees become components of the stand. Although oak did not produce abundant crops in 1998 and 1999, single annual seedlings appeared. In the years 1999–2003, the number of young oaks in the fresh mixed coniferous forest habitat was subject to large fluctuations (Table). The best conditions for the oak regeneration growth were found in several open areas, which were formed in wetter and slightly more fertile places. In 2003, a thick natural regeneration of oak with good silvicultural quality was growing in such areas. Such lighting and micro-habitat conditions are beneficial for the quick growth of this species. However, it is observed that more often such blanks in the stand in this habitat are filled mainly by expansive spruce, effectively competing with oak (Fig. 1). In this type of mixed coniferous forest (*Calamagrostio-Piceetum* association) in natural conditions oak may constitute only a small admixture.

Fresh mixed deciduous forest. In the Starzyna nature reserve, in the fresh mixed deciduous forest (*Melitti-Carpinetum* Sokoł. 1976) with a spruce-oak stand, in the conditions of a full canopy closure, despite its continuous self-sowing (Fig. 2a), oak does not enter second-growth (Fig. 2b). A generation gap lasts until a significant opening [of the canopy closure] occurs of the stand. Increased light access may enable the self-sown oak seedlings to advance into the highest strata, creating a start of a new stand generation. A stronger maintenance lighting up the stand that took place several decades ago allowed also for re-generation of heliophilous admixture species – birch, aspen, goat willow, maple, and even pine. However, the main obstacle in oak natural regeneration is constituted by well-developed lower layers of hornbeam. On small, one-are blanks, 2–3 m tall sapling, highly dense stands of that species were formed. The few oaks that were growing here were not browsed but were still strongly suppressed. In the years 1975–2003, the quantity of hornbeams in the lower layers of the stand largely increased (Fig. 2). In the W. Szafer Landscape Reserve, the highest (of the researched sample plots) density of lower layers of hornbeam was observed, exceeding 10,000 pcs/ha. In the years 1986–2003, the density of self-sown seedlings and saplings of that species increased by a factor of more than a hundred – from 50 pcs/ha to more than 5,000 pcs/ha. Therefore, the hornbeam expansion prevents the regeneration of moderately heliophilous oak.

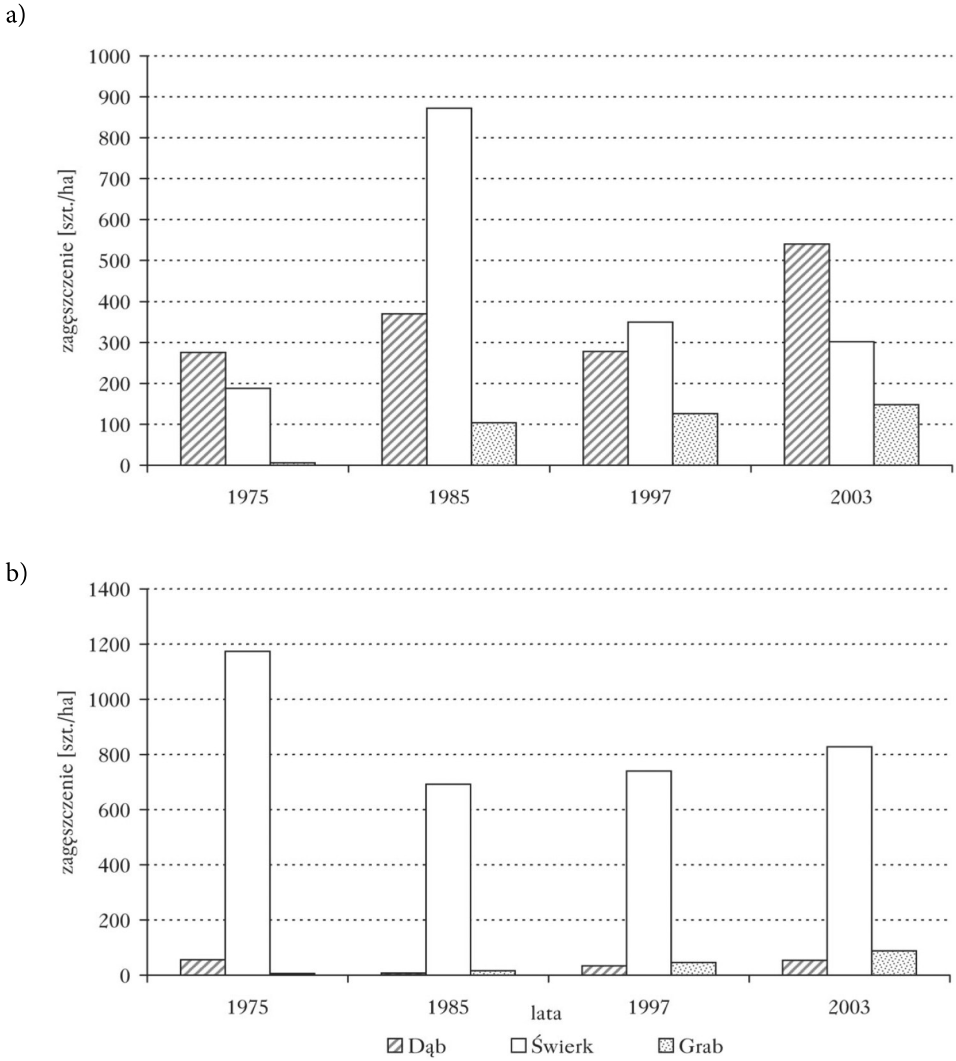

Fig. 1.
Density of self-sown seedlings and low second-growth forest a) and second-growth forest higher than 1.3 m b) in the fresh mixed coniferous forest habitat in the Starzyna Nature Reserve in the years 1975–2003

(zagęszczenie [szt./ha] – density [pcs/ha]; lata – years; Dąb – Oak; Świerk – Spruce; Grab – Hornbeam)

TABLE

Mean density of oak natural renewal in the years 1999–2003 in pcs/ha on permanent sample plots in the Białowieża Forest

Years / Forest habitat type	1999 one-year	1999 two-year and older	2000 one-year	2000 two-year and older	2003 one-year	2003 two-year and older
BMśw	54	632	0	494	12	564
LMśw	288	112	47	148	39	145
LMw	27	198	32	184	24	208
Lśw	25	116	19	104	4	58

In the fresh mixed deciduous forest, early successive species – aspen and birch – retreat from the stand, awaiting the appearance of conditions for repeated regeneration. Young oaks currently entering the stand constitute the second generation of this species. Previously, oak had probably regenerated together with pine, creating a small admixture. An oak with a diameter of 58 cm registered in 1986 constituted evidence of this. That previous regeneration period of the stand must have been characterised with special conditions favourable for pine regeneration. The quantity of self-sown oak is highly variable over time, but in general this self-seeding is continued even in a period between the seed years of oak (Table). Young oak trees cannot survive over the age of a few years and a height of 130 cm (Fig. 2). In the years 1999–2003, in the fresh mixed deciduous forest habitat, the density of self-sown oak was low and fluctuated from approx. 100 to 850 pcs/ha (Table). Significant shadowing of the forest floor caused mainly by lower oak-hornbeam layers is the most significant reason for the lack and quick reduction of oak seedlings. Moreover, self-sown oak seedlings are frequently browsed by game. They feature a low height and reduced quality.

Wet mixed deciduous forest. In the Białowieża National Park, in the small reed-hornbeam forest (*Tilio-Carpinetum calamagrostietosum* Sokoł. 1980), corresponding with the moist mixed deciduous forest habitat, oak regenerated previously together with aspen and birch as a result of significant opening [of the canopy closure] of the stand with dominant spruce. An increased light influx contributed to an intensified growth of the constantly occurring self-sown oak. That species advanced from lower to upper stand strata. In the years 1999–2003, a small number of self-sown oak seedlings (Table) amounting to approx. 250 pcs/ha remained. However, these self-sown oak seedlings did not grow into the higher layers and a generation gap emerged. Simultaneously, a growing share of hornbeam is observed, which will increasingly shadow the forest floor, thus hampering the regeneration of oak and other, more heliophilous species. In the years 1986–2003, the density of hornbeam in the lower a)

b)

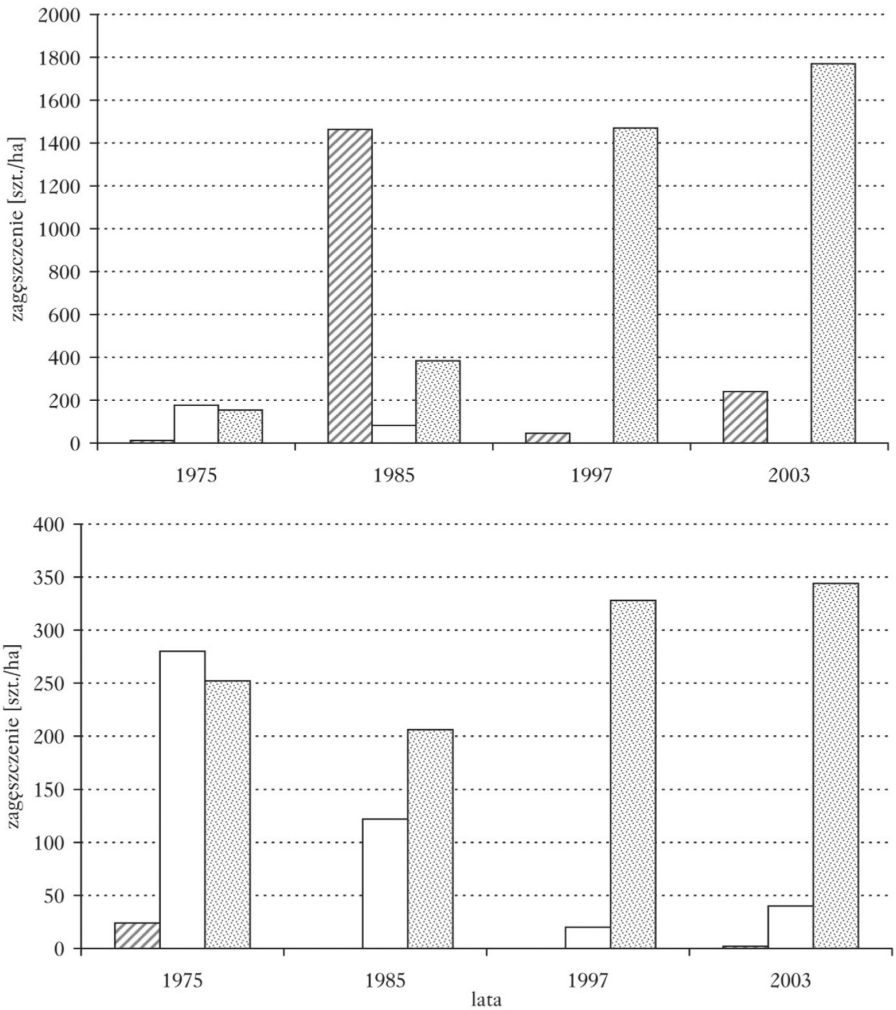

Fig. 2.
Density of self-sown seedlings and low saplings (a) and saplings higher than 1.3 m (b) in the fresh mixed deciduous forest habitat in the Starzyna nature reserve in the years 1975-2003

(zagęszczenie [szt./ha] – density [pcs/ha]; lata – years; Dąb – Oak; Świerk – Spruce; Grab – Hornbeam)

strata of the stand increased by a factor of five, and in 2003 there was 2,000 pcs/ha of self-sown trees in the undergrowth and 350 pcs/ha in the stand. Oak seeding still continues, but a quick reduction in young seedlings takes place and few of them survive to the age of six years or more. They are also characterised with very poor growth. Even the oldest, six to seven years old ones, reach only 45 cm. It proves current unfavourable conditions for the growth of oak natural seeding.

Fresh deciduous forest. In the fresh deciduous forest habitat, in the *Tilio-Carpinetum typicum* association (Traczyk 1962) for stands with full canopy closure, despite continuous natural seeding and the presence of many oak seed trees, the majority of the natural seeding of this species dies in the second or third year of age. Such a state may last for very long periods. In fertile deciduous forest habitats, under natural conditions, hornbeam is the major component of the stand. Present with high density in all stand layers, it strongly shadows the forest floor. Mainly for that reason the under-canopy self-sown oaks are distinguished by very poor growth. Several years old specimens were only 50–60 cm high, vegetating in insufficient amounts of light. In the years 1999–2003, the density of oak regeneration was very low and fell within the range 16 to 272 pcs/ha (Table). Moreover, the major part of the natural regeneration of oak was being browsed by game, which significantly diminished its viability and silvicultural quality.

Oak regeneration after removal of the bottom storey of the stand. In the fresh mixed deciduous forest, the removal of the bottom storey of the stand and of the undergrowth, and a reduction of stocking of the main stand to 0.4–0.5 in the fenced area of 0.5 ha, in a mast year for acorns, contributed to an abundant natural seeding. Single pine seedlings also appeared. After ten years, in 2000, the quantity of specimens from natural seeding was assessed at 12,000 pcs/ha. In the next three years, the number saplings dropped by approx. 2,000 pcs/ha. The oak sapling stand is basically even-aged at 13–15 years old.

In 2000, in the place shadowed by old oaks (plot A), young hornbeam trees were at 25,000 pcs/ha and oak from natural seeding at 16,400 pcs/ha (Fig. 3). Most of the young oak trees were in the height range from 45 to 90 cm, with only few of them reaching 150 cm. The low height of self-sown trees resulted from the insufficient amount of light reaching seedlings and from competition with hornbeam. In the years 2000–2003, as a result of, among other things, hornbeam expansion, the density of oak trees decreased by 27% and in 2003 was 12,000 pcs/ha (Fig. 3). The highest oaks reached 210–230 cm.

In 2000, in the place dominated by a 2–3 m high hornbeam (plot B) self-sown oak was rare – 5,000 pcs/ha (Fig. 3). In the years 2000–2003, the density of hornbeam increased significantly, exceeding 90,000 pcs/ha in the final period of research. In 2003, in that place (with insufficient clearing) only a half of the number of oak trees stated in the beginning of the research remained, i.e. 2,500 pcs/ha (Fig. 3). More than 90% of the young oak trees were in the middle and lower sapling stand layer. Most specimens reached 90–120 cm in height, and only a few of them 160 cm.

In the place where the density of hornbeam was the lowest (plot C), the self-sown oaks were more numerous (19,000 pcs/ha) and reached a significantly greater height. In 2000, few of the highest oaks were 270–290 cm high, with most of them falling in the range of 40–110 cm. In 2003, the density was reduced by 21% and was 15,000 pcs/ha (Fig. 3).

The highest saplings were then reaching 370–400 cm in height and occupied the biosocial position of dominant trees in the sapling stand. The lowest quantity reduction in the number of self-sown oak trees resulted from the reliable clearing (removal of hornbeams) from that part of the sapling stand and from relatively good lighting conditions (gap in the canopy of an old stand).

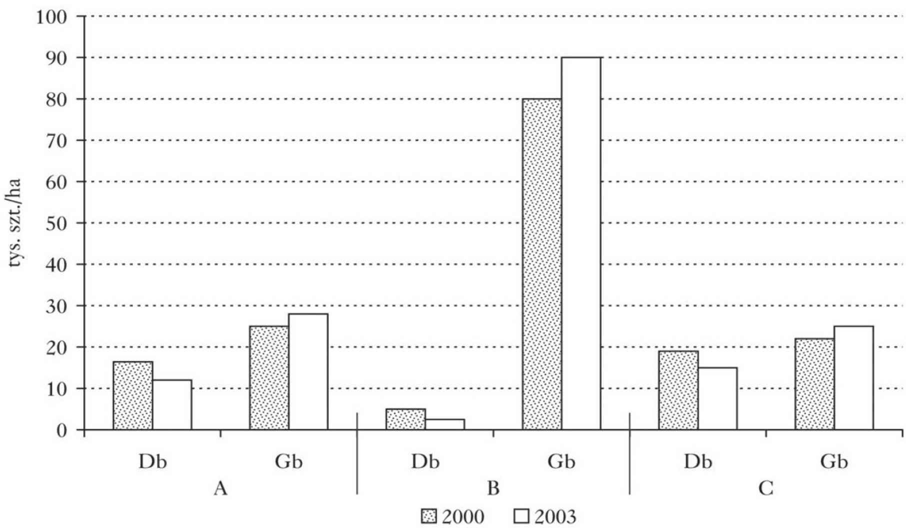

Fig. 3.
Changes in density of self-sown oak and hornbeam trees on permanent sample plots (A–C) in the years 2000–2003

(tys. szt./ha – thousand pcs/ha; Db – Oak; Gb – Hornbeam)

Therefore, the beneficial impact of maintenance work on the number and growth of self-sown oak trees was noticeable. Most of the young oak trees were in the area of trimmed hornbeam trees. The abundance of hornbeam in the upper layer of the sapling stand posed the highest threat to the growth of young oak. Oaks overtopping the hornbeam layer (approx. 10–20% of the population) are usually of good quality and form crop trees, with the highest vital potential. Specimens in the middle layer have often straitened crowns and compete strongly with hornbeam. Some of them, thanks to the forester's help, might become a valuable component of the future stand. Many of the young oak trees are suppressed by hornbeam and dying. Approx. 25% of the entire population of young oak trees shows poor quality of the bole and signs of weakening, while others are viable, of good or very good quality. The lower the density of hornbeam in the upper layer of the sapling stand, the better the quality and viability of young oak trees. Hornbeam trees in the middle and bottom layer (provided that density is low) may play a stimulating role for the growth of oak, if their growth is continuously suppressed. On the entire regenerated area, the maintenance treatment of a late cleaning nature (topping or elimination of hornbeams supressing oaks) is necessary. It should be oriented towards supporting valuable oaks.

Oak regeneration under the pine stands. In the fertile mixed coniferous forest habitat with fragments of fresh mixed deciduous forest, under the canopy of not fenced pine stands of artificial origin and of age class IV, very numerous young generations of oak emerge spontaneously (by reason of animals), creating the bottom storey of the stand. The breast-height diameter structure of oak in these stands indicates that this species may regenerate continuously here, but it requires more detailed research (determining the exact age). Apart from juvenile specimens, old oaks also grow there, probably the same age as the pine (they originate from natural regeneration, self-sown on a clear-cut by birds, or they were planted). Therefore, oak is uneven-aged and the oldest specimens reach into the upper storey. Oaks growing in the stands are characterised by low branches and thick boughs. So, it should be assumed that several decades ago the stand was growing with an open canopy closure and/or blanks occurred there.

In the years 2000–2003, the density of self-sown oak seedlings of up to 1.3 m high decreased by almost a half and in 2003 was 76 pcs/ha. In 2003, very few, one-year seedlings appeared in a one-are blank. The exiguous number of seedlings resulted from the lack of light and living space. Due to a significant density of young trees and an old stand, the regeneration process was inhibited. Also, some under-canopy oaks declined due to the strong canopy closure of the pine stand (too little light reaches the regeneration) and intraspecific competition. The few years old self-sown oak seedlings were attacked by mildew, necrosis and other pathogens, which evidenced their weakening. In stands with a lower density of trees, the emergence of new seedlings still continues.

In 2003, the density of young under-canopy oaks (higher than 1.3 m) was 2,000 to 5,000 pcs/ha. The oldest specimens were 25–30 years old. The density of oaks with diameter at breast height exceeding 7 cm was significant and was 250 pcs/ha. For comparison, the mean density of pine trees was nearly 400 pcs/ha. Probably, in the near future, a tendency towards an increasing share of oak at the expense of pine will be manifested, confirming the natural dynamic of pine-oak communities in mixed coniferous forest habitats. Approx. 70% of older oak saplings consisted of viable trees, of good or very good quality, with well-developed leader. Oak had better quality when it grew in groups or groves, in blanks in the pine stand. They may constitute a valuable component of the future stand. Despite missing maintenance, oak increases its share in the stand composition, advancing into its higher strata. Using this natural process for a conversion of the pine stand is absolutely recommended.

Discussion

In the scale of the entire II Masovia-Podlasie [physiographic forest] region, self-sown oak regeneration occurs rarely (Głaz, Zajączkowski 2002). Such a state in the Białowieża Forest was confirmed by detailed studies. According to the study, self-sown oak is usually observed in stands of age class VI in the fresh mixed deciduous and fresh deciduous forest habitat, where green cover occurs. Oak regeneration encounters large difficulties in the natural stands of the Białowieża National Park as well. Zajączkowski (1999) indicates that in the strict nature reserve of this park, natural regenerations of oak are continuously present and reach a height of up to one metre. These regenerations die quickly and are replaced by new ones. Over the last 60 years, only a few young oaks have exceeded the diameter at breast height of 5 cm. In the last 30 years, the number of those trees, so-called ingrowths, over an area of 15 ha was only 4 pcs/ha. Simultaneously, a clear expansion of hornbeam into oligotrophic and mesotrophic habitats was observed (Bernadzki et al. 1998, Sokołowski 1999a, Paluch 2001). Inventory data also confirm that in the Białowieża National Park a significant increase in the share of hornbeam in the composition of stands occurred, and stands with a share of oak aged less than 100 years are found very rarely (Michalczuk 2001). Kowalski (1993), referring to the research by Russian foresters (Pogrebniak 1961) and his own observations in the Jasień forests, claims that the young oak generation in primeval forests is developed jump-wise (in waves). The take-over of an area by oak in a natural way does not constitute a continuous process. It occurs when beneficial climate conditions arise over a short time. The oak's life strategy is undoubtedly related to its longevity. Observations of old oak stands in the Białowieża Forest indicate, though, that some of them have already ended cropping or they crop very poorly (Korczyk 1997), which may result in the lack or a very small quantity of regeneration of this species in overmature stands. Brzeziecki (2000) rates both oak species as representatives of a mixed strategy of stress tolerance and competition (C–S). Self-sown seedlings of these species are tolerant of weak accessibility to water and minerals. The high survival rate of seedlings in the initial growth stage is undoubtedly related to the large seeds created by the oak, richly equipped with nutrients. By constituting an initial source of energy and nutrients, the seeds partly reduce the stress experienced by seedlings in their first growth phases under the canopy of other trees and in the presence of herbaceous species (Brzeziecki 2000). That is one of reasons for the presence of self-sown oak seedlings under various stands, often with a high grade of canopy closure, but they usually live for quite a short time, due to the lack of sufficient development conditions.

However, it has been observed that oak regenerates well under pine stands originating from artificial regeneration on clear-cuts in the fresh mixed coniferous forest habitat, and less frequently in the fresh mixed deciduous forest habitat. In the Kampinos National Park, this species enters the pine stand at the age of approx. 70 years (Pigan 1999). Moreover, its features include also good productivity index and quality (Rumiński 1998). In the Białowieża Forest, oak has also efficiently regenerated under some, relatively young pine stands. Currently, the oak saplings aged 25–30 years create bottom storeys of pine stands of age class IV, showing good growth and quality. It becomes the co-dominant species in the stand. Oak seeding continues, but at this growth stage of the stand seedlings usually die back after two-three years, mostly due to the lack of light. The expansion of oak to poorer habitats (mixed coniferous forests), which has been clearly noticeable in the last 30–40 years, is associated with processes of plant community regeneration and with the eutrophication of habitats (Paluch, Sokołowski 2003). Kowalski (1993) states that the light demand of oak in the climate warming period decreases, and, as a consequence, it develops from a heliophilous species into a half-shade tolerant one.

It can be concluded from general observations that the natural seeding of oak occurs in natural conditions in the entire the Białowieża Forest, in various forest habitat types, also in places distant from fruit bearing parent trees (Paluch, Sokołowski 2003). A large role in the process of oak spreading is played by birds, in particular jay, and small mammals (among others Kowalski 1993; Fabijanowski 1995; Vera 2000). Effective oak regeneration and the entrance of a self-sown specimen into the stand occurs only with a sufficient light influx. It may occur under natural conditions (windfall, crown snow load) and after the application of treatments aiming at removing the shelter of emerging regenerations. It requires maintenance of the renewed young oak generation and protection against game. Only in the pine-oak mixed coniferous forest habitat did oak regenerate effectively, under the shelter of the pine stand, without maintenance treatments. In other forest habitat types (e.g. fresh deciduous forest), under natural conditions, self-sown oak also emerges, but it lives only a couple of years. This results mainly from the lack of a sufficient amount of light caused by the development of lower hornbeam layers and from the game browsing of the regenerations. Grzywiński (1998, 1999) presented a successful attempt to initiate a self-sown oak regeneration in the fresh mixed deciduous forest habitat in the Browsk Forest District. The removal of the lower storey of the stand and of the undergrowth, and loosening of the canopy closure of the overstorey of trees in a mast year for acorns resulted in an abundant appearance of oak seedlings. Single pine seedlings also appeared. The area was fenced to eliminate game access. In addition, the regular and careful maintenance of regenerations was ensured. The longstanding experience of forestry theory and practice within the scope of oak regeneration methods was applied, a synthesis of which might be found in all editions of *Silvicultural Principles* (including also the version valid as of 2003) and in papers by Puchalski (1972), Bernadzki (1974), and many others. The research also indicates that such a silvicultural handling approach is correct. It should be unambiguously emphasised that hornbeam, being the main component of oak-hornbeam forests, is not an enemy of the forest host, as it performs an important maintenance role in oak forests, but its natural regeneration should be formed under the young oak stand.

On the one hand, documents and guidelines (forest management plans, decisions of the Ministry of Environment) recommend in the Białowieża Forest a wide application of natural regeneration, but on the other hand, numerous binding prohibitions exist (including a moratorium on old tree cutting) restraining the possibility of effective regeneration of stands. In legal acts, which must be adhered to by the forest districts located in the forest, oak stands are treated particularly restrictively, introducing a complete prohibition of cutting specimens of this species older than one hundred years (Decision of the Directorate- General of the State Forests 1998, Decision of the Minister of Environment 2003). Chances for an effective natural regeneration of oak under the current environmental and legal circumstances, in particular in stands with a significant share of this species, have been strongly reduced.

In the Białowieża Forest, a significant condition for a renewal success is constituted in the case of self-sown oak by its protection from game, which causes serious damage, affecting the regeneration quality. Fencing of regenerated plots is the most effective, but very expensive method of protection. Under the conditions of sites difficult for a regeneration (weedy, often damaged by the game), good regeneration results would be achievable with the use of 'the patch method of oak plantation on posts' by Ogijewski as modified by Szymański (1977, 1983). This method deserves special attention, as from among all known methods of oak regeneration it may be of prophylactic character, partially preventing damage. Bernadzki i Zajączkowski (1992) emphasised that because of the game browsing of regenerations and due to the lack of appropriate maintenance in the cleaning stage, the share of expansive species, mainly birch and hornbeam, in the species composition of the stands of the forest, increased. Several years of observations of oak natural seeding confirm this tendency with regard to unfenced and untended places. The research results indicate that damage caused by game in the Białowieża Forest is still significant and without fencing the regenerations the risk of their failure is high.

Conclusions

- An effective regeneration of oak occurs only with sufficient light influx, as a result of a significant opening of the stand's canopy closure. Therefore, in natural conditions, the growth of oak regeneration is induced by destructive factors contributing to the formation of larger blanks or significant thinning (windfalls, crown snow load, simultaneous dieback of many old trees). Within the framework of a semi-natural forest cultivation, natural phenomena should be reasonably imitated, by applying in a controlled way treatments that initiate regeneration and then un-sheltering of the saplings.

- The research results, experience of previous generations of foresters, as well as the ecology of hornbeam and oak's high demand for light demonstrate that shelterwood cutting (while leaving some trees to their natural death) constitutes the best method of natural regeneration of this species in the stands of the forest.
- During the validity period of the absolute prohibition on old tree cutting, the effective natural regeneration of oak in the Białowieża Forest has been and will continue to be significantly hampered. The absolute prohibition on the removal of trees aged more than 100 years concerns also other species. The generation gap will gradually grow.
- In the Promotional Forest Complex 'Białowieża Forest', the silvicultural possibilities of forming conditions for the natural regeneration of oak and many valuable species are very limited.
- The basic condition for the effective regeneration of oak in the Białowieża Forest comprises its protection from game. The fencing of sites subjected to the regeneration is the best, but very costly protection method.
- It would be advisable to consider the possibility of using for the stand conversion valuable groves of oak saplings, being the existing pine stands.
- The maintenance of oak regenerations, consisting mainly in inhibiting the growth of more expansive species (birch, hornbeam) should be conducted in a reliable and regular way, as it is frequently necessary for the success of natural seeding.

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Opinion of the Forest Research Institute in Warsaw on the report of F. Verhart, BEng, H. Smeenge, BEng, and B. van der Linden, BEng, entitled 'Sustainable Forest Degeneration in Białowieża Forest' addressed to 42 institutions and natural persons*

The Forest Research Institute in Warsaw, for 75 years conducting scientific studies for the benefit of Polish forests and forestry, shares the concern of people from other countries about maintaining Białowieża Forest, being the most precious forest range, not only on the scale of our country, but on the European scale. The content of the above-mentioned report and its main assertions require an in-depth analysis, explanations and rectifications.

1. It is given in the report that Białowieża Forest is one of the best preserved natural lowland forests in Europe's temperate zone and that already before World War I, 'about 80% of the forests of Białowieża were classified as old-growth forest',[1] understood as a natural, primeval forest. This hypothesis suggests that the Białowieża Forest did not have any or almost no traces of human economic activity. This is contradicted by the extensive literature on that subject, according to which an exploitational approach to the forests of Białowieża commenced after 1795, when the forest was under Russian rule. In that time, over 40,000 ha of its woodlands were transformed (deforested) into farmland (Faliński, Okołów 1968). A reinforcement of the devastation of the forest's woodlands through increased felling, mainly of pine and oak, took place particularly in the period of the Napoleonic Wars (Więcko 1984; Program… 2002). That process was curbed only in the year 1888, when the forest was considered the private property of the tsar of Russia and treated as an exclusive hunting ground. However, that became a source of new threats to the forest, by bringing to it in the years 1901–1907 'red deer, fallow deer, roe deer and elk from Siberia, Caucasus, Germany, Austria, Czechia (…) The forest becomes a menagerie. The game population significantly exceeds the capacity of hunting grounds' (Faliński, Okołów 1968). The game started to seriously threaten the forest, 'not only because the entire ground cover, but also the undergrowth and self-sown saplings were being eaten, so that large patches of literally naked ground were seen everywhere (…), a gap between the mature stand and the young generation started

[1] 'Before World War I started, about 80% of the forest stands of Białowieża were classified as *Old Growths*' – quote from the report, p. 3.

* The text of the report may be found at http://www.franknature.nl

form' (Karpiński 1932) and 'currently, almost a complete lack of stands of medium age can be observed' (Faliński, Okołów 1968). The game feeding with food delivered from outside led to the spread of numerous plant species in the forest, formerly rare or unknown there (Faliński, Okołów 1968). Thus, it was not a state corresponding with the criterion of a primeval forest.

One should agree with the authors of the report that the worst damage to the forest environment were caused in the period of World War I, when in the years 1915–1918 the German occupants built in the forest 200 km of narrow-gauge railways and in its vicinity numerous wood processing plants, including 'the largest dry wood distillation factory in Europe for the processing of approx. 300,000 m^3 of non-coniferous timber per year' (Podgórski 1965). In order to meet the needs of industry, the Germans removed 5 million m^3 of merchantable timber from the area of the entire forest (Sokołowski 2004). The occupant's over-exploitation economy was the main reason for the mass occurrence of bark beetle, which in the years 1918–1923 caused very serious damage to spruce stands, estimated as more than 1 million m^3 of merchantable timber (Podgórski 1965).

Due to the need for the reconstruction of Poland, reborn after World War I, but in a devastated condition, the annual allowable cut established in 1921 for a forest covering an area of 105,000 ha was approx. 300,000 m^3 per year. To improve the state's financial situation, a controversial agreement on the exploitation of the forest was concluded in 1924 with an English company The Century European Timber Corporation, with an annual assignment of wood raw material harvesting of 325,000 m^3. By the time Poland terminated the agreement in 1929, the company harvested approx. 2.5 million m^3 of timber in the forest. In the subsequent years, until 1939, timber harvesting in the forest was almost 400,000 m^3 per year (150% of the annual allowable cut) (Podgórski 1965).

The data show that only in the years 1915–1930 approx. 9.4 million m^3 were harvested in the territory of the entire forest, i.e. almost 90 m^3/ha, at a mean yield of mature stands of 220 m^3/ha (Podgórski 1965). The forest maintained its primeval character, formed only by forces of nature, only between the 'exploited areas of Białowieża'.[2] Explanations of the reasons for this state are missing in the report, which may lead to an incorrect evaluation of the forest's past by the readers and suggest that a negative evaluation of each form of its utilisation in the present times is legitimate.

2. The presented examples of the exploitation of the forest, in particular during World War I, luckily did not touch its fragment coming to 4,600 ha, which on the initiative of Professor Władysław Szafer (1920) was transformed in 1921 into the Reserve

[2] 'Within the exploited area of Białowieża the Old Growth stands make up essentials remnants of the virgin forests' – quote from the report, p. 5.

Forest Subdistrict with the character of a 'Nature Park', and in 1924 into a separate administrative unit, the Reserve Forest District. In 1932, in turn, on the basis of that Forest District, by the decision of the Minister of Agriculture and Agricultural Reforms, the 'National Park in Białowieża' was established, administratively subordinated to the Directorate of the State Forests in Białowieża.

The establishment of a 'Nature Park' in the forest required the consideration of all the pros and cons at that point. The main originator of the Park establishment, Professor Szafer, wrote in 1920: 'The material value presented (…) by the stands of Białowieża Forest is huge (…) Therefore, while considering the plan to create an inviolable reserve from a part of Białowieża Forest, we must conscientiously consider also its economic aspect'. And further: 'Considering such enormous values as provided by the commercial exploitation of Białowieża Forest to a Polish State impoverished by war, it is even impossible to consider keeping Białowieża Forest as a whole as an inviolable forest reserve. Leaving aside such huge forest treasures and voluntarily relinquishing them, just when our State fights for its existence and economic independence so hard (…) would constitute indeed too large a sacrifice, or would even be simply reckless' (Szafer 1920).

Although decades have passed, these words have still not lost much of their currentness. Disregarding the economic aspect in such a country as Poland, with an annual income of 5,000 euro per capita, very low in comparison with the Netherlands at almost 28,000 euro per capita, would mean ignoring a difficult reality. Such an approach is presented by the authors of the report, who think, probably generalising the situation from the Netherlands, where the forest area per capita is 0.02 ha, while in Poland to 0.23 ha, that leaving the entire area of the forest subjected to natural processes would be the best solution. The arguments presented here indicate that the assumption of the primeval character of the entire forest[3] is only a hypothesis, and even when assuming its legitimacy, the issue of livelihood sources for residents of that poor region in the case of a complete cessation of the conduct of forest management in the forest cannot be ignored. Despite the imposed conservation regimes, it remains the main source of livelihood for the local population. At the end of the last century, the stream of money flowing from that [forest] management to its neighbourhood was 5.5 million USD, while the stream flowing from the neighbourhood to it was 5.9 million USD per year (Klocek, Gołos 2000).

[3] 'The influence of man on the forest ecosystems in Białowieża has been relatively small and rather constant over the last 8000 years – ever since the forest started its development' – quote from the report, p. 9.

The authors of the report seek a solution in the re-orientation of the professional activity of the population towards the tourism,[4] but the weekend and vacation tourism prevailing in the forest cannot satisfy the basic existential needs of the region's population. The development of tourism on a larger scale would require significant infrastructural investments with an environmental impact that is difficult to assess. The experience of other national parks (example of the Tatra Mountains) indicates the inevitability of conflicts between tourist business and the needs of nature conservation.

3. Description of the economy related to the territory of the Promotional Forest Complex 'Białowieża Forest' was presented in the report as a classical multifunctional economy.[5] This thesis is only partially true. Multifunctionality in the classical sense means a simultaneous performance of the production, ecological and social functions of the forest. In another case, despite many functions being performed by the forest, some of them may be considered dominant due to the specificity of the site. From the approved 'Programme for Nature Conservation and Protection of Cultural Values in the 'Białowieża Forest' Promotional Forest Complex (Program… 2002) there arises the unambiguously dominant function of nature conservation. It is evidenced by the existence on its territory of 20 former nature reserves with a total area of 3,500 ha and the recent encompassment of further 8,500 ha with reserve conservation, so that together with the Białowieża National Park 35% of the Polish part of Białowieża Forest is subject to reserve conservation. As a consequence of covering such a large area with nature reserves, the silvicultural and protective measures of three forest districts of the forest need to be subsidised, currently at the level of 6 million Polish zloty (information from the Directorate General of the State Forests, 2005), which is possible only thanks to profits achieved by the other forest districts belonging to the State Forests.
4. The planned annual allowable cut, criticised by the authors of the report, comes to 145,000 m^3 and has been calculated only based on the assessment of the state of the forest and of the silvicultural needs, and not as a clueless reader might think, imposed by the buyers of wood as a raw material. In any case, according to the data from the Regional Directorate of the State Forests in Białystok concerning the harvesting in the first years of validity of the current plan, the execution fluctuated between 119,000 m^3 and 138,000 m^3, a volume even smaller than the planned one.

   Currently, 75% of the managed area of the forest comprise young and middle-aged stands. A significant part of the criticised annual allowable cut, which includes intermediate cutting, is allotted to these stands. The remaining part of the annual allowable cut results from the execution of a conversion programme for stands growing in the

[4] 'The area has a growing importance for eco-tourism for modern man' – quote from the covering letter, p. 1.

[5] 'The "ustainable" multifunctional Białowieża Forest' – quote from the report, p. 3.

so-called *post-Century* clearcutting areas referred to in point 1. Young and middle-aged stands, overrepresented in the age class structure, originate from artificial regeneration, mainly with pine and from natural seeding of small-seeded species – birch, aspen. The first ones clearly do not conform to the habitat, while the latter due to the short lives of major species, are gradually entering the stage of maturity and decline. Both of them, regardless of the previously adopted objectives of the holding, require active silvicultural management, especially that it refers to a huge area of 6,000 ha (Borecki, Brzeziecki 2001). Leaving this entire area only to spontaneous regeneration processes is associated with a considerable level of uncertainty; especially the return of target species, such as oak, in the foreseeable future is particularly unlikely.

It is also worth emphasising that in scientific projects related to plans for the transformation of the entire Białowieża Forest into the Białowieża National Park (Gutowski et al. 2000) both the zonal system of conserved areas and the need for 'naturation' cuts have been foreseen.

5. Although the European spruce bark beetle (*Ips typographus* L.) is a permanent, intrinsic element of forest ecosystems with share of spruce, opinions on the proper approach to the rapidly growing population of this insect are divergent. Among scientists there are supporters of both, letting things to natural regulative mechanisms (Gutowski 2002) and of an intensive prevention, and, if needed followed by a gradation control (Michalski et al. 2004). In commercial forests, the latter option is indisputable, but in the case of protected sites the answer depends on the assumed conservation objective.

If the only subject to the conservation should consist in natural succession processes, the lack of any intervention would be justified. However, in the situation when the goal consists in the conservation (restoration) of the continuity of the forest community or, even going further, maintaining the largest possible diversity of plant associations, preventive and protective treatments are absolutely necessary. The view about the permanent resistance of natural forests to large-scale disasters,[6] taken by the authors for granted, is increasingly questioned (Szwagrzyk 2000). All the more such resistance cannot be assumed in advance in a forest range containing large fragments of artificial origin.

It should be noted that preventive measures (felling 'sawdust' trees) are carried out not only in the districts of the forest, but also in the area incorporated to the Białowieża National Park in 1996 (Hwoźna forest management unit). A cessation of such activities may result in a situation similar to the one found in the Belarussian part of the forest, where the lack of protection measures led to the dieback of spruce

6 'Within primeval forests the natural balance ensures long term health' – quote from the report, p. 9.

with a total volume of 1.1 million m^3 and to the formation of open spaces estimated at 3,000 ha (Brzeziecki, Zbrożek 2004).

As regards the comment on the apparent effected withdrawal of the FSC certificate for the Białowieża Forest, it should be remarked that this piece of information is inaccurate, because discussions about the certification of forests of the Regional Directorate of the State Forests in Białystok, to which the districts of the forest are subordinate, are in progress.

6. The contraposition of modern multifunctional forest management in the West to the allegedly backward forest management of the Central and Eastern Europe,[7] which was presented by the authors of the report, is a proof of their lack of knowledge about that region of Europe, encompassing Poland among others. The suggestion that the maintenance of high natural values in forests results only from the economic underdevelopment is for the Polish forestry even offensive. It should be emphasised that any commercial activities of foresters since the half of the 19th century have been regulated in most European countries by relevant acts, which define objectives, principles and methods of forest management, including nature conservation, and which is greatly reflected in the term of 'forest service'. The foresters perform only a role of executors of the will of society.

Despite the critical assessment of the main assertions of the report, we appreciate the very fact of interest in such a valuable natural site as Białowieża Forest. A substantive discussion, relying on facts, not on emotions, concerning the issues of the forest, may certainly support Polish foresters in their work oriented towards the effective protection of all its values, and local authorities in the promotion of the region and in the improvement of the living conditions of the population related to the forest for centuries and, as the authors anyhow admit, traditionally living in harmony with nature.[8] In order to come through joint efforts to proper solutions within that scope, we invite the authors of the report to visit our Institute and to make use of our remarkable large library collection.

Warsaw, March 2005

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[7] 'Within several Western European countries (…) sustainable, multi-purpose or integrated forest management are adequate, modern management strategies, regarding the character of the greater part of forests in Western Europe' – quote from the report, p. 9 and 'Thanks to the isolated situation of vast areas in Central and Eastern Europe, smaller and larger tracks of primeval nature have been able to persist deep into modern time' – ibidem.

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Review

Woodlands of the Białowieża Forest – a new scientific monograph. Presentation of the work by Professor A. W. Sokołowski, PhD, DSc

The work by Professor A. W. Sokołowski, PhD, DSc, titled *Woodlands of the Białowieża Forest*, published by the Information Centre of the State Forests at the end of 2004 is a book addressed to a large group of people interested in the Białowieża Forest as a natural site, unique on a European scale. It constitutes a summary and conclusion of the considerable scientific contribution of its author, for many years head of the Department of Natural Forest of the IBL [Forest Research Institute] in Białowieża, undoubtedly belonging to a very slim group of real experts on the nature of the Białowieża Forest. This work corresponds with the series of famous 'primeval forest' scientific monographs developed by exceptional scientists, appreciating the environmental values of this area (e.g. the works of Paczoski, Karpiński, W. Matuszkiewicz, Faliński). The study is written in a reader-friendly style, and includes many figures, tables, and colour pictures created by the author.

In the introduction to the book, the author mentions numerous features distinguishing the Białowieża Forest from other areas of Poland. The most important of them include high compactness and vastness of the forest range with fragments of natural forest, great diversity of forest communities, abundance of flora and fauna, and the zonal system of the conservation regime. In section 1, the author discusses the location, scope and abiotic background (e.g. climate, geology, soils, air pollution) of the research object. In section 2 the author provides general historical data and emphasises, based on numerous publications, that the utilisation of the forest in past centuries was not limited to a sporadic tree felling. Large volumes of timber were being harvested in the 16th century for the production of potash, charcoal, tar and many other products. For the 18th and 19th centuries many hundreds of thousands of logs were plunder cut and clear-cut to be sold. The artificially maintained game overabundance at the end of the 19th century and at the beginning of the 20th century, in combination with cattle grazing, caused extensive damage to the forest, making forest renewal impossible. During World War I, the Germans felled more than 6,500 ha of stands.

Then the author presents the present state of nature in the forest, and its environmental abundance composed of almost 11,000 species. Based on the forest management planning data, he broadly discusses the share of trees in the stand composition, their forest-forming role and occurrence in forest communities and generally in the entire Polish part of the forest. Special attention is paid to tree and shrub species of alien origin, many of which show a tendency to invade the forest areas.

Most attention is paid by the author to the description of the forest communities of the forest, their state and dynamics, presenting a reliably documented synthesis of his long-time research. As a result, Professor Sokołowski distinguishes 27 forest associations and four associations of shrub vegetation. He does this on the base of his own original classification of forest communities, adapted particularly to climatic and natural conditions of north-eastern Poland [Sokołowski 1980], which excellently completes and specifies in more detail the typological classification of forest habitats. The author describes each plant community by including selected, ordered phytosociological tables with calculated synthetic features (permanence, coverage ratio).

The stand structure and species composition are presented in drawings. Descriptions of plant communities are also enriched with a description of the soil conditions. Permanent sample plots, established by the author since the 1960s, representing the entire variability of habitat conditions in the forest, have enabled [the author] to conduct thorough research into changes in vegetation. It has a huge value, not only in terms of understanding but also application-related, for many disciplines of forest science, including silviculture and nature conservation. These considerations result in the determination of directions and the nature of changes in forest communities.

While summing up this issue, the author writes that changes in vegetation in primeval forest communities have significantly accelerated in the last 30 years. The most important primary factors responsible for these changes include the lowering of ground water level, environmental pollution, climate changes, and regeneration of communities after former distortions (livestock grazing, excessive game stock). Detailed and long-standing research studies have allowed the determination of several important regularities, such as stating that the pace of vegetation changes is the highest in the habitats of mixed deciduous forest, mixed coniferous forest and fresh coniferous forest, while in case of other habitat types it is usually low. The author emphasises that the phenomenon present in all forest [habitat] types in the forest is a progressing increase in the share of hornbeam in the stands, while the importance of spruce decreases. In the opinion of the author, changes in vegetation are of a directional nature and indicate an eutrophication of habitats. From the observed tendencies the author draws conclusions within the scope of forest management in various forest habitat types and emphasises, how important phytosociological survey is for the silvicultural planning.

Another important topic discussed in this part of the work is the impact of final cutting on the species composition of forest communities. The changes in vegetation over time after clear-cutting are presented in numerous phytosociological tables. Based on an extensive research material, the author provides many conclusions important for silviculture.

Then Professor Sokołowski provides the characteristics of primeval forests with regard to the level of their naturalness, stating that the area of natural forests in the Promotional Forest Complex 'Białowieża Forest' comes to approx. 3,600 ha. Based on a forest inventory carried out by the author, the 'Natural Woodlands of the Białowieża Forest' reserve was created in 2003 (8,500 ha). That decision resulted in a significant increase in the area under conservation in the managed part of the forest.

In section 4, general directions of the forest management in the Promotional Forest Complex 'Białowieża Forest' are presented. It is a synthesis of the author's opinions on the directions of silvicultural-protective conduct in the forest, based on his thorough knowledge about this site, acquired through longstanding studies and observations of the processes occurring therein.

An extensive section 5 includes a description of the forest management conducted in the years 1920–2001. The author pays special attention to the currently binding forest management plan, which includes the principles of management of the forest woodlands, adapted to the objectives established for this site and its environmental values.

In the following part of his work, the author discusses the problem of nature conservation in the forest, describing the numerous previous activities in this area, decisions made and their implementation. He also presents directions of conservation in the Belarussian part of the forest. In the entire work, the author follows the rule of objective presentation of facts, avoids excessive commenting on them, leaving a substantial freedom [of interpretation] to the reader. After all, the work deals with a site arousing many emotions. At the end of his work, the author asks a very important question: what should the Białowieża Forest be in the future? Simultaneously, he emphasises the significance of this unique site for the understanding of rights ruling the nature, for the development and improvement of methods of forest management harmonised with the nature and pays attention to the importance of the Białowieża Forest going over the borders of Poland.

The information published by the Author constitute a valuable documentation for various considerations concerning the forest and facilitating a discussion with numerous stereotypes or demagogic slogans preached by persons not equipped with a deeper knowledge about this site. The author, quoting numerous figures illustrating the situation of the forest, often avoids commenting on them, also because the accuracy of these data contained in various documents and publications is hard to be defined. The most important part of the publication consists of the description of forest communities. Thanks to the rich, properly composed documentation, it constitutes a good point of reference for further research on changes in vegetation and habitat conditions appearing in forests marked by a limited human interference. The work by Professor Sokołowski includes plenty of material concerning the state of phytocenoses of the forest and their dynamics, and well-balanced recommendations for the silvicultural-protective processes, which result from observed regularities.

Researchers of the nature of the Białowieża Forest will find in it a starting point for further studies, while for foresters–practitioners an explanation of the processes taking place in stands with very differentiated intensities of commercial interference. This work includes solutions reliably grounded with research material, resulting from the idea of a multifunctional forest and adapted to the nature and role of the forest, where the conservation of natural processes comes to the fore. This work is a good documentation for considerations on the development of silvicultural concepts. It also familiarises the reader with the 80-year-history of activities of foresters aimed at the understanding and conservation of the woodlands of the Białowieża Forest. It provides objective information allowing for a critical assessment of appeals, often illegitimate, directed against the activities of foresters in this territory. For these reasons I highly recommend the work of Professor Sokołowski as enhancing our understanding of the Białowieża Forest.

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Threatened tree species of the Białowieża National Park (Strict Reserve)*

In the present discussion concerning the broadening of the Białowieża National Park by encompassing the entire Polish part of the Białowieża Forest and subjecting almost its entire territory to strict conservation, the supporters of this solution often use the argument about true or apparent threats to various species of plants and animals, which results from silvicultural and protective measures applied in the managed part of the forest. However, in most cases these arguments are not based on specific evidence, e.g. in the form of long-lasting (several decade) sequences of observations concerning the dynamics of the populations of these, theoretically threatened, species.

The situation is different in the Białowieża National Park (BPN) and in particular in its oldest part, i.e. the former Strict Reserve (the present Orłówka Conservation Unit), at least with regard to the major components of the forest ecosystems of the park, i.e. the trees. In 1936, on the initiative of Professor T. Włoczewski, permanent sample plots were established in the territory of the park to track the natural, multiannual dynamics of stands excluded from commercial activity (Włoczewski 1954). This research has been conducted by subsequent generations of employees of the Department of Silviculture [KHL, Katedra Hodowli Lasu] of SGGW [Warsaw University of Life Sciences] to date. It allows, among other things, the determination of multiannual trends in the quantity of tree species present on sample plots, and indirectly – in the territory of the entire reserve. The results within this scope have frequently been presented at various conferences and seminars, and published in many scientific and popular papers (Bernadzki et al. 1998a, b; Brzeziecki 2004, 2005, 2008; Brzeziecki, Bernadzki 2008). However, in some cases they were questioned or considered not fully credible due to the specific nature of the transects, which do not strictly correspond with modern requirements concerning the method of stand surveys in a large forest range. It was hard to dispute that accusation as long as there was no other alternative source of information with which the transect data of the KHL might be compared. Currently, such a situation has come into being. In 2009, within the framework of the Białowieża National

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Park conservation plan, an assessment of the dynamics of forest ecosystems (Brzeziecki et al. 2010) was carried out. This study is based on permanent circular sample plots, distributed in a regular grid, covering practically the entire Park area within its range.

This study aims at determining the current dynamic status of tree species in the Strict Reserve and assessing which of the populations of these species can now be considered 'safe' or 'threatened'. This assessment is based on three basic population-related parameters of these species: 1) current density, 2) number of specimens in size classes replacing the age-development classes, and 3) multiannual count trends. While describing species, relinquishing the attempt to explain the reasons for the observed and foreseen dynamic tendencies was intentional. Firstly, it is not the most important issue from the point of view of this study, and secondly, potential discussion concerning these reasons would be very difficult and long lasting. In the case of this study, it is only about the presentation of what happened over several decades and what currently happens with tree species occurring in the Białowieża National Park, in its environmentally most valuable part.

Material and methods

Within this study, data were used from permanent plots of the Department of Silviculture in the Białowieża National Park, established in 1936 by Professor Włoczewski. These plots have the form of transects with a total length of 3,660 m and width of 40–60 m. The aggregate size of these plots is approx. 15 ha. In 1936, a map was created showing the positions of all trees with a diameter at breast height exceeding 5cm was drawn up, as well as the first measurement and classification of all trees. The diameter at breast height was measured in two perpendicular directions with an accuracy of 1 mm. For subsequent measurement periods, these measurements were repeated, and all naturally eliminated trees and ingrowths, i.e. trees with a diameter at breast height exceeding 5 cm in the period between two subsequent measurement dates, were registered. So far, six control measurement have already been conducted (the last one in 2001–2003). Starting from the third term, the measurements on particular plots have been carried out at regular 10-year intervals. In this study the data used presented the changes in the aggregate count of trees of particular species, present on all sample plots.

The role of a second source of data was played by 385 permanent circular sample plots, each measuring four ares, established with a link to the grid of spatial division. In the territory of the Orłówka Conservation Unit, they were established on the grid of an incomplete square 250 × 250m (missing fourth point, located inside the compartment). Those plots were established and measured for the first time in the years 1998–1999 by A. Keczyński, MSc, BEng. A repeated measurement conducted in 2009 included an accurate survey (species, diameter at breast height, spatial coordinates) of standing trees (alive and dead), down trees (dead) and regeneration (trees with a diameter at breast height <5cm). These data allowed the calculation of the mean density of all tree species present in stands of the Strict Reserve upon measurement, as well as the development of diagrams presenting the diameter structure of those populations.

Results

A comparison of the mean density and species composition of the stands in the Strict Reserve, calculated on the basis of data from the circular plots with analogous data determined on the base of the KHL transects is shown in the table. It may be easily noticed that the similarity of these data points is very strong. This concerns both the aggregated density of stands (the difference was 9 pcs/ha, or approx. 1%) and the density and share of particular species. In both cases, first three places are occupied by the same species, i.e. hornbeam, linden, and spruce. At present, in the stands of the Strict Reserve, they are the dominant species. The total share of these species is 83–84% (Table). This means that almost 16–17% comprise the remaining tree species. At the level of individual species, the differences between the two inventory methods are generally not large. Some of them (e.g. the relatively high density of ash on the transects) may be explained with the differing measurement periods. The transect data concern the period 2001–2003, thus before the occurrence of the phenomenon of mass ash dieback. The next measurement will certainly demonstrate a large decrease in the count of trees of this species.

TABLE

Species composition of stands of the Strict Reserve of the Białowieża National park based on various source data

	Circular plots (as of 2009) [N/ha]	[%]	Transects (as of 2002) [N/ha]	[%]
Hornbeam	248	37.6	274	41.0
Linden	167	25.3	168	25.1
Spruce	130	19.7	118	17.6
Alder	36	5.5	25	3.7
Birch	29	4.4	13	1.9
Oak	14	2.1	16	2.4
Pine	11	1.7	15	2.2
Ash	9	1.4	28	4.2
Maple	7	1.1	6	0.9
Elm	4	0.6	5	0.7
Aspen	3	0.5	1	0.1
Rowan	1	0.2	–	0.0
Other	1	0.2	–	0.0
Total	660	100.0	669	100.0

The data obtained from the measurements present an image of the stands in the Strict Reserve at a specific moment. However, this leads to the question: how stable is the state of the forest resulting from this image? It may be answered through the analysis of: 1) multi-annual counts in trends for individual species, and 2) their diameter structure.

Assuming the density as a criterion for the classification, three species groups may be distinguished:

1) group of species dominating with regard to their count (hornbeam, linden, spruce),
2) group of codominant species (alder and birch), and 3) group of rare (admixture) species comprising oak, pine, ash, maple, elm, and aspen (rowan may be ignored as it takes the form of a tree relatively rarely).

If multiannual trends are to be considered, each species in the group of the dominant ones behaves differently. Hornbeam, which is currently the most numerously represented species (Table), shows a continuous upward trend (Fig. 1), increasing its share not only in deciduous forest habitats, but, as it is demonstrated by more detailed research, appearing in habitats theoretically less appropriate for this species, i.e. in mixed coniferous forests or even coniferous forest habitats. This is probably one of the reasons for the high share of relatively thin trees of this species – almost 2/3 of all specimens of this species represents the 5–15 cm class (Fig. 2). It is undeniable that both on the basis of multiannual trends and of the distribution of breast-height diameters, the current state of hornbeam may be defined as 'very safe'. The second place in terms of count is currently occupied by linden (Table) – a species that 75 years ago was represented very sparsely in the stands of the park. Since that time, its role among trees in the stands of the Strict Reserve has increased the most. The present count of this species is approx. 25 times higher than at commencement of the research. For comparison, the hornbeam count increased by a factor of 3.5 in that time. However, it should be emphasised that the linden population state has been stable for quite a long time (Fig. 1), since approximately the same number of new trees grow as old trees die for natural reasons. The distribution of tree count in size classes is similar as for hornbeam, i.e. it is characterised by a high share of thin trees (Fig. 2). This is proof of the continuity of the regeneration processes. For now, it can be said that linden is in the group of 'safe' species. The last species in the group rated as dominant is spruce. An analysis of the multiannual data shows unambiguously that its dynamic status is completely different from the hornbeam and linden (Fig. 1). While the count of linden and particularly hornbeam increases, that of spruce decreases. The pace of this process is very high. The data collected from the permanent KHL plots demonstrate that this species' population decreases at a rate of 70 specimens net, i.e. after consideration of possible ingrowth.

For this reason, the process of spruce decline in the stands of the Białowieża National Park is the most spectacular and the most frequently noticed, obscuring similar phenomena occurring with other species. As a result of the high mortality rate of spruce, its share in the pool of dead trees (standing and down) is now very high. The data collected on circular plots show that it is, respectively, 60 and 50% (Brzeziecki et al. 2010). This share is much higher than the current share of spruce as live trees (almost 20%). Nevertheless, the general shape of the diameter distribution (Fig. 2) allows, at least temporarily, the spruce to be classified in the group of 'safe' species, with the reservation that its role in stand formation continues to decrease. How much it decreases will be seen in the future. However, there is no doubt that the supply of dead spruce timber, constituting valuable 'ecological fuel', will soon decrease clearly.

In the group of relatively safe species two species may be included, with an assigned codominant role, i.e. birch (both the common birch and downy birch together) and alder. Such a diagnosis is again based on the form of tree count distributions in size classes (Fig. 2). However, the situation of these species differ in the long-term perspective. While the alder tree count remains at a relatively stable level (changes with the nature of fluctuations), the birch count continuously decreases (Fig. 1). Therefore, birch resembles spruce in this regard.

The remaining species determined on the basis of their current density as 'admixture' species are those that undoubtedly meet the criteria of species at risk of retreat from the stands of the Strict Reserve in a shorter or longer time horizon. These criteria comprise of low total density in the form of breast-height diameter distribution (lowered number of the thinnest classes indicating inhabited ingrowth processes) and a multiannual downward count trend. The group of threatened species is headed by oak and pine. Their density, levelled in the scale of the entire Strict Reserve area, amounts to approx. 10–15 pcs/ha. The transect data show that several decades ago the density of both species was more than twice its current levels (Fig. 1). The pine and oak decline process is relatively slow (compared with spruce or birch), which results from the fact that these species are relatively resistant to adverse external factors, and at the same time as they are long-living (especially oak). In such a situation, the decrease in the population count of both these species results mainly from an inhibition or even complete interruption of the renewal and ingrowth processes. It may be given as some kind of 'curio' that no single pine ingrowth has appeared on the transect plots throughout the research period. In case of oak, the situation is not much better. The multiannual trends are evidenced by the current diameter distribution of both species, characterised by a serious shortage of trees in the thinnest size classes (Fig. 2).

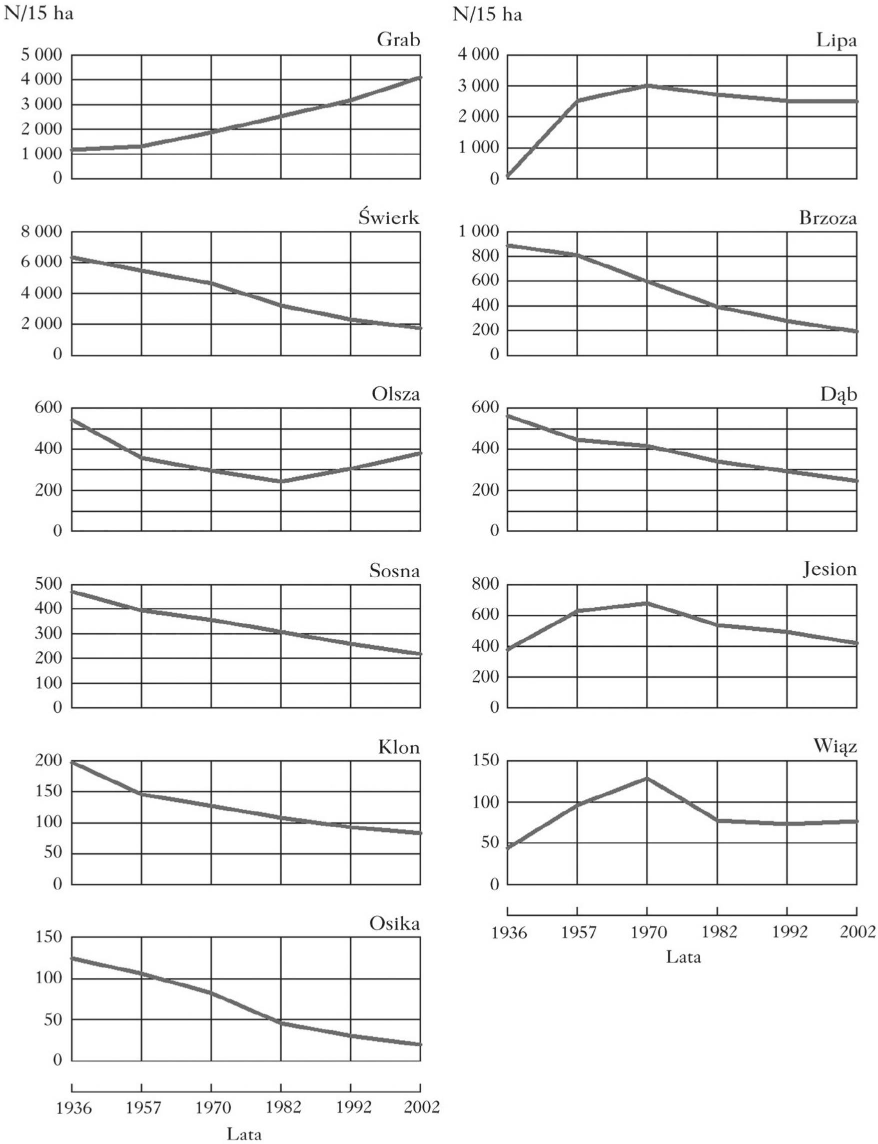

Fig. 1.
Multiannual changes in the count of tree species present in the Strict Reserve of the Białowieża National Park.

(Grab – Hornbeam; Lipa – Linden; Świerk – Spruce; Brzoza – Birch; Olsza – Alder; Dąb – Oak; Sosna – Pine; Jesion – Ash; Klon – Maple; Wiąz – Elm; Osika – Aspen; Lata – Years)

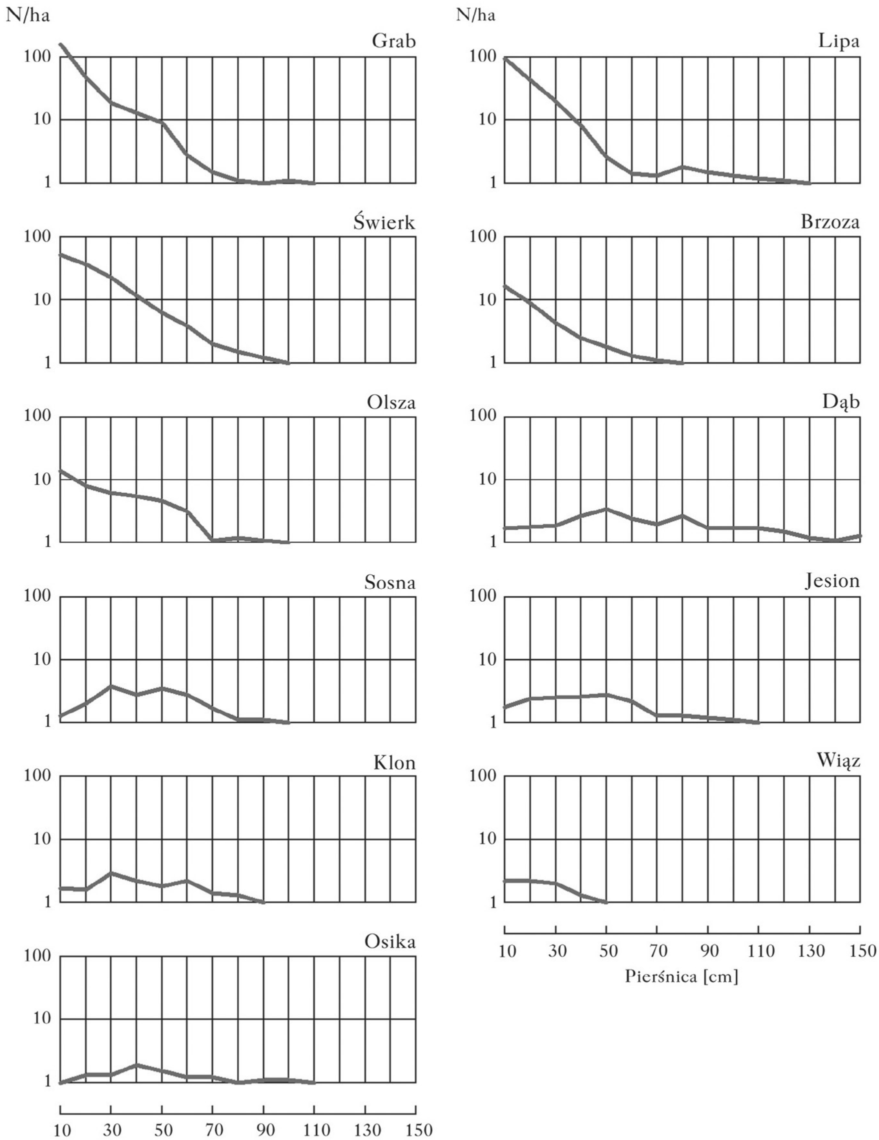

Fig. 2.
Diameter structure of major tree species present in the Strict Reserve of the Białowieża National Park in the year 2009.

(Grab – Hornbeam; Lipa – Linden; Świerk – Spruce; Brzoza – Birch; Olsza – Alder; Dąb – Oak; Sosna – Pine; Jesion – Ash; Klon – Maple; Wiąz – Elm; Osika – Aspen; Pierśnica [cm] – Diameter at breast height [cm])

The group of threatened species is also represented by ash, maple and elm (mainly wych elm). The fact of including ash in this group was largely affected by the phenomenon of mass dieback of that species which has occurred unexpectedly in the last ten years, and not just in the Strict Reserve of the Białowieża National Park. However, a conclusion resulting from the analysis of multiannual data should be noticed, that in the case of ash the downward trend appeared before the mass dieback phenomenon (Fig. 1). The ash dieback phenomenon has affected the thinnest classes (Fig. 2) particularly strongly, therefore any regeneration of this population will be a slow process. At this occasion, it should also be emphasised that ash is highly sensitive to game browsing. At present the very high count of bison and red deer will remain an additional factor strongly reducing the chance of this species renewal, even if it should theoretically happen. Maple shows a continuous downward trend, noticeable for a longer time (Fig. 1). The pace of retreat of this species is similar to that of oak and pine. Maple grows to a diameter of 5 cm very rarely, which is also evident in the diameter distribution (Fig. 2). This is even the more interesting since maple, next to hornbeam, belongs to a species most numerously represented in the stage of self-sown seedlings. However, the capacity to create a permanent stock of self-grown seedlings apparently does not translate to the phenomenon of its advancement into the stand layer. It seems that the main limiting factors in this case include generally unfavourable lighting conditions caused by competition from hornbeam and linden, and the pressure from game. Elm, represented here by three species, a genus threatened mainly by Dutch elm disease, is on the brink of complete retreat. Elm regenerates quite well and probably grows even better than maple. Its high threat level is determined by its very low count (Table). The list of all species discussed here is closed, quite unexpectedly, by aspen. From both data sources considered in this study, the density of aspen is the lowest of all the species mentioned so far (Table). Aspen exhibits a multiannual downward trend (Fig. 1) and is characterised by a clear inhibition of renewal processes, which is evidenced by the diameter distribution of this species (Fig. 2). This is not easy to be explained, as many stands of the Strict Reserve have currently entered the decline stage (Brzeziecki et al. 2010), in which conditions for the regeneration of heliophilous aspen are theoretically present (e.g. birch regenerates relatively easily under such conditions). The situation of aspen starts to resemble the situation of another heliophilous and quick-growing species, namely goat willow, which is currently rarely found in the territory of the Strict Reserve, but used to be significantly more common there some time ago.

Summary

The analysis indicates differentiated threat levels for the tree species present in the Strict Reserve of the Białowieża National Park. Under the consideration of the current threat level, they may be ranked as follows (from the 'safest' to the most 'threatened' species): hornbeam,

linden, alder, spruce, birch, oak, pine, ash, maple, elm, and aspen. Starting with oak, the threat level may be determined as critical, i.e. indicating the possibility of a complete retreat of the given species, or at least of its degradation to the role of an insignificant admixture.
In any case, the density of population of the most species is already at present very low (Table). Taking into account two species extremely different with regard to the density (hornbeam and aspen), it may be noticed that their count ratio comes approx. to 80:1.
The low density for many species results partially from their specific requirements concerning habitat, which have necessarily not been considered in the framework of the general analysis. For example, if the density of maple and elm were defined only in reference to fertile and moist habitats (moist deciduous forest), the relevant coefficients would certainly be higher. However, low density is not the only problem. The dynamic status of a species is demonstrated to the largest extent by changes in population count, monitored over a long period, in combination with their current diameter distributions (Fig. 1, 2). These parameters, essential for the assessment of the dynamic status, show unambiguously that despite the large size of the considered area (almost 5,000ha), the populations of many tree species are very far from a state of balance, whereby downward trends occur much more often than upward ones. Apart from species rated as the most 'threatened' ones, the group of relatively 'safe' species include those whose role in the structure of stands of the Białowieża National Park regularly decreases (mainly spruce and birch). Due to the role performed by particular species in the functioning of the forest ecosystem, their high level of threat translates into a high threat level for all those components of the forest biocenosis that depend on them (live and dead trees). There are many examples of such species representing various groups of forest organisms (birds, insects, fungi). Therefore, the radical decrease in population count of many tree species may probably result in the retreat and decline of numerous other elements of the biodiversity.

Of course, it could always be argued that someday something will happen and a wave of renewal (and ingrowth) of certain species will appear, as happened with linden in the first decades of the last century. Immediately after the end of World War I, the population of that species was considered to be dying out, and then later it suddenly seemed to erupt. Several decades after that event, linden is the second major species in stands of the Białowieża National Park. For the moment, it is really hard to judge whether any other species will manage to repeat this scenario. Any suggestions of this kind can only be pure speculation at the present. It should not be forgotten that if it happens (since it cannot be entirely excluded as nature likes to surprise), from the moment of the start of renewal to the time of occupying an appropriate position in a stand several decades at least have to pass, not even mentioning the time needed to achieve a really large size (usually measured in terms of hundreds of years).

All the above-presented findings have far-reaching consequences for the general level of diversification of the species composition and structure of the stands, and indirectly also for biodiversity in general. The currently dominating trend may be defined as the pursuit of simplification and homogenisation in conjunction with a decline in the differences between communities, particularly visible in the contact zones of various phytocenoses. All this indicates that strict conservation, which follows the superior principle of conservation of natural processes, is not the only universal method of conservation of environmental richness and does not automatically guarantee the conservation of a high level of diversity in forest ecosystems. While being beneficial for some groups of species, including many precious and authentically threatened ones, it leads simultaneously to a deterioration in the living conditions of many other, including also valuable and threatened species, up to their complete extinction from the ecosystem.

It may be said that approx. 80 years ago, on the current area of the Strict Reserve, a certain experiment was begun, one which still has yet to end. Some of its results are, at least from the purely nature point of view, certainly very interesting, even spectacular. However, this should not obscure the fact that also 'the other side of the coin' exists, and that not all results of this experiment are unambiguously positive. For this reason it would be recommended to take the utmost care in making decisions on the further extension of the strict conservation scope of the Białowieża Forest.

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Dynamics of the natural development phases of stands in the Białowieża National Park

Introduction

The classification of stands by development phase is a research method or process description used for natural forests. According to Koop (1989), the first model of a stand structure was published by Watt in 1947. Later, more than dozen original classification systems or their modifications were developed. Despite their differences, the general objective of such a division consists in a synthetic description of the stand structure and the indication of its place in the cycle of transformations which take place in a natural forest. For this purpose, an assessment of a number of features is applied, such as tree density, structure of their dimensions and age, stratification, cover, tree viability, yield, increment, development trend or intensity of the renewal process (Twaróg 1991).

In most cases, the classifications were applied in studies conducted in forests that were not too much transformed by a previous commercial activity. These sites were frequently small. While attempting to introduce such a classification to the forest management planning works performed by teams of gaugers on much larger forest areas in national parks, some practical problems appeared, e.g. the necessity of applying unambiguous criteria for distinguishing the phases or the difficulty of demarking them in the field. Przybylska (1993) proposed a simple division into three phases – initial, optimal and ageing. In the practical implementation (Przybylska, Kucharzyk 1999) it was more extended through the division of the optimal and ageing phases into two forms and the addition of a pre-crop phase. Miścicki (1994), while using the Leibundgut's classification (1959, 1982), developed criteria for its practical use in forest management planning field works. They were applied at the valuation of protected forests, e.g. the Bielany Forest (Miścicki 1994), the Stołowe Mountain National Park (Jędryszczak, Miścicki 2001) and the Karkonosze National Park (Rączka 2004). On the majority of these sites, the picture of natural forest obtained on the basis of measurements with use of natural development phases may be considered incomplete. As its main reasons, the existence of large stands, often homogenised by the former management processes, controlled or nullified the impact of natural distortions and disasters in the past, and currently also in the areas of active conservation, can be given. For these reasons, it was decided to carry out the research on the structure of natural forest, with the use of the classification of natural development phases, in stands of the Białowieża National Park (BPN). This range is large and considered one of the best preserved European lowland forests.

The goal of the study was to determine, with use of the classification of natural development phases, of the current natural forest transformations, including the frequency of phases, their yield, tree density, regeneration count, as well as the current volume increment, ingrowth and elimination of trees as elements of the growing stock dynamics.

Research object

The study was conducted in the oldest part of the Białowieża National Park, formerly and traditionally referred to as the Strict Reserve. In 1921, it was the stirring of the national park (called Reserve Forest Subdistrict). Currently, it constitutes a part of the Białowieża National Park, comprising of 4,584 ha of stands, from which initially 1,061 and, from 1929, all were under strict conservation. The Norway spruce *Picea abies,* pedunculate oak *Quercus robur* and European hornbeam *Carpinus betulus* demonstrate the highest frequency in the stands (Krasuska, Miścicki 2002). In the periods 1994–1996 and 2000–2002, during two strong gradations of European spruce bark beetle *Ips typographus,* spruce dieback occurred (Michalski et al. 2004).

Material and methods

The research material was collected on temporary and permanent sample plots. The data collected on the temporary sample plots were used to calculate the state and differences in state in the period 1995–2005 concerning the majority of features used here, except features of the growing stock dynamics. The plots were measured in June and July 1995 and in August 2005, 460 each time, on the same grid (100 m × 1000 m) of sample plot centres, with its shorter side having the 330° azimuth orientation. For both periods, 320 sample plots were measured by the same executors. The data collected from the permanent sample plots were used to calculate the growing stock dynamics in the period of 2000–2004 (current volume increment, eliminated trees, tree ingrowth to the parent stand part, changes in yield). The measurements of 160 such plots were conducted in August 2000, 2002 and 2004, thus including a period when measurements with the use of temporary plots were conducted. As their centres, points designated by employees of the Białowieża National Park in 1999 were applied. In three regions in which such points did not exist, supplements were made to obtain an even cover of a sample plot grid. Those centres created a grid with average dimensions of 267 m × 1067 m, with the shorter side having an approximate azimuth orientation of 86°. The conduct of frequent (every two years) measurements resulted from the need to determine the reasons for tree dieback.

Each temporary and permanent sample plot was composed of five concentric circles of the following sizes: 5.31 m^2 (measurement of all trees – including self-sown seedlings of height $h<0.3$ m and of ≥2 years old), 20 m^2 (measurement of trees $h \geq 0.3$ m), 50 m^2 (measurement of trees with breast-height diameter $d_{1.3} \geq 2$ cm), 200 m^2 (measurement of trees $d_{1.3} \geq 12$ cm) and 500 m^2 (measurement of trees $d_{1.3} \geq 36$ cm). The species were defined and the diameter at breast height (or height if $h \geq 1.3$ m) was measured for all trees included in the sample. In every stand layer, the height of one to three trees was measured for each species (depending on its frequency) to plot the height curve. On permanent sample plots, by measuring the distance and azimuth in relation to the central point, the positions of trees were specified. On that basis, for subsequent times, changes in tree dimensions and their status (survival, dieback, change in dimensions) were determined. On an area of approx. 2,500 m^2 around the centre of the sample plot, with use of Leibundgut's classification (1959, 1982), slightly modified (Miścicki 1994), the natural development phase was determined. The following phases were distinguished: early optimal, late optimal, early ageing, late ageing, regeneration, selection, decay, initial, juvenile, even-aged pole and pre-mature stand. The border between sub-compartments was indicated – if it existed. The minimum area covered by a given phase amounted to 1,000 m^2, which customarily corresponded with the size of a blank that would not be closed as a result of the development of crowns of neighbouring trees.

The volume of merchantable timber rated to the sample was calculated according to formulas by Bruchwald et al. (2000). The lower threshold of diameter at breast height was assumed as 8.0 cm. For the determination of the regeneration count the sum of tree heights on the area unit was used. The data from the year 1995, used in a previous publication (Krasuska, Miścicki 2002), were verified and the calculations were carried out again (with the application of changed height curves). While calculating features of the stock dynamic the fact was considered that they were permanent concentric sample plots (Miścicki, Nowicka 2007).

The structure of the frequency of development phases was defined based on the number of samples placed at the given term (in 1995 and 2005) in the individual development phases. The assessment of differences in that structure between two terms was carried out with use of the χ^2 test. The transitions between phases, occurring over time, were determined for the 2000–2004 period based on data from permanent sample plots. Two-feature table was applied for that purpose. Due to the short period between subsequent observations, these data were treated as auxiliary.

The assessment of the differences in values of the mean yield, tree density and sum of heights of regeneration was conducted on the grounds of a two-way analysis of variance (term × development phase), and the mean values of the current periodic volume increment, ingrowth to the parent stand part and decline on the grounds of a one-way analysis of variance. The 'term' and 'development phase' were treated as permanent factors. The random variable was the value of the given feature on the sample plot. In the case of yield, tree density, current volume increment and net change in yield, the original data were applied in the calculations. In the case of the remaining features, transformed data $y'=\log(y+1)$ were applied. For *post-hoc* analyses of sites, the Tukey's HSD multiple comparison test was applied.

Results

The results are presented in aggregated form for stands classified in a given natural development phase for a given term or period (in the case of features of stock dynamics). In the Białowieża National Park, in the former Strict Reserve, all the natural development phases of stands were present, but their frequency by area was diversified (Fig. 1). In the years 1995–2005, that structure underwent a change ($\chi^2_9 = 66.1$; $P<0.0001$). For both terms, a large part was occupied by the optimal (early and late) and ageing (early and late) phase – 68% (in 1995) and 81% (in 2005) in total. The frequency of stands in these phases, whose structure underwent changes as a result of tree dieback occurring at a diverse pace (early optimal, late ageing and decay phase), increased. There were fewer stands with a simple structure, with trees at a similar age (juvenile, pole and pre-mature stand phase). In 2005, stands in the pole phase and pre-mature stand phase were more often rated as [being in] optimal phases. The formation of the decay phase resulting from the dieback of stands of various phases and a frequent exchange of the early optimal phase for the late optimal phase and back (Table 1) constituted important phenomena. In the latter case, the reason, apart from the accuracy of interpretation of the structure of phases being quite similar to each other, was a minor opening, in the research period, of the crown cover as a result of the natural elimination of single trees or the closure of small gap blanks due to the growth of crowns.

The yield of merchantable timber, the mean value of which in stands of the Białowieża National Park was 396 ±21 m^3/ha in 1995 and 377 ±20 m^3/ha in 2005, differed between the natural development phases ($F_{10;898}=27.4$; $P<0.001$). Its significant spread – from the largest in the early ageing phase to the smallest in the initial phase – reflected the differences in the condition and structure of stands (Fig. 2). A relatively high yield in the latter phase resulted from the presence of old trees from the previous generation. For the period 1995–2005 it was not observed that a change in the mean value of that feature was different for individual phases (interaction date *x* phase, $F_{10;898}=1.45$; $P=0.15$).

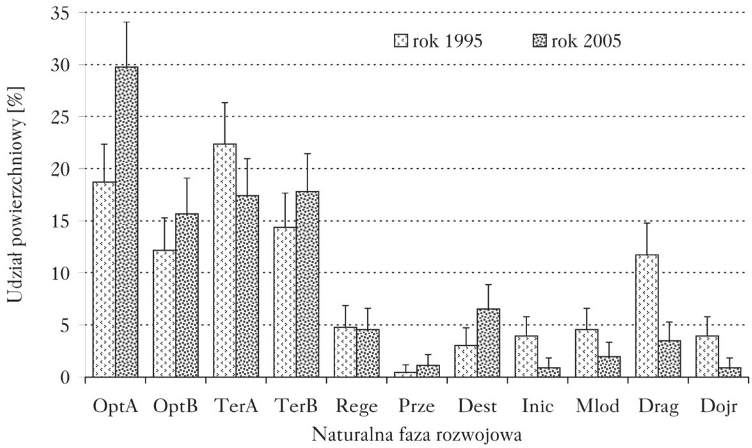

Fig. 1.
Frequency of natural development phases of stands in 1995 and 2005 determined on the basis of the number of sample plots located in the given phase.
* error is given at P=0.05; OptA – early optimal phase; OptB – late optimal phase; TerA – early ageing phase; TerB – late ageing phase; Rege – regeneration phase; Prze – selection phase; Dest – decay phase; Inic – initial phase; Mlod – juvenile phase; Drag – transitional, even-aged pole phase; Dojr – transitional pre-mature stand phase
(Udział powierzchniowy [%] – Area share [%]; Naturalna faza rozwojowa – Natural development phase)

TABLE 1

Number of cases of the natural development phase of the stand on the same 160 plots in 2000 and 2004

	OptA	OptB	TerA	TerB	Rege	Dest	Inic	Mlod	Drag	Total 2,000
OptA	26	13			2					41
OptB	8	22				1				31
TerA			40	3		1				44
TerB			1	10						11
Rege					9					9
Dest						4				4
Inic							1			1
Mlod								5		5
Drag	1	1				1			9	12
Dojr	1		1							2
Total 2004*	36	36	42	13	11	7	1	5	9	160

* in 2004 there were no sample plots in the Dojr phase. Denotations as in Fig. 1

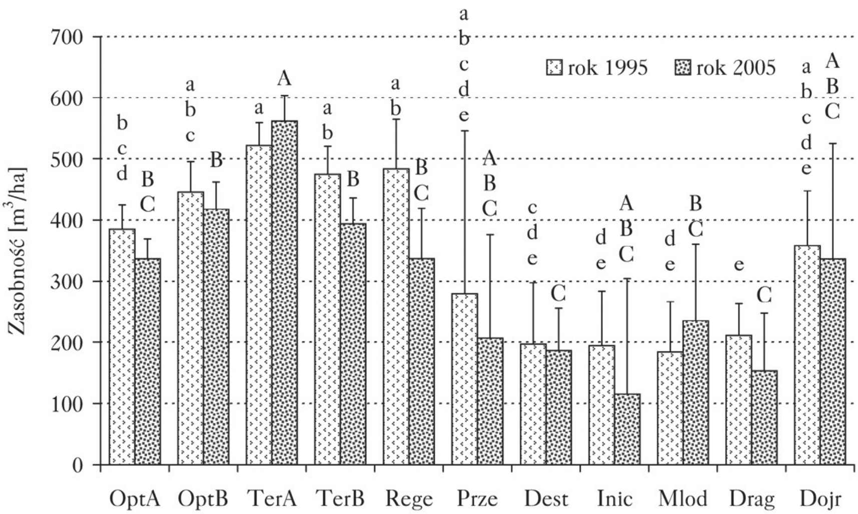

Fig. 2.
Mean (± error at *p=0.05*) yield of stands in individual natural development phases in 1995 and 2005.
Values marked by the same letter did not differ significantly, p<0.05; lowercase letters – sites in 1995; capitals – in 2005. Denotations as in Fig. 1)
(Zasobność [m^3/ha] – Yield [m^3/ha])

The tree density with a breast-height diameter of at least 8 m, the mean value of which in 1995 was 515 ±29 pcs/ha and in 2005 was 515 ±28 pcs/ha, differed between the natural development phases ($F_{10;898}$=16.0; P<0.001). It was relatively high in the late optimal phase (higher than in the early optimal phase featured by an uneven cover) and progressively lower in subsequent phases: early and late ageing, decay and initial (Fig. 3). Higher density in the regeneration phase than in the late ageing phase resulted from the presence of trees that exceeded the conventional dimension threshold of the regeneration layer and were classified as the parent layer. The specific structure of the selection phase, which usually includes many thin trees, meant that the density of trees was one of the highest – similar to that in the pole stand phase. The low mean value of that feature in the juvenile phase resulted from the fact that many trees were below the threshold of breast-height diameter of 8 cm (Fig. 4). In stands classified as that phase, in the 1995–2005 period, the differences in density were the largest, but no significance of differences in mean values between two terms was stated – similarly to the case of other development phases.

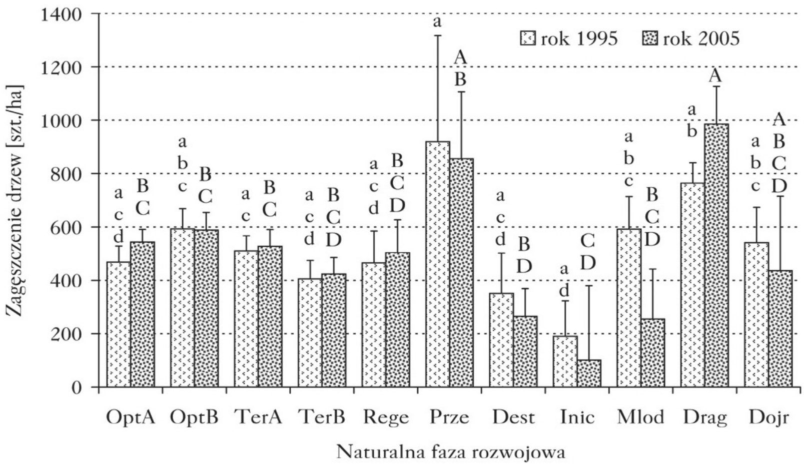

Fig. 3.
Mean (±error at *p*=0.05) density of trees ($d_{1,3}$≥8.0cm) in stands in individual natural development phases in 1995 and 2005.
Values marked by the same letter did not differ significantly at p<0.05; lowercase letters – sites in 1995; capitals – in 2005. Denotations as in Fig. 1.
(Zagęszczenie drzew [szt./ha] – Density of trees [pcs/ha]; Naturalna faza rozwojowa – Natural development phase)

The sum of the heights of regeneration trees, the mean value of which in 1995 was 5,228±573 m/ha and in 2005 was 6,549 ± 872 m/ha, differed between the natural development phases ($F_{10;898}$=19.9; P<0.001). For most the difference was similar and quite small, which resulted from difficult conditions in the development of renewal (Fig. 4). It was quite large (above 8,000 m/ha) in the selection and initial phase, and the largest in the juvenile and regeneration phase. In that latter phase, it was larger in 2005 than in 1995 (*P*<0.001). In the juvenile phase, the larger, but only formally, sum of heights of the regeneration in 2005 was related to the lower density of trees with a diameter at breast height of at least 8 cm.

The differences in structure, viability and transformations between stands classified in natural development phases were reflected in the majority of features of the stock dynamics measured in the period 2000–2004 (Table 2). The mean value of the current periodic volume increment differed between phases ($F_{8;151}$=3.87; *P*<0.001). However, in the case of six of them it was related to the yield – the relative increment (against the yield) showed only minor differences and was approx. 2.1% per year (Fig. 5). In stands in the juvenile and pole stand phases, largely composed of young trees, it was higher. No significance of differences in the mean values of ingrowth of tree volume (over the threshold of breast-height diameter of 8 cm) in the years 2000–2004 between phases ($F_{8;151}$=1.19; *P*=0.31) was found.

Formally, it was the largest in those stands subject to rejuvenation – in the juvenile, regeneration and late ageing phase (Table 2). The volume of tree decay in the years 2000–2004 was diversified between phases ($F_{8;151}$=3.35; P=0.001). It was the largest in stands, whose structure was subjected to transformations, i.e. in decay, late ageing and regeneration phase (Table 2). In the remaining phases, the decay was minor. In relation to the yield it did not exceed 2% per year (Fig. 5). It should be emphasised that in the 2000–2004 period almost half of the tree decays (i.e. 4.4 ±2.4 m^3/ha/year) consisted of spruce dieback as a result of infestation by the European spruce bark beetle.

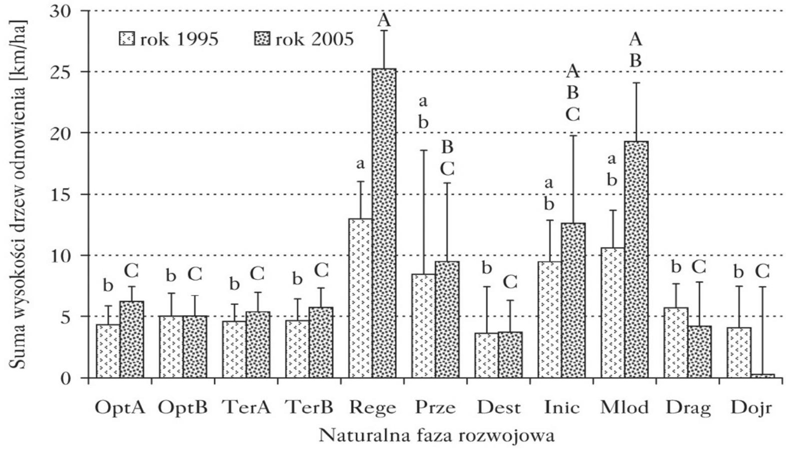

Fig. 4.
Mean (±error at P=0.05) sum of heights of regeneration trees ($d_{1.3}$<8.0 cm or h≤1.3 m) in stands in individual natural development phases in 1995 and 2005.
Values marked by the same letter did not differ significantly at p<0.05; lowercase letters – sites in 1995; capitals – in 2005. Denotations as in Fig. 1.
(Suma wysokości drzew odnowienia [km/ha] – Sum of heights of regeneration trees [km/ha] Naturalna faza rozwojowa – natural development phase)

TABLE 2
Mean±error (at P=0.05) in the dynamics of stock (m^3/ha/year] in the years 2000–2004 in stands in the natural development phases according to the situation in 2004

Phase	Number of plots	Increment	Ingrowth	Decay	Change*
early optimal phase OptA	36	8.8±1.1 ab	0.08±0.07 a	6.1±3.6 ab	0.9±4.1 a**
late optimal phase OptB	36	8.4±1.3 b	0.08±0.07 a	4.7±4.1 ab	3.2±4.5 a**
early ageing phase TerA	42	11.6±1.3 a	0.10±0.11 a	8.8±5.3 ab	2.1±5.6 a**
late ageing phase TerB	13	9.4±2.8 ab	0.16±0.19 a	21±20 ab	−12±19 ab
regeneration phase Rege	11	7.5±2.0 ab	0.27±0.35 a	12±13 ab	1.9±14 ab

Phase	Number of plots	Increment	Ingrowth	Decay	Change*
decay phase Dest	7	7.0±3.9 ab	0.13±0.32 a	34±32 a	–29±35 b
juvenile phase Mlod	5	8.1±5.3 ab	0.42±0.78 a	0.0±0.0 b	5.7±5.6 ab
even-aged-pole stage Drag	9	5.6±2.9 b	0.08±0.18 a	2.9±5.4 ab	4.1±5.4 a
BNP***	160	9.1±0.6	0.11±0.05	8.9±2.9	–0.5±3.0

* The value of change is not equal to the sum of increment and ingrowth decreased by the decay, because artificial features related to concentric plots were considered, whose total mean value in the years 2000–2004 in all stands of the Białowieża National Park was –0.75 ±0.60 m^3/ha/year

** differences at the limit of significance P=0.06–0.08

*** Białowieża National Park including 1 plot in Inic phase; values marked by the same letter in a given column do not differ at p<0.05 according to Tukey's HSD multiple comparison test.

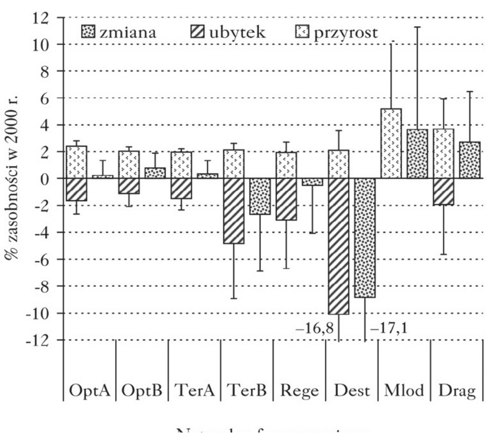

Fig. 5.
Mean (±error at *P=0.05*) annual dynamics of the current increment of volume, decay and net changes in stands in individual natural development phases in the period 2000–2004 related to the yield in 2000

In 2004 no sample plots existed in the Dojr and Prze phases, the Inic phase which included one sample plot was taken into consideration.

zmiana – change; ubytek – decay; przyrost – increment; % zasobności w 2000 r. – % of yield in 2000; Naturalna faza rozwojowa – Natural development phase; OptA – OptA; OptB – OptB; TerA – TerA; TerB – TerB; Rege – Rege; Dest – Dest; Mlod – Mlod

The net change in the yield resulting from the proportion of decay to the increment and ingrowth was also diversified between individual phases ($F_{8;151}$=3.30; P=0.002). Although the accuracy of estimation of that feature was low (due to the significant variability of the decay volume), the following groups of development phases of stands may be indicated: (1) 'developing', i.e. juvenile and pole stand phase, in which the change in yield had a relatively high positive value, (2) 'stable, slowly developing', i.e. optimal phase (early and late) and early ageing – the change in yield was slightly above zero, (3) 'stable, slowly transforming', i.e. regeneration phase – the change in yield was slightly less than zero, and (4) 'unstable, quickly transforming', i.e. late ageing and decay phase – the change in yield was negative (Table 2, Fig. 5).

Discussion

In the Białowieża National Park (in the former Strict Reserve), a significant part of its area (approx. ¾) was occupied by stands ranked into optimal and ageing phases, which was compliant with a description by Twaróg (1991). However, over a ten-year-period the proportions of frequency of these phases have changed, so it is hard to answer the question about the frequency of individual natural development phases in a natural forest. Apart from diverse intensity of dieback of trees or complete fragments of forest, this proportion is determined probably by the habitat, species composition and period elapsed since bringing the given forest under conservation. In comparison to the data by Leibundgut (1982) concerning spruce-beech-fir mountain forests (developed on the basis of studies on the Peruciča and Dobroč reserves), in the Białowieża National Park the frequency of the optimal phase was larger, of the decay phase smaller, and of the selection phase scant. The differences concerned also the proportions of yield between individual development phases. In the Białowieża National Park, they were similar to those in the Peruciča reserve. The yield of the ageing phase may be treated as a maximal one (approx. 560 m^3/ha), which is achieved by stands under the given conditions of a large site (approx. 1,000 ha), and are not applicable to single small sites. In this context, it should be indicated that phases with the regeneration process underway or in which the regeneration was solidified, covered a relatively small area (approx. 12–14%), but the renewal count measured by the sum of tree heights was at the level considered to be optimal, i.e. 8,000–12,000 m/ha (Bernadzki 1965). However, a separate problem may be deemed the change in species composition of regeneration as a consequence of damage caused by ungulates (Kuijper et al. 2010).

The extensive presence of spruce in stands of the Białowieża National Park, its diverse frequency and better resistance to European spruce bark beetle when growing on fertile sites, and first of all moist ones, have variously affected the pace of spruce dieback, thus changes in stand structure and frequency of the development phases. Three kinds of situation might be distinguished. In the first one, the intensive tree dieback in stands with a high share of spruce led to the formation of the decay phase (and then the initial one) and created conditions for potential regeneration of heliophilous species. In the second one, with quite even self-thinning of stands led to the formation of the regeneration and late ageing phase, which favoured regeneration occurring in half-shade, on a relatively large area. In the third one, small blanks emerged as a result of the elimination of single trees or small groups, associated with the existence of the early ageing and sometimes late ageing phase, which allowed the regeneration of shade-tolerant species on small isolated areas. Bobiec et al. (2000) generalised similar processes in the form of a cycle of phases. The impact of European spruce bark beetle on the stands of the Białowieża National Park was compliant with the opinion of Bobiec (2002) who stated that in the situation of the absence of fires, when most stands grow on 'non-flammable' fertile and moist habitats, the main factors affecting their structure are insect gradations and windthrow.

That research has confirmed Koop's opinion (1989) that classification of the stand to the given natural development phase is not fully repeatable and depends on personal interpretation. The main reason was that the rating of a given forest area into a development phase results from the synthesis of numerous features. The mosaic-like structure of the forest, hampering the delineation of boundaries between phases, creates an additional difficulty in the Białowieża National Park. In this context, the study by Meyer (1999) deserves attention. He proposes an algorithm to distinguish the six development phases he defines. He used features gathered from repeated measurements of a given forest area – stock growth coefficient, stock compensation coefficient (ratio of decays to ingrowths and increments), and in the case of some phases also the present maximum diameter at breast height and the level of coverage by the regeneration. However, the arbitrarily adopted threshold values meant that in seven surveyed sites only one phase, the optimal one, covered 67–98% of the area. The author predicted that his method might be used to distinguish development phases on sample plots, into which the experimental area was divided, or on random sample plots. However, such an approach seems to be problematic. The sample plots serve for gathering data to characterise previously distinguished interpretation units, in this case natural development phases. That is how it was conducted in this study. The inversion of the situation – distinguishing development phases on the basis of features measured inside the sample plot, on a small forest fragment being subject to high variability, may lead to erroneous results.

Conclusions

- In the years 1995–2005, in the former Strict Reserve of the Białowieża National Park, a change in the frequency of areas of individual natural development phases of stands occurred, the main reason for which should be sought in the spruce dieback resulting from the impact of European spruce bark beetle.
- The renewal of stands in the Białowieża National Park took place according to various methods: (1) on large open areas (decay and initial phase), (2) on areas distributed in form of strips or groves, under an opened canopy of old trees (regeneration phase and sometimes late ageing phase), (3) in small blanks completing the parent layer of the stand (early optimal phase and sometimes late ageing phase), and (4) continuously, gradually filling in of places after individually declining trees (selection phase).
- A long-term observation of changes in the development phases, conducted on permanent sample plots, is recommended, which would allow the understanding of the pace of transition of stands from one phase to another, and of the cycle of these transformations in the stands of the Białowieża National Park.

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Long-term dynamics of old-growth stands in the managed part of the Białowieża Forest: expansive and declining species*

Introduction

The Białowieża Forest constitutes a forest range valued and inimitable in scientific, environmental and educational terms on the European scale. The specificity of the Białowieża Forests is manifested in the occurrence of mixed-species, uneven-aged and multi-storey stands to which the term 'primeval' is applied, in which trees reach dimensions found nowhere else in other regions of our country. Examples of such stands can be found in the managed part of the forest by old-growth stands, for which since the end of 1940s there has been a search for management methods that would allow maintaining their primeval character. The multiply demanded foundation of woodland management in the Białowieża Forest was to be the maintenance and restitution of a diversified species composition and structure of stands and production of high-value thick assortments achievable over a very long production period (Graniczny 1968; 1969]. It was thought that in stable stands characterised by high biological resistance, special large-sized timber could be obtained (Graniczny 1957a, b).

In order to determine optimal methods for the regeneration of major forest-forming species in the old-growth stands of the Białowieża Forest, five sample plots were established in 1949 in the most frequent forest habitat types (fresh mixed coniferous forest, fresh mixed deciduous forest, fresh deciduous forest, moist deciduous forest and alder-ash carr). The research results were to uncover such a method of management of unique primeval stands, which would serve the maintenance of their natural character with a simultaneous accomplishment of economic objectives. Those plots constituted a logical supplement to a series of research plots established in the Strict Reserve of the Białowieża National Park in 1936.

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The research was to answer the question about the impact of conducted silvicultural treatments on the species composition and structure of stands, in comparison with the Strict Reserve of the Białowieża National Park (Włoczewski 1954; Bernadzki 1999).

This study aimed at determining the dynamic status of tree species present in old-growth stands in the managed part of the Białowieża Forest in the years 1949–2006 on the basis of three population-related parameters: 1) density, 2) basal area, and 3) mean diameter at breast height. The research results allowed the determination of which tree species present in old-growth stands might be rated as expansive and which as declining, as well as whether the dynamic status of these species is similar as in the Strict Reserve of the Białowieża National Park (Brzeziecki et al. 2012).

Material and methods

Permanent sample plots in the managed part of the Białowieża Forest were established in 1949 in stands of complex structure (mixed-species and uneven-aged) in the following forest habitat types and in the following compartments: fresh mixed coniferous forest (526C), fresh mixed deciduous forest (312A), fresh deciduous forest (582A), moist deciduous forest (334D) and alder-ash carr (582C) in the territory of the Białowieża and the Hajnówka Forest Districts. The sample plots measure 100 m × 200 m (except 582C, which is 50 m × 260 m large) and cover 9.3 ha in total. After the establishment of the plots, a master's thesis within the scope of the silvicultural planning was completed on each of them (Dudek 1950; Grabowski 1950; Sieczkowski 1950; Mierzejewski 1951; Niedźwiedzki 1951) under the guidance of Professor Tadeusz Włoczewski from the Department of General Silviculture, SGGW [Warsaw University of Life Sciences].

In the years 1949–1954, the Department of Silviculture of the Forest Research Institute conducted intensive research works on the sample plots on the possibility of renewing major forest-forming species with use of the patch-selection system (Graniczny 1979). To that end, both natural and artificial renewals of species relevant for the forest habitat types were initiated. The regenerations were conducted mainly under the conditions of side shelter from the parent stand on patches of various shapes and sizes, as well as in naturally formed blanks. In that way, pine, oak, and alder were regenerated artificially, mainly through seeding, more seldom through planting. Other species (ash, elm, maple, linden, spruce and birch, but also pine, oak and alder) were to regenerate naturally. In addition, regenerations were conducted with shelterwood cutting of diverse intensity considering the biology of individual species. Spruce, linden, maple and hornbeam were regenerated in that way.

In the years 1955–1975, on sample plots, only single-tree and so-called 'group selection cutting' was conducted i.e. patch cutting on an area not exceeding two to 5 are. From 1975 to 2006 (except the area where the Dębowy Grąd reserve was established in 1985

(334D), as well as the 'Natural Woodlands of the Białowieża Forest' in 2003 (582A, 582C)), only sanitation cuts were carried out. In that time, the treatment had the nature of extensive management, expressed by felling single trees in the stand and governed mainly by the forest protection considerations.

In 1949, the first detailed inventory of stands (P1) was performed on sample plots. During further research works, five subsequent inventories were carried out (P2 – 1963 (1960–1966); P3 – 1970 (1968–1972); P4 – 1986; P5 – 1996 and P6 – 2006), consisting in the accurate determination of the tree coordinates on the plot and in the measurement of the diameter at breast height with a simultaneous determination of the health condition and its stand layer affiliation. The diameter at breast height was measured in two perpendicular directions with an accuracy of 1mm, with a simultaneous recording of all eliminated trees and ingrowths, i.e. trees with diameter at breast height exceeding 7 cm (5 cm starting from the fourth inventory).

In this paper data concerning the density of trees of individual species (N), their basal area (G) and the mean diameter at breast height (Dg) accumulated for all plots and converted per hectare are used. Considered were only trees exceeding the diameter at breast height of 7 cm at each subsequent inventory. The species were grouped according to the mean share, determined on the basis of the tree count, for the entire research period, into dominant (above 20%), codominant (5–20%) and admixture (up to 5%), and then their dynamic status was described.

Results

In the years 1949–2006, on the permanent research plots of the Department of Silviculture SGGW [Warsaw University of Life Sciences] in old-growth stands of the Białowieża Forest, the tree density was subject to the biggest changes, fluctuating between 445 pcs/ha at the second inventory to 593 pcs/ha at the fifth inventory (Fig. 1a). Also, the basal area was also subject to change. It was the smallest after the regeneration cutting in the early 1950s (29.3 m^2/ha), and then it continued to grow regularly until the last inventory in 2006 (35.1 m^2/ha). The average diameter at breast height of all trees was the most stable feature, as it was changing only slightly, within the range from 27.0 to 30.2 cm (Fig. 1a).

Over almost 60 years of observations, it was possible to observe periodic changes in the share of individual species, both with regard to the count of trees and the stand basal area. With regard to the count of trees, throughout the research period the following species may be assigned to the groups as follows: dominant species – spruce and hornbeam, codominant species – ash, alder, and oak, admixture species (scarce) – the remaining analysed species, i.e. linden, birch, maple, pine, elm, aspen, rowan and goat willow. The species structure with regard to the frequency of the basal area differed slightly (Table).

In the group of dominant species, the highest share over the entire research period was spruce, although it decreased from 50% to 35% with regard to the count of trees and from 38% and 39% (at the second and third inventory) to 33.7% in the last inventory with regard to basal area (Table). Its density decreased from 242 to 193 pcs/ha, at a slight increase in the basal area (11.1–12.7 m^2/ha), which resulted in an increase of the mean diameter at breast height from 24.8 to 28.0 cm (the highest value of Dg was observed at the fourth inventory and was 28.9 cm) (Fig. 1b). The changes in the above-described parameters indicate a relatively safe status and stable share of spruce in old-growth stands of the managed part of the Białowieża Forest.

The share of hornbeam increased from 11.5% (at the second inventory) to almost 39% with regard to the count of trees, while with regard to the basal area from 9.5% to 14.5%. Starting from the second inventory, both its density and the basal area demonstrated a permanent upward trend (from 51 to 214 pcs/ha) and (from 2.8 to 5.1 m^2/ha) (Fig. 1c). In the entire research period the mean breast-height diameter was decreasing regularly (from 33.2 to 17.0 cm), which demonstrates the intense rejuvenation of the hornbeam population and its strong expansion.

The species ascribed to the codominant group was ash, the share of which with regard to the count of trees increased initially from 5.8% to 16.7%, to again decrease to 6% in the last period. That species increased its density from 28 pcs/ha in 1949 to 99 pcs/ha in 1996, however its intensive dieback, which occurred after 2000, led to a decrease in its count in 2006 almost back to the initial state (33 pcs/ha). Also, the basal area, which was regularly increasing from the second inventory (from 2.3 to 4.2 m^2/ha in 1996), decreased in 2006 to 2.8 m^2/ha (Fig. 1d). The mean diameter at breast height was subject to significant fluctuations from 1949, decreasing in parallel to the population rejuvenation from 37.7 cm to 21 cm, and then suddenly increased to 33 cm in 2006 as a result of dieback of usually young ash trees. For this reason, ash has changed from an expansive species to a declining one.

Another codominant species was alder, where the share fluctuated only slightly throughout the research period, both with regard to the count of trees (from 7.4% to 9.8%) and basal area (from 8.9% to 10.3%). The density of alder remained at a nearly unchanging level and was on average 44 pcs/ha (Fig. 1e). The basal area was also subject to insignificant fluctuations (from 2.6 to 3.6 m^2/ha). The mean diameter at breast height remained within the range 27.5 to 32.8 cm. This is an indication that that species is relatively safe and maintains a stable share in stands of the managed part of the Białowieża Forest.

The last species rated as codominant is oak. Although its share decreased from 8.2% to 4.9% with regard to the count of trees, it increased from 14.7% to 22.3% with regard to basal area, as it grew systematically from the first inventory at 5.1 to 7.8 m^2/ha (Fig. 1f). At the same time, the density of trees continued to decrease (from 40 to 27 pcs/ha) and the mean diameter at breast height increased (from 40.5 to 60.6 cm). This indicates unambiguously the quick ageing of the oak population, thus classifying it to the group of declining species.

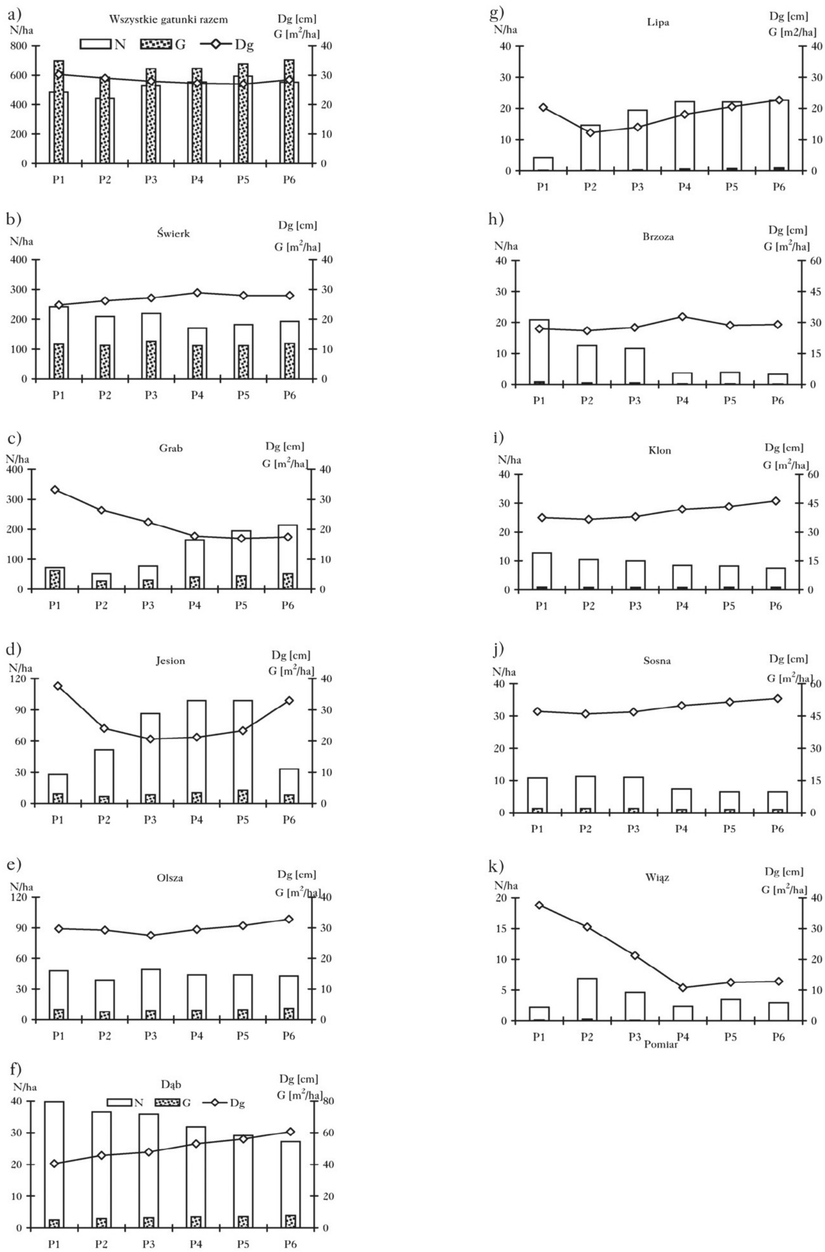

Fig. 1.
Changes in the count of trees (N), basal area (G) and average diameter at breast height (Dg) of all trees

(a) and individual species (b–k) in old-growth stands of the Białowieża Forest at subsequent inventories (P1 – 1949; P2 – 1963; P3 – 1970; P4 – 1986; P5 – 1996 and P6 – 2006)

(N/ha – N/ha; Wszystkie gatunki razem – All species together; Dg [cm] – Dg [cm]; G [m²/ha] – G [m²/ha]; N – N; G – G; Dg – Dg; Lipa – Linden; Świerk – Spruce; Brzoza – Birch; Grab – Hornbeam; Klon – Maple; Jesion – Ash; Sosna – Pine; Olsza – Alder; Wiąz – Elm; Dąb – Oak)

TABLE

Structure [%] of species composition of stands on permanent research plots in old-growth stands of the Białowieża Forest at subsequent inventories (P1 – 1949; P2 – 1963; P3 – 1970; P4 – 1986; P5 – 1996 and P6 – 2006)

Species	Count of trees							Basal area						
	P1	P2	P3	P4	P5	P6	Av.	P1	P2	P3	P4	P5	P6	Av.
Spruce	49.9	47.0	41.6	30.7	30.7	34.9	39.1	33.5	38.3	39.3	34.5	33.0	33.7	35.4
Hornbeam	14.9	11.5	14.8	29.7	32.8	38.7	23.7	18.0	9.5	9.5	12.5	13.0	14.5	12.8
Ash	5.8	11.6	16.4	17.9	16.7	6.0	12.4	8.9	8.0	9.0	10.8	12.5	8.1	9.6
Alder	9.8	8.7	9.3	7.9	7.4	7.7	8.5	9.5	8.9	9.1	9.2	9.6	10.3	9.4
Oak	8.2	8.2	6.8	5.7	4.9	4.9	6.5	14.7	20.4	20.0	21.8	21.2	22.3	20.1
Linden	0.9	3.3	3.7	4.0	3.7	4.1	3.3	0.4	0.6	0.9	1.8	2.2	2.6	1.4
Birch	4.3	2.8	2.2	0.7	0.7	0.6	1.9	3.4	2.3	2.1	1.0	0.7	0.6	1.7
Maple	2.6	2.3	1.9	1.5	1.4	1.4	1.9	4.0	3.7	3.5	3.6	3.6	3.6	3.7
Pine	2.2	2.5	2.1	1.3	1.1	1.2	1.7	5.4	6.4	5.9	4.4	4.0	4.1	5.0
Elm	0.5	1.5	0.9	0.4	0.6	0.5	0.7	0.7	1.7	0.5	0.1	0.1	0.1	0.5
Aspen, rowan, goat willow	0.9	0.5	0.4	0.2	0.1	0.1	0.4	1.4	0.3	0.3	0.3	0.2	0.2	0.5

The most numerous species belonging to the group of admixture species was linden, whose share increased regularly throughout the entire research period both with regard to the count of trees (from 0.9% to 4.1%) and basal area (from 0.4 to 2.6%). The density of trees from that species increased from 4.2 to 22.6 pcs/ha and basal area grew from 0.1 to 0.9 m^2/ha (Fig. 1g). Also, the average diameter at breast height, except for the first and second inventory, when it was 20.3 and 12.2 cm respectively, grew continuously until reaching 22.7 cm. It proves that the population of that species, despite the small count of trees at the beginning of the study, continued to develop intensively, such that and now it may be considered expansive.

The other tree species, i.e. birch, maple and pine, due to their small and regularly decreasing shares (Table), tree densities and basal areas (Fig. 1h–j), accompanied by increases in mean diameter at breast height, should be regarded as ageing populations, thus declining.

The declining process of elm (Fig. 1k) is very specific, the mean breast-height diameter has decreased significantly, which proves that at present young trees prevail in the population (at the three last inventories the mean diameter at breast height fluctuated between 11 and 13 cm), but they do not advance to higher size classes. Currently, the share of this species in the surveyed stands is marginal and does not exceed 0.5% of the count of trees and 0.1% of the basal area (Table).

The remaining species, such as aspen, goat willow and rowan, which already at the beginning of the research period in 1949 been considered a scarce admixture, in 2006 had almost completely declined (Table). For example, on all the sample plots (in total 9.3ha) at the last inventory, only two aspen trees were present.

Discussion

The results obtained indicate a diverse dynamic status of the tree species present in old-growth stands of the Białowieża Forest. While considering the dynamics of the presented population-related parameters (density, basal area and mean diameter at breast height) in the years 1949–2006, they may be ranked in the following sequence (from expansive to declining species): hornbeam, linden, alder, spruce, oak, ash, maple, pine, birch, elm and aspen. This ranking is close to a similar ranking prepared for the Strict Reserve of the Białowieża National Park (Brzeziecki et al. 2012), which proves that in an extensively managed forest, the processes which occur are similar to those in forests excluded from direct human activity.

The most expansive species in the old-growth stands were hornbeam, linden and, in some periods, ash. All these species increased their share intensively within the period covered by the research. The count of hornbeam doubled, while linden, which was scarce in 1949, saw a five-fold increase. The intense development of the ash population (by a factor of three) was stopped by a sudden dieback of that species after 2000. In the first instance, young ash trees died back, which resulted in a large reduction in the count of trees and an increase in the mean diameter at breast height of that species, which also happened in the Strict Reserve of the Białowieża National Park, and is why the regeneration of the ash population may take a very long time (Brzeziecki et al. 2012). Due to the ash dieback, only hornbeam and linden were classified as expansive species, while ash was rated as a declining species.

The development of the alder and spruce populations looked relatively stable. Although the population-related parameters of those species were subject to some changes, both those species maintained their high share with regard to the count of trees and basal area. Spruce in the Strict Reserve of the Białowieża National Park (Brzeziecki et al. 2012) behaved differently, where most stands with a dominant share of that species in poorer habitats entered the decline phase. That process did not occur in old-growth stands of the managed part of the forest, e.g. on plots 526C (fresh mixed coniferous forest) and 312A (fresh mixed deciduous forest). Well-performed prevention by the forest administration, consisting in the regular removal of so-called 'sawdust' trees, and thus limiting the expansion of harmful insects, has contributed to the conservation of spruce stands.

The most numerous group in old-growth stands consisted of declining species: oak, maple, pine, birch, aspen, mountain ash and goat willow. The first four species of these behaved similarly with regard to the population-related parameters. In each case, the tree density and the basal area decreased (except for oak), while the mean diameter at breast height grew. For all these species, over the six decades of observations, no ingrowth exceeding the measurement threshold (7 cm) was recorded. This picture is typical for ageing populations, whose pace of decline depends on species longevity. Another declining species is elm, threatened by the Dutch elm disease, which was regenerating but also quickly declining at a young age. The other species, such as aspen, rowan and goat willow, were very scarce throughout the entire research period and for that purpose they were deemed declining from old-growth stands of the Białowieża Forest.

The dynamics of development of the populations of forest tree species in old-growth stands of the managed part of the Białowieża Forest strictly coincides with the history of direct human impact, i.e. performed silvicultural treatments. From the very beginning of the establishment of sample plots, these stands have been managed according to the patch selection cutting system, which was to ensure the renewal of major forest-forming species (oak and pine), with the simultaneous maintenance of the so-called primeval character of stands. Various regeneration cutting was performed, usually extending naturally formed blanks in the stand, establishing new patches, as well as opening selected parts of stands (shelterwood cutting). For maintenance treatments, the species of greater economic significance were preferred. However, the large red deer and bison population hampered the regeneration. In 1960s and 1970s, biogroup [group selection] cutting was applied primarily (Graniczny 1979), facilitating the regeneration of half-shade tolerant species, in particular hornbeam and linden. In the 1980s and 1990s, sanitation cutting treatments were performed, in the form of single-tree and small-group cutting (e.g. in 'bark beetle infested patches'), and continued until the establishment of nature reserves on plots 334D, 582A and 582C. The last cutting and the subjection of the mentioned plots to conservation, thus a cessation of silvicultural works, contributed even more to the expansion of half-shade tolerant species.

Practically across the entire research period, stands in the regeneration phase or regenerations with a relatively high basal area (29–35 m^2/ha) occurred on the plots. Spruce was intensively regenerating and advancing in the mixed coniferous forest and mixed deciduous forest habitats, ash and partially alder in the alder carr habitat (Brzeziecki, Żybura 1998), linden in the moist deciduous forest habitat, while hornbeam dominated the habitats of fresh mixed deciduous forest, fresh deciduous forest and moist deciduous forest, as well as appearing independently in habitats less appropriate for that species, such as fresh mixed coniferous forest and alder-ash carr (Brzeziecki, Drozdowski 2005).

As a result of silvicultural works conducted with use of the patch selection system, the primeval nature of stands on the sample plots was maintained, but the achievement of oak and pine renewal was not successful, although they are important from the economic and environmental point of view. The directing of mixed-species stands, whose species composition includes species with diverse lighting requirements with the use of the patch selection system is difficult and requires intensive regeneration and maintenance works, abandonment of which leads to the domination of the bottom stand storeys by more expansive species. Hornbeam is one such species, as it hampers the renewal of other species in the habitats of fresh mixed deciduous forest, fresh deciduous forest and moist deciduous forest. For a long period, ash was also such a species, outperforming alder, particularly under opened stand canopies. Limitations in forest management, introduced for nature conservation reasons, especially in the last research period when only sanitation and protective cutting were applied, were also important. This led to the occurrence of very similar processes to that in the strict reserve of the Białowieża National Park, i.e. to a homogenisation of forest communities through hornbeam domination connected with the successive retreat of oak, pine, maple and other less numerous species (Bernadzki et al. 1998a, b). However, it should be clearly emphasised that this process in old-growth stands of the managed part of the Białowieża Forest is not as advanced as in the Strict Reserve of the Białowieża National Park. This is mainly thanks to the previously conducted silvicultural treatments (regeneration treatments, stock maintenance and structure regulation), upon which the growth conditions for threatened species were being improved, thus the preservation of the high biodiversity of these stands, which conditions their high environmental values, was promoted.

Conclusions

- In old-growth stands of the managed part of the Białowieża Forest, in the years 1949–2006, hornbeam and linden were considered expansive species, alder and spruce were stable species, and oak, ash, maple, pine, birch, elm and aspen were declining species.
- In old-growth stands of the managed part of the Białowieża Forest, one may observe very similar processes to those that take place in the Strict Reserve of the Białowieża National Park, i.e. a homogenisation of forest communities, caused mainly by the expansion of hornbeam, combined with a successive retreat of oak, pine, maple and other less numerous species.
- The process of homogenisation of forest communities in old-growth stands of the managed part of the Białowieża Forest is not as advanced as in the Strict Reserve of the Białowieża National Park, thanks to previously conducted silvicultural treatments, which improved the growth conditions for threatened species, thus supporting the conservation of the species-related diversity of those stands.

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Arkadiusz Bruchwald, Elżbieta Dmyterko

Threat of wind damage to forests on the example of forest districts in the Białowieża Forest*

Introduction

Forests in north-eastern Poland are characterised with a high risk of damage caused by wind. This was demonstrated by the hurricane of 2002, which severely damaged the woodlands of Piska, Borecka and Kurpiowska Forests (Mikułowski 2002; Filipek 2008), as well as the 'white squall' of 2006, which seriously damaged the stands of Piska Forest. Damage caused by wind also happen in the stands of the Białowieża Forest. The largest of them, estimated at 440,000 m^3 of wind-broken trees, windthrows and snags, occurred in 1983 (Kawecka, Gutowski 1988).

Bruchwald and Dmyterko (2010) published models of wind damage risk to stands. In the course of further research, some of their elements have been improved (Bruchwald, Dmyterko 2011, 2012). The selected model may be applied to determine the damage risk factor for every stand in a given forest range. The higher the factor, the more likely the occurrence of damage to the stand in the case of strong wind. A high share of stands with high values of the risk factor proves the high threat to the forests in the studied area.

This goal of the paper is to present the results of applying models of wind damage risk to stands in the forest districts of the Białowieża Forest, without consideration of the Białowieża National Park. In this way it shall allow the determination of the wind damage risk factor for each stand, and then for the assessment of the threat to the forest. The most important factors shaping the threat to the woodlands of the forest shall be discussed.

Material and methods

The Białowieża Forest, situated in the north-eastern part of Poland, is located on the Bielsk Plain, a part of the North Podlasie Lowland (Kondracki 2002). It covers an area related to the

* The study was carried out in the framework of the research project 'Development of simulations of threats from abiotic factors to forest ecosystems' commissioned by the Directorate-General of the State Forests. The results were presented in part at the Conference 'Diversity of ecosystem conservation forms within the forest management planning in the 'Natura 2000 Site Białowieża Forest" held on 19–20 May 2011 in Białowieża.

recession of the Warta Glaciation. The kame hills, visible on the plain, originate from that period (Kondracki 2002). From among geological formations, glacial sands with boulders prevail, in some places on boulder clay, as well as the landscape of periglacial plains. Due to its environmental values, the forest range was distinguished as an independent Białowieża Forest Division of the Masovian-Podlasie Region in accordance with the natural-forest regionalisation by Trampler et al. (1990). The forest is located in the subboreal ecoclimatic zone, macro-region of Wysoczyzna Białostocka (Trampler et al. 1990), and according to the geobotanical division in the Northern Division, Bielsk-Knyszyn Subdivision and the Białowieża Forest Region (Szafer 1978).

The compact territory of the forest is split by the state border into its eastern part in the territory of Belarus, and the western part, in Poland. In the Polish part, the forests are administered by the Browsk, Hajnówka and Białowieża Forest Districts and the Białowieża National Park. The presented study results concern only stands of these three forest districts.

The research material was gathered from the database of the State Forests IT System (SILP). It comprises inventory features of each stand and the volume of harvested wind-broken trees, windthrows and snags in the individual forest districts from the period 2004–2010. An original piece of software was used to process the data, applying algorithms for the models of damage risk to a stand (Bruchwald, Dmyterko 2010) and stand growth (Bruchwald 1986). In addition, for spatial analyses of the threats to stands, digital maps of the given forest districts were also applied.

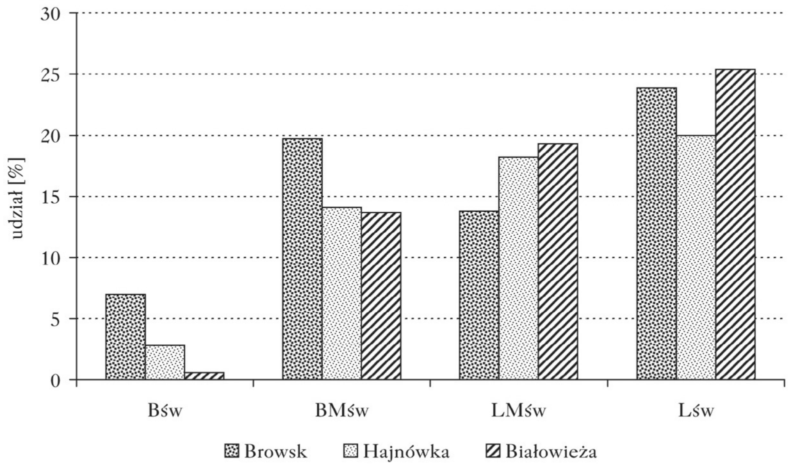
The Białowieża Forest is characterised by a great diversity of habitats. Among fresh habitats, the fresh deciduous forest is dominant, with a share in the Białowieża Forest District exceeding 30% (Fig. 1). The share of fresh mixed deciduous forest is also high, just like the share of fresh mixed coniferous forest in the Browsk Forest District. Moist deciduous forests dominate among moist habitats, and the share of alder-ash carr (OlJ) is significant (Fig. 1).

While determining the species composition, the level [i.e. form] of species mixture in the stand was considered, regardless of the height of its share. In the Białowieża and Hajnówka forest districts, the most represented species is spruce, while in the Browsk Forest District is pine (Fig. 2a). The accumulated share of spruce and pine in the districts of the forest exceeds 50%. Alder dominates among deciduous species. The share of ash is also significant, exceeding 5% in the Białowieża Forest District, while the share of aspen, linden, and maple is low (Fig. 2b).

The research area is characterised by a high share of old stands, aged more than 100 years (Fig. 3). Most of them grow in the Białowieża (35%) and Hajnówka (25%) forest districts.

The share of the stands of age class V is high, and in the Browsk and Hajnówka forest districts also of class III and IV. There are very few stands of age class I, and in the Białowieża Forest District also of class II.

a)



b)

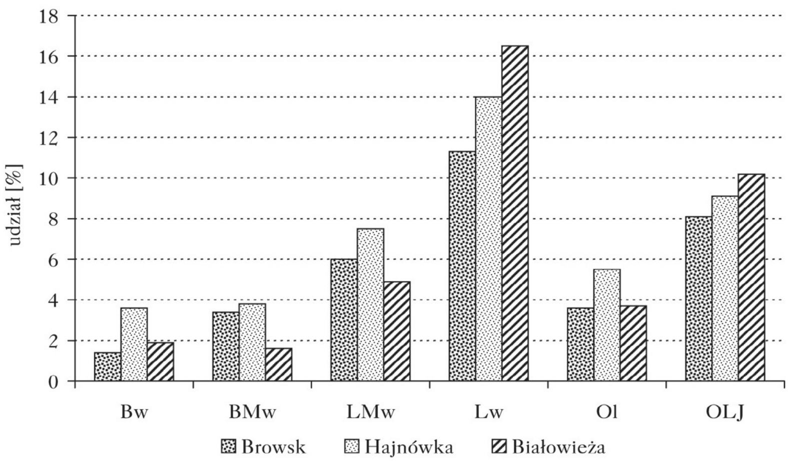


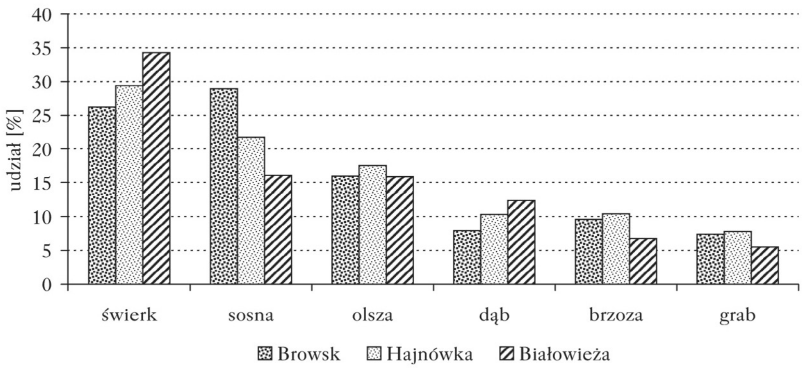
Fig. 1.
Area-related share of fresh (a) and moist (b) forest habitat types in the Białowieża Forest districts.

(udział [%] – share [%]; Bw – Moist coniferous forest; BMw – Moist mixed coniferous forest; LMw – Moist mixed deciduous forest; Lw – Moist deciduous forest; Ol – Alder carr; OLJ – Alder-ash carr)

No clearcutting-based forest management system is applied in the forest districts of the Białowieża Forest. The forests have been divided into two types of management units: a management unit with clear- and selection cutting, and a special management unit (Fig. 4). The first of them, dominating in the Browsk and Hajnówka forest districts, requires the application of complex cutting systems, e.g. shelterwood cutting or irregular shelterwood cutting systems. The use of natural regenerations is assumed, mainly for high-value tree species: oak, ash, elm, linden, and others. The management unit of special type is composed of strict and partial nature reserves, which dominate in the Białowieża

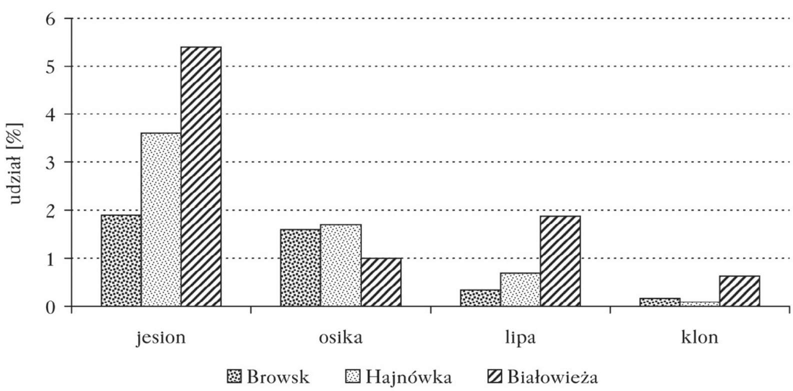
Forest District. Stands of strict reserves are not subject to human interference, while partial reserves are managed in accordance with approved plans.

a)



(udział [%] – share [%]; świerk – spruce; sosna – pine; olsza – alder; dąb – oak; brzoza – birch; grab – hornbeam)

b)



(udział [%] – share [%]; jesion – ash; osika – aspen; lipa – linden; klon – maple)

Fig. 2.
Actual share of tree species in forest districts of the Białowieża Forest: a) – tree species with high share of the area; b) – tree species with low share of the area.

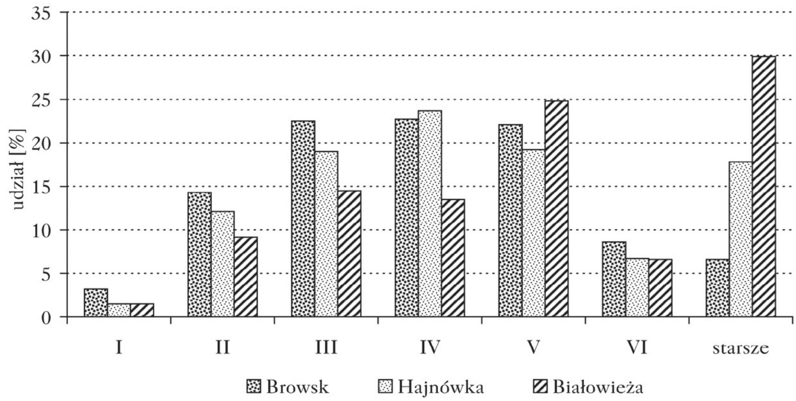


Fig. 3.
Area-related share of stands in age classes.

udział [%] – share [%]; starsze – older

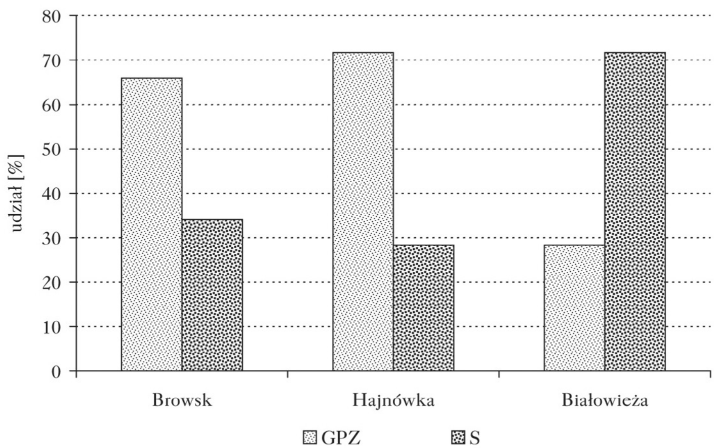


Fig. 4.
Area-related share of the management units: with clear- and selection cutting (GPZ) and special (S) in the forest districts of the Białowieża Forest.

(udział [%] – share [%])

Results and discussion

The damage risk models define for individual stands a risk damage factor ranging from 0 to 3. A higher factor value corresponds with a higher probability of occurrence of damage caused by wind.

The wind damage risk models for stands are based on four groups of features:

1. variable features of the stand,
2. permanent features of the stand,
3. location of the forest district, thus forest stand, in a particular region of Poland,
4. value of damage emerged in the stand in recent years.

For the first group of features, model I stand damage risk was developed using the formula:

$$R_1 = 0.505 \cdot X_1 + 0.030 \cdot X_2 + 0.240 \cdot X_3 + 0.160 \cdot X_4 + 0.065 \cdot X_5 \quad [1]$$

where:

X_1 – average height of the major species,
X_2 – age of the major species,
X_3 – species composition of the stand,
X_4 – slenderness of the major species,
X_5 – stocking index.

The sum of weights in the formula [1] comes to 1, while the value of the weight assigned to a given feature testifies its impact on the stand damage risk factor. The highest importance is ascribed to mean height of the major species, followed then by the species composition of the stand. The age of the major species is sparsely significant, although it is considered in the mean height, with which it coincides.

From among the permanent features of the stand, the forest habitat type is considered. Following the transformation of that feature to $X6$, model II of the stand damage risk was developed, where the risk factor was defined by the following formula:

$$R_2 = R_1 + X_6 \quad [2]$$

The conducted analysis of the spatial distribution of damage in the forests in Poland shows that the highest threat concerns stands of forest districts of the Regional Directorates of the State Forests in Wrocław, Katowice, Olsztyn, Białystok, and Gdańsk, while it is the lowest in the Regional Directorates in Warsaw and Lublin (Bruchwald, Dmyterko 2011]. Those data allowed the determination of a regional stand damage risk factor for each individual forest district in Poland. The value of this factor ranges from 0 to 3, thus from small to very high threat. For the Białowieża Forest, the factor of the regional stand damage risk amounts to 2, which means a high threat.

By transforming the regional damage risk factor to X_7, the formula [2] was modified, creating model III of stand damage risk:

$$R_3 = R_2 + X_7 \quad [3]$$

Wind usually does not destroy the entire stand, but only a part of it. In a damaged stand, the probability of emergence of further damage during another strong wind grows. With consideration of the SILP [IT system of the State Forests] data on the volume of wind-broken trees, windthrows and snags harvested over the last ten years, the feature X_8

was introduced to the formula [3], thus leading to the formation of model IV of stand damage risk:

$$R_4 = R_3 + X_8 \quad [4]$$

The model of stand damage risk will still undergo further improvements. It will be used to verify the impact of the stand neighbourhood on the risk of its damage, while for mountain stands the impact of elements of topographic relief.

In the years 2004–2010, in the Białowieża Forest no greater damage caused by wind occurred. Assuming the volume of harvested wind-broken trees and windthrows as the size of damage, it was ascertained that the damage in the Browsk Forest District reached its maximal extent of up to 10,000 m^3 of wood raw material in 2005, in the Hajnówka Forest District of 8,000 m^3 in 2007, while in the Białowieża Forest District of 3,500 m^3 in 2005 and 2007 (Fig. 5). A larger damage [extent] is obtained when, apart from the volume of wind-broken and wind-thrown trees, the snag volume is considered as well. In such a case, damage caused not only by the wind impact will be included, but also due to other factors, e.g. sinking groundwater level, insect gradation or infectious tree diseases. In certain years the harvested volume of such raw material in the Browsk Forest District exceeded 20,000 m^3, in the Hajnówka Forest District – 14,000 m^3, and in the Białowieża Forest District – 22,000 m^3 (Fig. 5). Spruce dominated among the harvested tree species. In the Białowieża Forest District, its share was approx. 90%. In the Browsk Forest District, quite a lot of pine and oak was removed, and in the Hajnówka Forest District – pine and birch (Table 1). The windstorm in March 1983 caused very serious damage to the stands. In consequence, the following volume of wind-thrown trees, wind-broken trees and snags was harvested in the individual forest districts: Browsk – 150,000 m^3 of wood raw material, Hajnówka – 149,000 m^3 and Białowieża – 121,000 m^3. Considering the 20,000 m^3 from wind-thrown trees in the strict reserves, the total volume was 440,000 m^3. Among the harvested tree species, spruce prevailed (64%), followed by pine (14%), birch (8%), aspen (5%), oak (4%), and alder (3%) (Kawecka, Gutowski 1988).

By applying the model IV of stand damage risk, a damage factor risk was calculated for each individual stand of the particular forest districts. Then, six classes of that factor were created, each 0.5 wide, to which the individual stands were assigned. The higher the class of risk factor indicates stands under greater threat. A share of the area of forest stands was calculated for every class (Table 2). A characteristic feature of the Białowieża Forest districts is the very low share of stands in the three lowest classes of damage risk factor. This results from the low share of young stands, in particular plantations and sapling stands. Most stands, i.e. almost 50%, belong to class 5, with values within the range 2.0–2.5. Many stands are class 6, with the factor range of 2.5–3.0. In the Białowieża Forest District, this share is approx. 34% (Table 2).

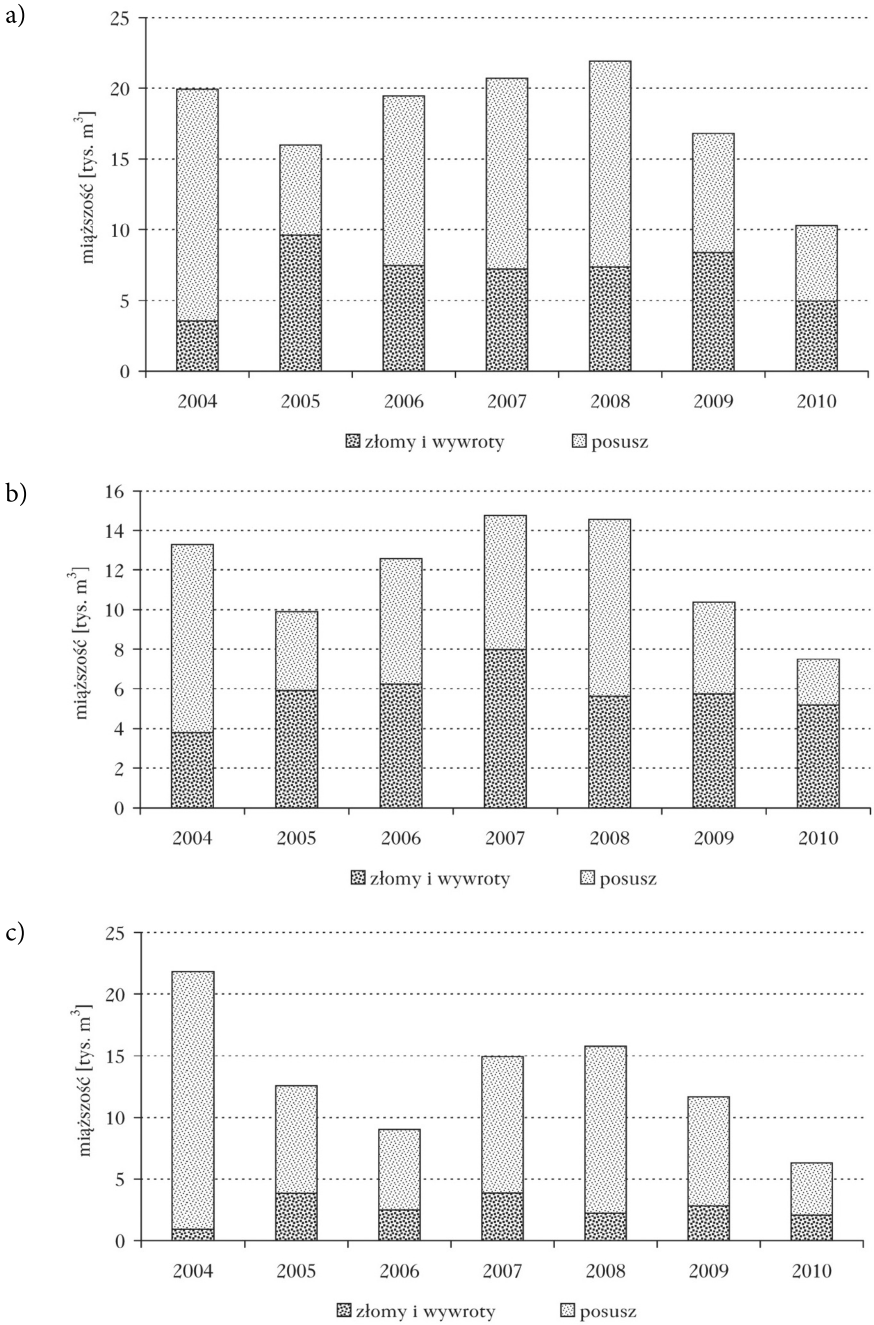


Fig. 5.
Volume of wind-broken trees, wind-thrown trees and snags harvested in the years 2004–2010 in the a) Browsk b) Hajnówka, and c) Białowieża forest districts.

(miąższość [tys. m^3] – volume [thousand m^3]; złomy i wywroty – broken and wind-thrown trees; posusz – snags)

TABLE 1

Species structure of wind-broken and wind-thrown trees and snags, harvested in the period 2004–2010 in the analysed forest districts

Species	Browsk		Hajnówka		Białowieża	
	volume [thousand m^3]	share [%]	volume [thousand m^3]	share [%]	volume [thousand m^3]	share [%]
Spruce	73.7	58.5	55.4	66.7	83.2	90.3
Pine	28.7	22.8	7.0	8.5	3.3	3.6
Oak	8.6	6.9	1.3	1.6	0.7	0.7
Birch	2.2	3.5	6.3	7.5	1.5	1.6
Alder	1.6	1.3	3.0	3.6	0.5	0.6
Other	8.8	7.0	10.0	12.1	3.0	3.2
Total	125.9	100	83.1	100	92.1	100

The assessment of the model of the stand damage risk emergence was executed with use of data on wind-broken trees, wind-thrown trees and snags harvested in the surveyed forest districts of the Białowieża Forest in the years 2004–2010. That assessment required a definition of the term 'damaged stand'. It was premised that in a damaged stand an accelerated tree decline process takes place, and this happens when the volume of self-thinned trees, per hectare, exceeds the threshold value specified with the use of the following formula (Bruchwald, Dmyterko 2010):

$$Damage = 1 + \frac{H}{12} \qquad [5]$$

where H is the mean height of the major species in the stand.

In young stands, the threshold value exceeds 1 m^3/ha and in old stands it is up to 4 m^3/ha.

Each stand of a forest district was rated in one of two groups: undamaged, if the volume of harvested wind-broken trees, wind-thrown trees and snags did not exceed the threshold value specified by the formula [5], and damaged when the volume exceeded the limit. In the second variant, only the harvested wind-broken and wind-thrown trees were considered upon the creation of those stand groups, without considering the snags. The data applied in both variants came from the 2004–2010 period. After creating these stand groups, the share of their area was calculated, both in relation to the entire forest district and in the individual classes of the stand damage risk factor.

TABLE 2

Area-related share of stands in classes of stand damage risk factor for the forest districts of the forest in 2010

Forest district	0.0–0.5	0.5–1.0	1.0–1.5	1.5–2.0	2.0–2.5	2.5–3.0
Browsk	0.2	2.5	6.0	29.5	48.4	13.3
Hajnówka	0.0	1.7	5.1	23.1	45.0	25.0
Białowieża	0.0	1.4	2.9	16.9	45.0	33.8

In the Browsk Forest District, the correlation between the share of damaged stands and the damage risk factor calculated with use of model IV is very strong (Fig. 6). An increase in the risk factor is accompanied by an increase in the share of damaged stands. This concerns both the variant when the group of damaged stands included only wind-broken and wind-thrown trees (a part of damaged trees), and the variant when snag was also included, apart from wind-broken and wind-thrown trees (all damaged trees). A strong correlation between the share of the area of damaged stands and the risk factor occurs in the Hajnówka and the Białowieża forest districts (Fig. 6). An analysis of relationships between the share of damaged stands and the risk factor, carried out for the studied forest districts, indicated that this model worked very well. This is confirmed by an analogous survey conducted in other forest districts with serious damage caused by wind (Bruchwald, Dmyterko 2010, 2011).

When assessing the threat to forests, the spatial distribution of stands with a high damage risk factor is of importance. In the Browsk Forest District, the highest risk factor class contains 13.3% of the stand area, spread mostly evenly over the entire area of the district, (Fig. 7). Larger aggregations of these stands, assumed as places at higher risk, are located in the southern part of the forest district. In the Hajnówka Forest District, having a 25.0% share of the stands rated in the highest class of the risk factor, large agglomerations of stands with high damage risk are found in the northern and southern part (Fig. 8). In the Białowieża Forest District, with a 33.8% share of stands in the highest risk factor class, large agglomerations of stands with a high damage risk are found in the northern and central part (Fig. 9).

The share of stands in the two highest risk factor classes is of the greatest importance for the assessment of the risk to forests in a given forest district. The following formula was used to measure the threat to forests in a forest district:

$$Ms = \frac{1}{5}\left(2\,p_5 + 3\,p_6\right) \qquad [6]$$

where p_5 and p_6 is the share of area of stands in the fifth and sixth risk factor classes.

The value of this factor indicates the level of threat to the forest. When the value of *Ms* is within the range 0–10%, the risk is low, 10–20% – increased, 20–30% – average, 30–40% high, and above 40% – very high. In 2010, the values of the adopted measure of threat to forest were as follows: Browsk Forest District – 27.3%, Hajnówka Forest District – 33.0%, Białowieża Forest District – 38.3%. Thus, the threat to forests in these districts ranges from average to high. The main reason for the high threat to forests in the described area originates from the high share of old spruce stands. The area-related share of spruce stands aged more than 60 in the individual forest districts is as follows: Browsk – 27.0%, Hajnówka – 31.6%, Białowieża – 39.8%. The total growing stock of spruce in these stands is estimated at five million m^3. In order to reduce the threat to the forest, planning and performing of cutting volume at an appropriate level, in particular with regard to final cutting, is required.

With the use of a growth model for processing stand inventory data contained in the SILP, the potential cutting volume of wood raw material was determined for the forest districts of the Białowieża Forest. This step was limited to the stands assigned to the management unit with clear- and selection cutting. For the Browsk Forest District, the potential wood raw material harvesting volume is 80,000 m^3, including 52,000 m^3 from intermediate cutting. In 2010, the forest district's cutting plan determined the total harvest at 60,100 m^3, thus 20,000 m^3 less than results from the potential of the woodlands of the forest district. 53,000 m^3 were planned for harvesting in the intermediate cutting, which is approximately as much as the potential volume, while in final cutting – 7,000 m^3, i.e. 21,000 m^3 less than the potential volume. In the Hajnówka Forest District, the potential harvesting volume of wood raw material was specified as 127,000 m^3, including 67,000 m^3 from the intermediate cutting. The forest district's plan for 2010 assumed 40,000 m^3 in total, including 34,000 m^3 from the intermediate cutting. The utilisation volume included in the forest district's plan was very much depressed for both cutting categories. In the Białowieża Forest District, the potential volume of wood raw material harvesting was 41,000 m^3, including 19,000 m^3 from the intermediate cutting. The utilisation volume specified in the forest district's plan was set to 18,000 m^3, divided into 16,000 m^3 from the intermediate cutting and 2,000 m^3 from the final cutting.

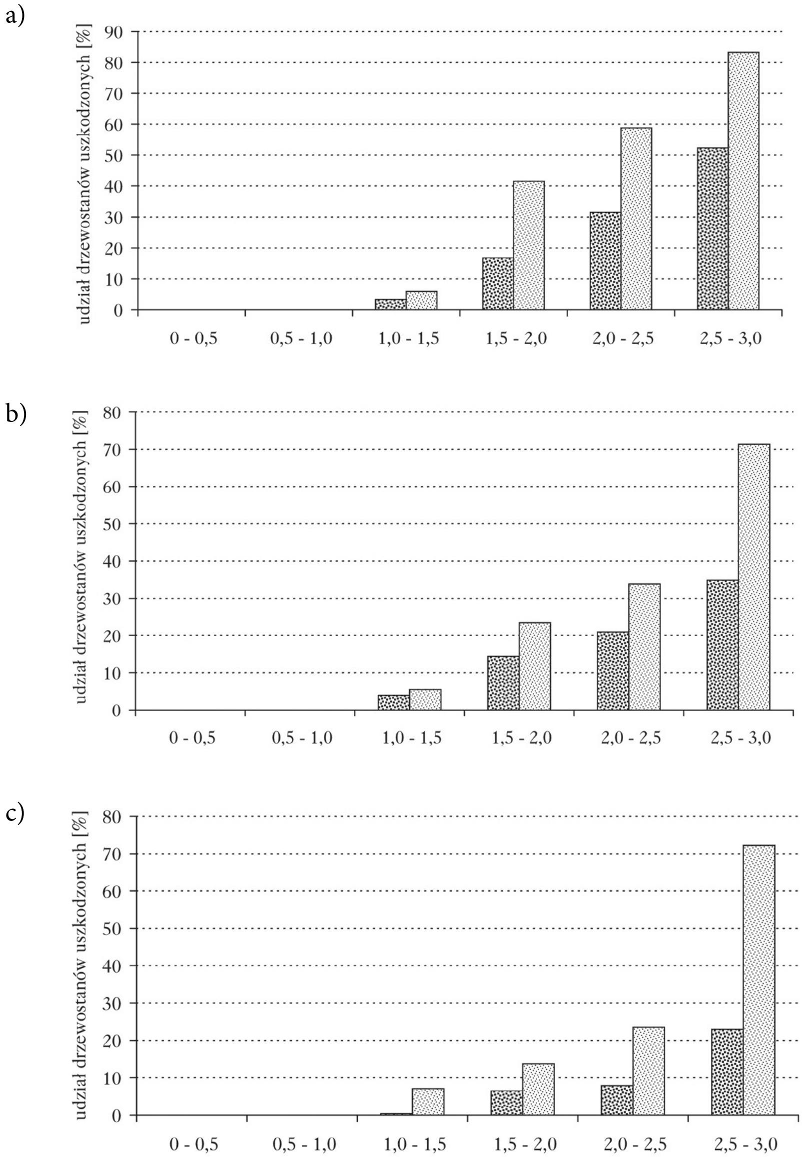


Fig. 6.
Share of area of damaged stands in damage risk factor classes in the a) Browsk, b) Hajnówka, and c) Białowieża forest districts.

(udział drzewostanów uszkodzonych [%] – share of damaged stands [%]; współczynnik ryzyka – risk factor; złomy i wywroty – broken and wind-thrown trees; złomy, wywroty i posusz – broken and wind-thrown trees, and snags)

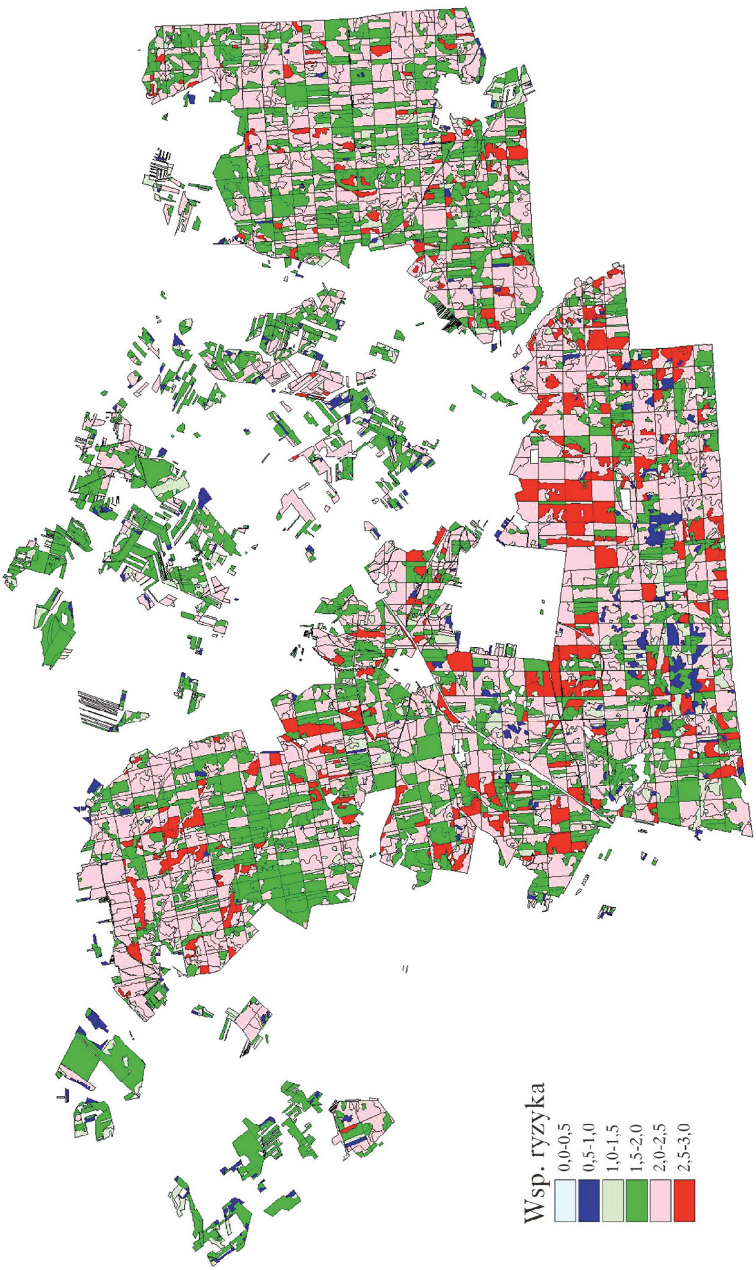


Fig. 7.
Spatial distribution of stands with a given stand damage risk factor in the Browsk Forest District

(Wsp. ryzyka – Risk factor)

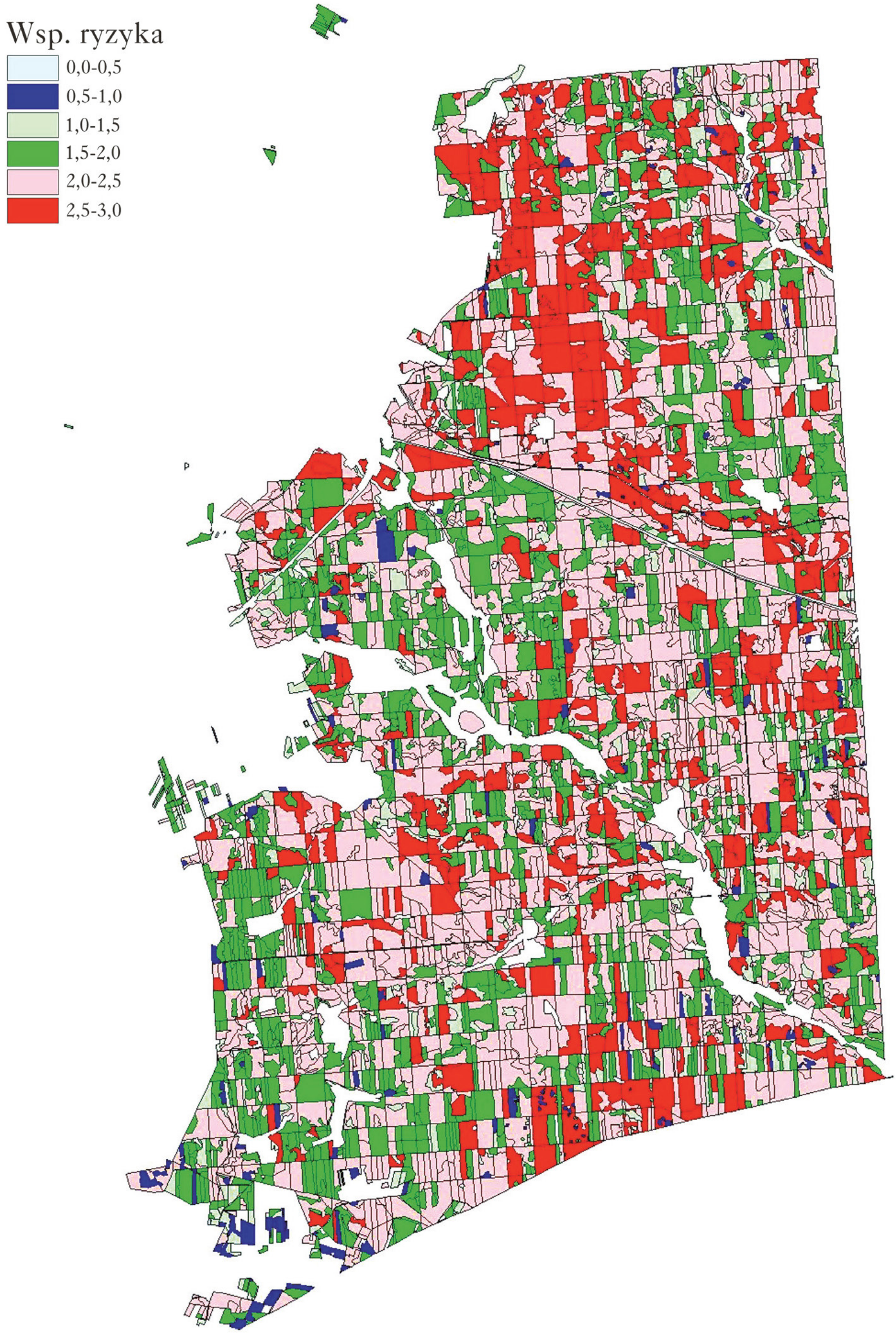


Fig. 8.
Spatial distribution of stands with a given stand damage risk factor in the Hajnówka Forest District

(Wsp. ryzyka – Risk factor)

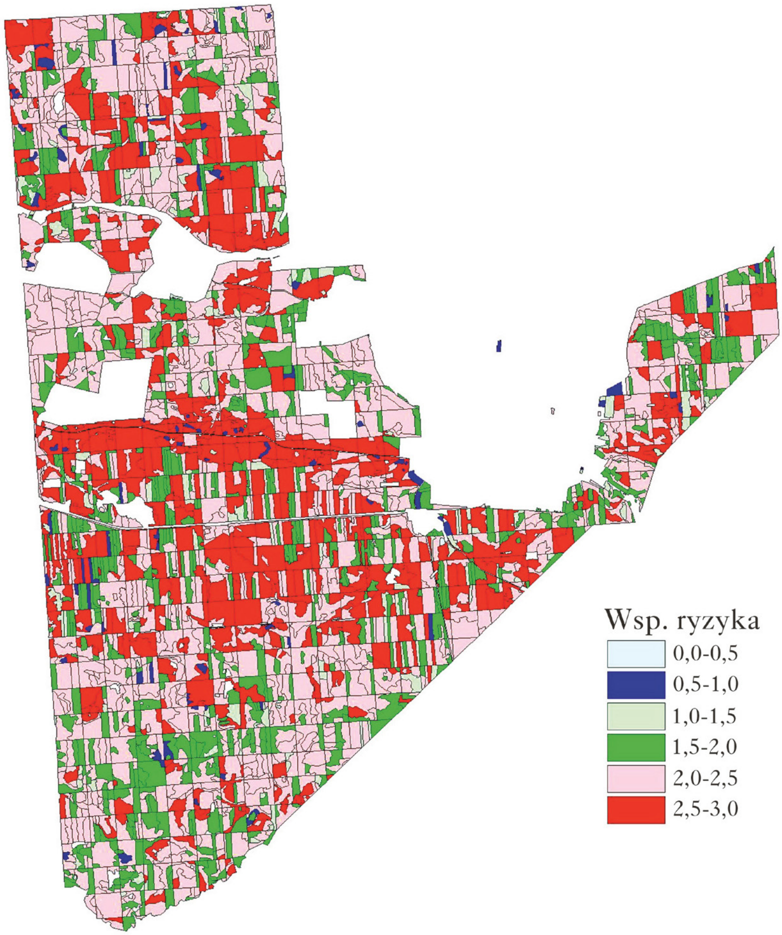


Fig. 9.
Spatial distribution of stands with a given stand damage risk factor in the Białowieża Forest District

(Wsp. ryzyka – Risk factor)

Conclusions

- The woodlands of the Białowieża Forests belong to the group being the most exposed to extreme abiotic factors in Poland, as they demonstrate a high share of stands with a high damage risk factor. The spatial distribution of these stands is clustered, which leads to large-area damage in the case of strong wind.
- The most important reasons for the high level of threat to the Białowieża Forest woodlands include: high share of spruce stands, as well as climatic conditions changing to unfavourable for the growth of spruce, especially an increase in the mean air tempera-

ture and the ground water level sinking continuously since 1980s, attacks of insects and fungi on weakened spruce stands, a high share of moist and bog habitats, as well as a high share of very old and tall stands.

- The cutting volume is set in the plans of the forest districts of the forest at a much lower level than results from the productivity potential of these forests. The final cutting has the largest impact on the level of threat to the forest. Depressing its volume leads to an increase in average age and average height of stands of the forest district, thus to an increased threat to the forest.
- The high threat to the woodlands of the Białowieża Forest, deepening due to the depressed harvesting volume of the final cutting, poses a threat of the occurrence of very serious damage in the case of strong wind. Such damage may be much larger than the damage observed in the Białowieża Forest after the windstorm of March 1983, estimated then at 440,000 m^3 of timber.

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Genetic profile of the oldest *Picea abies* (L.) Karst. trees in the Białowieża Forest*

Introduction

The genetic diversity of forest trees plays a key role in the stability and dynamics of forest ecosystems (Gregorius 1991). It is also extremely important from the economic point of view, as it determines the sustainability of economic characteristics, constitutes a basis for selection oriented towards the improvement of selected stand features and reduces the consequences of the impact of negative biotic and abiotic factors (Matras 2006). The conservation of forest genetic resources thus constitutes one of the highest priorities of silviculture (Burczyk, Chybicki 2005). It is thought that old forest stands play a priceless role in the conservation of biodiversity (Mosseler et al. 2003). Poland still has scarce fragments of native stands and a significant number of single old trees (Korczyk 2005). According to Korczyk (1994, 2005), the old stands preserved in the Białowieża Forest have a huge value for science, but also for forest management: they are relicts of native wild populations developed in the process of natural selection. Their genotypes came into being in the pre-industrial age and were not subject to selection by humans. They demonstrate also a high adaptive capacity, thanks to which they have reached such an advanced age.

The woodlands of the Białowieża Forest create a unique opportunity to observe the processes of natural renewal of the stand in a formed forest ecosystem, which has been minimally distorted as a result of human activity. It is particularly important in reference to the Norway spruce (*Picea abies* L. Karst.), intensively cultivated for more than 200 years, which is one of the major forest-forming species in Poland and Europe. With regard to above, a 'genetic inventory' of old trees of Norway spruce from the area of the Białowieża Forest, aimed at the exploration and conservation of their gene resources (primary gene pools), is extremely important (Korczyk 2008).

The objective of this paper is: 1) develop a description of the genetic structure of the population of old *Picea abies* trees in the Białowieża Forest; 2) design a genetic database for

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each examined tree, containing its genotype pattern, number of alleles and level of individual heterozygosity within the scope of the analysed markers.

Material and methods

Sample plot and material. The sample plot is situated in the Białowieża Forest, in the Hajnówka Forest District. The research was conducted in a forest stand originating from a natural regeneration of *Picea abies* in compartment 631A, sub-compartment 'b', with a wooded area of 9.9 ha (Korczyk 1994). The examination comprised 117 *Picea abies* trees aged 89–213. The age of each individual was identified on the basis of the breast-height diameter measurement and with the drilling method (for 97 trees).

Analysis of enzymatic proteins. The analysis of genetic variability was carried out with use of isozyme markers. For the extraction of enzymatic proteins, two to three winter buds from each individual and extraction buffer 0.5 M TRIS-HCl pH 7.5 containing EDTA, KCl, $MgCl_2$, PVP and TRITON were used. The electrophoretic separation of proteins was conducted in two buffer systems: A) tris-citrate pH 7.0 (electrode buffer) / tris-histidine pH 7.0 (gel buffer); B) LIOH-borate pH 8.5 (electrode buffer) tris-citrate-LIOH-borate pH 8.5 (gel buffer) (Cheliak, Pitel 1984; Conkle et al. 1982). The analysis was carried out for 13 enzymatic systems coded by 26 loci: FEST (EC 3.1.1.1. – 3 loci), GDH (EC 1.4.1.2. – 1 locus), GOT (EC 2.6.1.1. – 3 loci), IDH (EC 1.1.1.42 – 2 loci), MDH (EC 1.1.1.37. – 3 loci), SHDH (EC 1.1.1.25 – 2 loci), PGM (EC 2.7.5.1. – 2 loci), 6PGD (EC – 2 loci), G6PD (EC 1.1.1.49 – 2 loci), NDH (EC – 2 loci), PGI (EC 5.3.1.9. – 1 locus), DIA (EC 1.6.4.3. – 2 loci), ME (EC 1.1.1.40 – 1 locus).

Data analysis. The resulting data were subject to statistical analysis with use of the GenAlEx 6.5 software (Peakall, Smouse 2012). The genetic variation level was elaborated at the population and individual scale, with the following parameters: percentage of polymorphic loci, number of alleles found in analysed loci, mean number of alleles per locus, heterozygosity observed (H_o) and expected (H_e), fixation index (F) as a measurement of deviation from the Hardy-Weinberg equilibrium (chi-square tested), analysis of principal coordinates conducted based on genetic distances (Nei 1972) between individual trees and the individual heterozygosity for each individual (H-ind). The individual genotype pattern of each tree was also determined in 26 analysed loci.

Results

The variability of 117 Norway spruce trees was analysed in 26 isoenzyme loci. The share of polymorphic loci was 85%, while four loci were monomorphic: DIA A, FEST C, GOT B, and SHDH A.

In the entire population of the examined trees, the mean number of alleles per locus was 2.4 (from 1 to 5 in the individual loci). The mean heterozygosity observed was rather low (0.110), but significant value differences for that parameter (0.000–0.521) occurred in particular loci (Fig. 1). The highest heterozygosity observed was found in the following loci: GOT C, NDH B and PGI. The mean fixation index value for all loci – 0.012 – indicates that the population is in Hardy-Weinberg equilibrium. That index value was quite varied among individual loci (−0.081–0.215) (Fig. 2). A statistically significant deviation from the Hardy-Weinberg equilibrium (excess of homozygotic genotypes), demonstrated by the chi--square test, was identified in three loci: 6PGD, FEST B, and GDH.

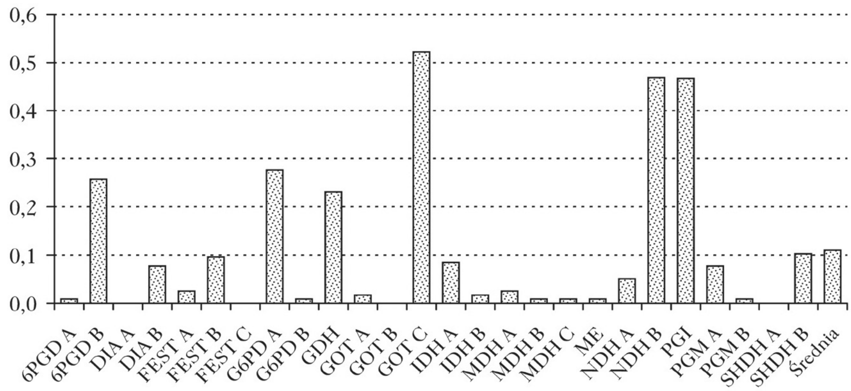

Fig. 1.
Observed heterozygosity of *Picea abies* population in 26 analysed isozyme loci

(Średnia – Mean)

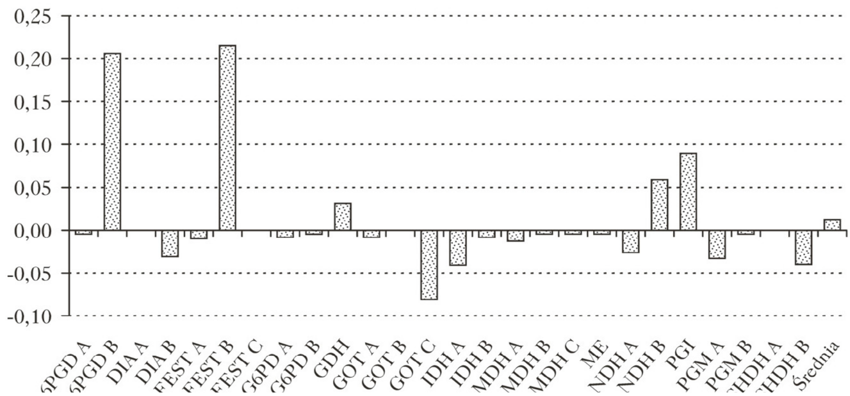

Fig. 2.
Wright's fixation index of *Picea abies* population in 26 analysed isozyme loci

(Średnia – Mean)

For each examined tree, its genotype pattern was defined within the scope of 26 analysed isozyme loci (table with detailed genetic parameters available at the corresponding author). Six genotype patterns marked as A, B, C, D, E, and F were stated for two, three and five individuals. The remaining genotype patterns, marked from 1 to 101, were unique, represented only by one tree. Based on the values of genetic distances between individual trees, an analysis of principal coordinates was conducted (Fig. 3). It showed the relatively homogeneous nature of the examined tree population of *Picea abies*, except for eight individuals (1028, 1096, 1155, 1156, 1185, 1195, 1205, 1210), which form a genetically separate group. All these eight trees have a unique genotype pattern in 26 loci. Moreover, in locus 6PGD B those individuals appeared to be heterozygous. The heterozygosity calculated for particular individuals (H-ind: individual heterozygosity) was 0.00–0.25 (Fig. 4). Twenty individuals of Norway spruce were completely homozygous within the scope of 26 analysed loci, while the highest H-ind values (0.20–0.25) were observed in only eight individuals.

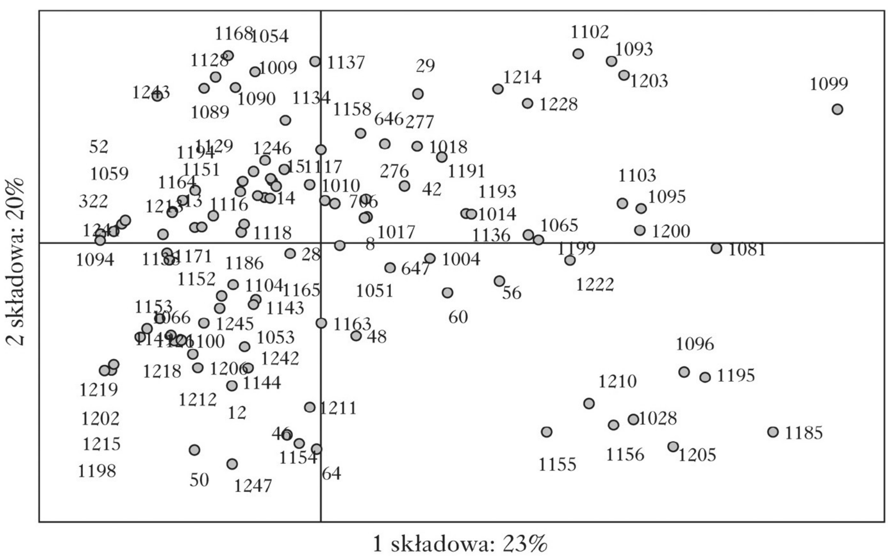

Fig. 3.
Principal coordinates analysis construed on the basis of Nei's genetic distance for individual *Picea abies* trees

(2 składowa: 20% – PCo1 20%; 1 składowa: 23% – PCo2 23%)

Discussion

The comparison of the obtained results with previous works on the isozyme variability of Norway spruce populations demonstrates quite an interesting picture. The population from the Białowieża Forest (P% 85; A/L 2.4; H_o=0.110) shows a slightly lower level of genetic variability, particularly in reference to natural populations of this species from Austria (P% 45; A/L 2.8–3.3;

H_o=0.165–0.170) (Geburek 1998) and Latvia (P% 69–81; A/L 2.0–2.5; H_o=0.171–0.201) (Goncharenko et al. 1995) and earlier reports by Krzakowa and Korczyk (1995) on selected trees from the Białowieża Forest (P% 100; H_o=0.237). Especially the latter paper presents a significantly higher level of genetic variability of the *Picea abies* population. These differences may largely result from a different selection of isozyme loci, differing in the polymorphic level, and from the age of examined tries. It is confirmed by the large range of heterozygosity values observed in the individual loci (0.000–0.521) shown in this study. The examined population from the Białowieża Forest shows a lower level of the observed heterozygosity also in relation to the spruce provenance from IUFRO experiments: H_o=0.076–0.174 (Lagercrantz, Ryman 1990); H_o=0.190–0.310 (Kannenberg, Gross 1997); H_o=0.106–0.234 (Prus-Głowacki, Modrzyński 2003). Both, the results of described analyses and reports by Krzakowa and Korczyk (1995) indicate that the population of the oldest trees of Norway spruce in the Białowieża Forest is in Hardy-Weinberg equilibrium. The results obtained for the population from the Białowieża Forest do not confirm the hypothesis implied by Lagercrantz and Ryman (1990) and supported by Goncharenko et al. (1995) about the higher level of genetic variety of spruce populations from the eastern part of its European geographical range.

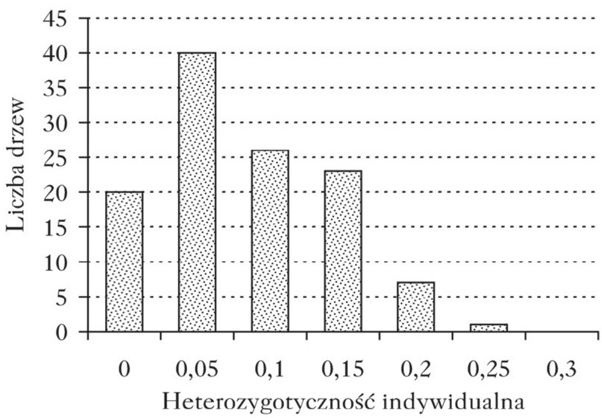

Fig. 4.
Mean individual heterozygosity for particular spruce trees

(Liczba drzew – Number of trees; Heterozygotyczność indywidualna – Individual heterozygosity)

For each examined tree, a form of 'genetic certificate' was created, including the genotype pattern in the analysed 26 isozyme loci, the number of stated alleles and the level of individual heterozygosity. It appeared that from among 117 trees, 101 have a unique (unrepeatable) genotype pattern, while 20 individuals are completely homozygous in the analysed loci. Such 'genetic certificates' allow the identification of individuals, as well as of their vegetative descendants in the clone archive.

The genetic distances demonstrate rather balanced values between individuals, as exhibited by the principal component analysis graph. The exception involve the eight trees that formed a genetically distinct group. The obtained results do not confirm the division of the population into two 'genetic subpopulations' indicated in the paper by Krzakowa and Korczyk (1995). These discrepancies result probably from the number and type of analysed marker loci and the age structure of examined trees. The research results allow to state that the oldest trees of *Picea abies* in the Białowieża Forest are characterised by rather low, against the species, level of genetic variability and their mostly homozygous genotypes that are well-adapted to their environment, let them live to such a ripe old age.

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Rafał Paluch

Long-term changes of tree species composition in natural stands of the Białowieża Forest*

Introduction

The Białowieża Forest is one of the largest and best-preserved forest ranges on the lowland of the Central-Eastern Europe. Therefore, this area is of the utmost importance for environmental studies, as it constitutes an unusual research laboratory, allowing a thorough understanding of the processes and functioning of natural ecosystems, which is very important for the development of the close-to-nature silviculture concept [Brzeziecki 2008).

Permanent sample plots create a basis for long-term ecological research, including those on the natural changes in the species composition of stands. It seems that they may provide at least an approximate answer to the question: how close can we bring our silvicultural measures to natural ecological processes, without losing economic and protection objectives evaluated from the human point of view (wind, soil and landscape protection functions and other)? The oldest permanent sample plots in the Białowieża Forest are those of the Department of Silviculture, SGGW [Warsaw University of Life Sciences] established in 1936 by Professor T. Włoczewski (Włoczewski 1954, Bernadzki et al. 1998). They have a layout of five transects with a total area of approx. 15 ha, situated in the Strict Reserve of the Białowieża National Park. They represent the most important forest associations of the Białowieża Forest. The research is continued on them (Włoczewski 1954, Kowalski 1982, Bernadzki et al. 1998, Brzeziecki 2008, Brzeziecki et al. 2012). Paczoski (1930) described the attempts to establish permanent research transects, but only the work by Włoczewski brought durable results. During the research conducted in the Forest Research Institute, Professor A. Sokołowski also established since the 1970s numerous permanent sample plots in all [types of] forest associations. These plots may be treated as a valuable completion of previously conducted unique research on the development of natural stands. Certain important and precious forest communities of the Białowieża Forest, e.g. all coniferous forest

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habitats (fresh, moist and bog coniferous forests) or subboreal spruce forest on peat bog, are not present now on the permanent sample plots of the Department of Silviculture. Recently, the research on these habitats has been partially completed (Brzeziecki et al. 2012; Drozdowski 2014). This paper confirms to a large extent the regularities of long-term changes in species composition of the natural stands of the Białowieża Forest described by other authors (Bernadzki et al. 1998; Brzeziecki 2008; Brzeziecki et al. 2012; Drozdowski et al. 2012).

The research objective was the identification of changes in species composition and structure of stands on permanent trial plots over the last 30–40 years, as well as at the assessment of trends, directions and pace of these changes.

Material and methods

The Forest Research Institute stores a very large collection of archive materials, including stand measurement data and others constituting a basis for the long-term monitoring of the flora. Permanent sample plots, usually of 50x50m, were being established over a period of almost 40 years in various forest communities in north-eastern Poland (Sokołowski 2004). The survey was repeated regularly, approx. every 10–15 years, in the research periods 1974–1975, 1985–1986, 1996–1997, and 2011–2012. The boundaries of the plots were marked out with oak rods and white bands on corner trees. Moreover, for the plot recreation location plans (rectangular grid-based measurements of distances to fixed terrain objects) and other archive materials were used (Sokołowski 1960–2004). On the trial plots, the diameter at breast height of all trees was measured in 1–2 cm wide size classes, as well as trees and shrubs up to 1.3 m high were counted, with division into species. In addition, the plot markings were renewed and geographical coordinates of sample plot corners were measured with the use of a GPS receiver, which was important for their more durable indication. That survey was performed on 120 selected permanent structural plots in the nature reserves of the Białowieża Forest and in the Białowieża National Park, using the methodology described in previous papers (Sokołowski 1991, 2004). The survey was conducted in the nature reserves: Starzyna, Sitki, W. Szafer Landscape Reserve, and Natural Forests of Białowieża, Lipiny, and Michnówka. They have the status of partial reserves, where mainly sanitation cutting of low intensity was conducted by the early 1990s, with the consent of the nature conservation service. Then, human interference has been significantly limited, i.e. no protective treatments are performed on their territory (except of assuring the safety of people and property, as in the Białowieża National Park). Moreover, no current protection plans for nature reserves exist. The survey covered natural stands in selected forest communities of the Białowieża Forest, which represented initially at the first measurement term (in brackets, abbreviations used hereinafter and the number of sample plots are given):

- fresh coniferous forest *Vaccinio vitis-idaeae-Pinetum* Sokoł. 1981 (VP-11),
- fresh mixed coniferous forest *Calamagrostio arundinaceae-Piceetum* Sokoł. 1968 (CP – 18),
- bastard balm-hornbeam deciduous forest *Melitti-Carpinetum* Sokoł. 1976 (MC – 22),
- typical oak-hornbeam forest *Tilio-Carpinetum* Traczyk 1962 (TCt – 52),
- alder-ash riparian forest *Fraxino-Alnetum* W.Mat. 1952 (FA – 17).

The forest association was determined by taking a phytosociological relevé with the Braun-Blanquet method within the plot at each measurement term (Sokołowski 2004).

An analysis of changes in the species composition of stands over time was carried out on the basis of their density. The dynamics of natural regenerations was presented in three groups of young trees: self-sown seedlings and small saplings (N), saplings with breast-height diameter 0.1–3 cm (P1), and older saplings with diameter at breast height 3.1–7 cm (P2). Similarity coefficients (*S*) were calculated for the stands between the research periods, and at the beginning and end of the research, according to the following formula (Brzeziecki 2008 after Badeck et al. 2001):

$$S = 1 - \frac{\sum_{i=1}^{n} \left| f_{1,i} - f_{2,i} \right|}{200}$$

where:
$f_{1,i}$, $f_{2,i}$ – percentage share of species *i* in compared research periods,
n – total count of species in both compared research periods.

The share of species calculated on the basis of the density of trees was applied, whereby trees with a diameter at breast height exceeding 3 cm were taken into account. The analysed coefficient is a synthetic measurement of the similarity of stand composition in the compared research periods, in the range from 0 to 1. The closer the value to 1, the higher the similarity of objects should be (Brzeziecki 2008).

Results

In the fresh coniferous forest (VP), the mean share of Norway spruce was subject to a noticeable, almost double increase: from 30% in 1975 to approx. 60% in the last research period. It happened mainly to the detriment of Scots pine, for which opposite trends were observed (Fig. 1a). The share of oak slightly increased: from several percent in the 1970s and 1980s to 10% at present. The significance of birch was and continues to be small, fluctuating between 10 and 20%. Moreover, it was observed that the share of hornbeam significantly increased in the last decade and in 2012 reached approx. 10% on such a poor habitat, which may be considered an indication of its expansion. In the fresh coniferous forest, spruce was regenerating well and efficiently – it appeared in all lower layers of the stand with the highest density, both in the layer of self-sown seedlings, and low and high saplings (Table). Its smooth transition from the layer of self-sown seedlings to higher levels breast-height size classes also proved the regeneration efficiency. Pine was regenerating, but much more poorly and only with regard to the first research period (1975–1986) it was possible to talk about a wave of regeneration. Few individuals advanced to the upper layers of the stand. Similar regularities were identified in the case of oak and birch. It may be said that in this poor habitat oak regenerated, but only a small portion of individuals advanced to the higher layers of the stand. The mean density of self-sown seedlings of this species with a diameter at breast height of 3–7 cm was 30–100 pcs/ha. Oak demonstrated a particularly high density

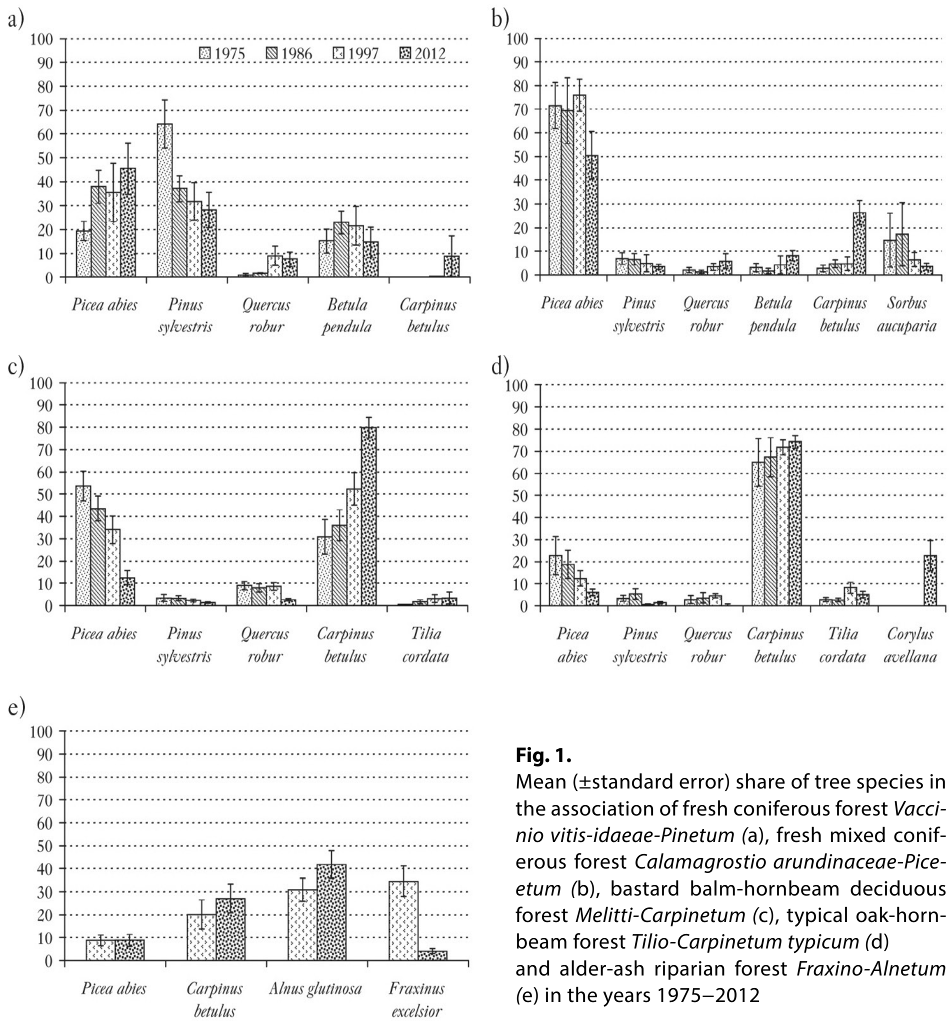

Fig. 1.
Mean (±standard error) share of tree species in the association of fresh coniferous forest *Vaccinio vitis-idaeae-Pinetum* (a), fresh mixed coniferous forest *Calamagrostio arundinaceae-Piceetum* (b), bastard balm-hornbeam deciduous forest *Melitti-Carpinetum* (c), typical oak-hornbeam forest *Tilio-Carpinetum typicum* (d) and alder-ash riparian forest *Fraxino-Alnetum* (e) in the years 1975–2012

among the lowest trees (self-sown seedlings and saplings up to 1.3 m). It should be emphasised that in the beginning of the research (1970s) in the lower layers of the stand the existence of hornbeam in the sapling layer was not observed. Currently, this species has marked its presence, both among self-sown seedlings and up to 3cm thick saplings, achieving a mean count of more than 100 pcs/ha (Table).

In the fresh mixed coniferous forest (CP), a significant reduction of the share of Norway spruce, being an important species to this association, was identified, i.e. from over 70 to 50% (Fig. 1b). Simultaneously, a multiple increase in the share of hornbeam was registered, from several percent to approx. 30% over the last 15 years, which might result in distinct changes in vegetation and in the formation of communities similar to the oak-hornbeam forest. The share of other species was quite balanced and did not exceed 10–15%. It was observed that the regeneration of spruce with high density was permanently present in all categories of lower layers of stands in the mixed coniferous forest, reaching in the layer of self-sown seedlings a count of up to 600 pcs/ha, and in the saplings layers usually 200–400 pcs/ha (Table). Currently, hornbeam may form important competition, as it is advancing to the higher layers of the stand. A multiple increase in the density of that species was found in the layers of self-sown seedlings (100–700 pcs/ha) and saplings of up to 3 cm of diameter at breast height over the last 15 years (10–400 pcs/ha). It was slowly becoming the dominant species in the regenerations, in the relatively poor – regarding fertility – mixed coniferous forest habitat. It should be emphasised that in the entire period of almost 40 years of observations pine did not regenerate on the habitat that seemed to be optimal for it (Table).

TABLE

Mean (± standard error) density [pcs/ha] of self-sown seedlings and saplings up to 1.3 high (N), saplings with breast-height diameter 0.1–3.0 cm (P1) and saplings with breast-height diameter 3.1–7.0 cm (P2) in surveyed forest associations in the years 1975–2012

		1975	1986	1997	2012
		Vaccinio vitis-idaeae-Pinetum			
Norway spruce	N	260±20	255±44,2	168±59,8	138±31,2
	P1	120±40	91±39,4	193±70,6	305±90,8
	P2	110±10	164±41,1	84±44,8	194±42,3
Scots pine	N	324±96	0±	23±17	54±51,4
	P1	373±280,5	9±9	15±14,7	10±7,6
	P2	214±213,5	38±28,3	84±84	60±60

		1975	1986	1997	2012
English oak	N	158±69,5	583±178,9	456±67,5	312±120,8
	P1	4±4	6±3,8	102±43,1	144±78,3
	P2	6±1,5	4±2,3	8±4,2	6±1
Silver birch	N	209±15,5	190±41,6	154±16,9	58±37,3
	P1	164±16	68±20,5	139±68,1	107±73,7
	P2	32±12	112±12,9	63±17,3	30±26,1
Common hornbeam	N	7±	46±1,5	44±36	90±67,4
	P1	0±	0±	4±3,5	117±113,5
	P2	0±	0±	0±	5±5,3
Melitti-Carpinetum					
Norway spruce	N	307±94,4	189±72	24±21,4	25±16,2
	P1	171±52,8	132±38,8	28±17,7	11±5,7
	P2	172±44	68±18,1	38±19,2	12±4,2
Scots pine	N	0±	0±	5±	0±
	P1	0±	0±	0±	0±
	P2	0±	0±	0±	0±
English oak	N	26±17,9	672±213,9	44±15	18±7,2
	P1	25±14,6	5±4,7	0±	0±
	P2	21±14,8	8±3,5	1±0,5	0±
Common hornbeam	N	155±36,2	628±247,3	1668±494,2	764±210,5
	P1	322±204,8	94±22,8	807±433,3	1878±591,6
	P2	292±173,4	163±79,1	89±33,6	199±82
Small-leaved linden	N	16±	4±4	48±48	76±44
	P1	8±	0±	9±5,8	37±29,5
	P2	4±	6±2	9±5,3	4±2,8
Calamagrostio arundinaceae-Piceetum					
Norway spruce	N	623±193,4	492±184,2	350±46	378±149,4
	P1	396±330,3	302±139,4	436±144	252±83,4
	P2	125±91,6	73±52,4	274±154	138±52,5
Scots pine	N	0±	0±	0±	0±
	P1	0±	0±	0±	0±
	P2	0±	0±	0±	0±

		1975	1986	1997	2012
English oak	N	272±31,5	205±123,9	276±16	138±41,2
	P1	18±14,3	25±22,4	32±4	102±50,9
	P2	8±5,7	2±2	2±2	1±1
Silver birch	N	16±7,2	64±24,7	292±32	114±57,3
	P1	3±2,6	2±1,6	56±56	170±94,5
	P2	0±	0±	4±4	21±19,7
Common hornbeam	N	129±75,1	144±25,9	126±6	719±312,7
	P1	13±9,1	73±59,8	38±18	476±158,8
	P2	10±3,8	8±2,8	2±2	27±9,3
Jarząb pospolity	N	618±486,4	668±214,7	1182±78	807±571,3
	P1	128±122,1	500±489,1	68±16	40±28,8
Rowan	P2	0±	1±0,8	0±	11±11,2
Tilio-Carpinetum typicum					
Norway spruce	N	420±212,7	59±28,8	0±0	93±51,3
	P1	37±15,7	23±10	27±13,4	16±9,3
	P2	39±22,4	5±3,9	25±7,5	10±3,2
Scots pine	N	0±	0±	0±	0±
	P1	0±	0±	0±	0±
	P2	0±	0±	0±	0±
English oak	N	90±73,7	14±8,1	0±	99±37,8
	P1	2±1,7	3±2	0±0,3	4±2
	P2	7±5,7	0±	0±	3±2,8
Common hornbeam	N	248±91,5	350±80,1	0±	1412±308
	P1	1065±550,9	374±230,5	308±109,2	1075±249,7
	P2	594±243,3	289±129,3	324±40,3	182±28,4
Common hazel	N	497±212,9	312±160,9	0±	321±95,6
	P1	0±	0±	0±	799±316,3
	P2	0±	0±	0±	162±69,5
Small-leaved linden	N	31±17,3	51±10,9	0±	89±35,4
	P1	19±6,1	3±1,3	18±11,3	25±7,4
	P2	13±4,3	4±1,5	17±6,8	9±3,2

		1975	1986	1997	2012
		Fraxino-Alnetum			
Norway spruce	N			0±	0±
	P1			1±0,6	3±1,7
	P2			4±1,4	1±0,6
Common hornbeam	N			0±	220±135,4
	P1			61±24,5	167±71,5
	P2			71±25,1	44±13,8
Black alder	N			0±	57±31,4
	P1			136±64,1	118±41,4
	P2			52±22,3	47±18,6
Common ash	N			0±	19±18,7
	P1			**297±111,1**	**20±7,3**
	P2			37±19,2	1±0,7

In the bastard balm-hornbeam mixed deciduous forest (MC) habitat, which is one of poor forms of the subcontinental oak-hornbeam forest, even more drastic changes in the stand species composition occurred. The share of spruce decreased fivefold. In the beginning of the research, its share was 55%, and at the end (in 2012) – only to approx. 10%, which means the retreat of the species from the surveyed forest association in the next future (Fig. 1c). Moreover, it was found that the largest reduction in spruce share occurred in the last decade, thus the pace of changes distinctly accelerated. A significant dynamics of population growth was recorded for hornbeam, which accounts currently for approx. 80% of all trees in this forest association. Pine and oak have significantly decreased their share in the stand formation. The one and only species efficiently regenerating and putting under its domination the lower layers of the stand was hornbeam, and this situation continues. That species clearly dominated the lower layers, both of self-sown seedlings and saplings, achieving a very high density: almost two thousand pcs/ha of saplings up to 3cm in diameter at breast height. Spruce was very clearly in decline, particularly in the last decade of the survey (Tab). Its density in all analysed categories of lower layers underwent a reduction, dropping to more than dozen trees per ha in 2012. Oak and pine, i.e. species with higher heliophilous requirements, also significantly diminished their density, as they did not find conditions suitable for regeneration and growth (Table).

In the typical oak-hornbeam forest (TCt), despite the relatively stable nature of the association, there occurred significant changes in the species composition, consisting generally in spruce retreat over the past nearly 40 years and a simultaneous increase of the role of hornbeam, a major component of oak-hornbeam phytocenoses. Spruce decreased its share fivefold, from the level of 25% to approx. 5%, while hornbeam was just the opposite, its significance in the stand formation increasing systematically over the last 40 years by approx. 10% (Fig. 1d). More than a dozen years ago, the oak share was several percent, while now this species is not found at all. The role of pine also largely decreased, while the share of linden remained in the individual research periods at a similarly low level of approx. 5–10%. However, the appearance of a significant number of young hazel trees in the last research period is worthy of attention, the density of which exceeded 20% of the aggregate count of all species together. That species often took a tree form with a breast-height diameter of up to 13 cm, which certainly may constitute a further limitation of the possibility of effective regeneration of other species, e.g. oak.

In the ash-alder riparian forest (FA), a huge, sevenfold reduction in the share of European ash in the species composition of natural stands was observed. A drop of share of that species from 35% in 1997 to almost 5% in 2012 was noticed (Fig. 1e). Often only single ash trees in a seriously deteriorated health condition remained on the sample plots. Profiting from the reduction in ash count, black alder, and to a lesser extent hornbeam, increased their role in the stand structure. In the lower layers of the stand, the natural regeneration of ash in each group was minimal and decreased considerably over the last 15 years. Hornbeam demonstrated evidences of expansion, regenerated in the layer of self-sown seedlings, and saplings with a breast-height diameter of up to 3 cm. Alder was also effectively regenerating, but its density was lower than that of hornbeam, except for saplings in the breast-height size class of 3–7 cm.

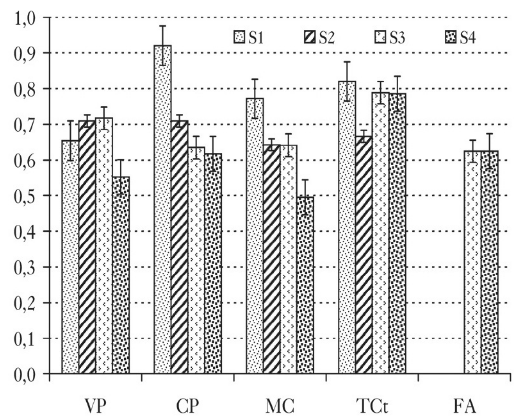

Fig. 2.
Change in the similarity coefficient of the stand species composition (S) in the surveyed forest associations in the years 1975–2012

1. 1975–1986, 2. 1986–1997,
3. 1997–2012, 4. 1975–2012;
VP – *Vaccinio vitis-idaeae-Pinetum*
CP – *Calamagrostio arundinaceae-Piceetum*
MC – *Melitti-Carpinetum*
TCt – *Tilio-Carpinetum typicum*
FA – *Fraxino-Alnetum*

It was observed that the largest changes in the similarity coefficient of the stand species composition arose in the bastard balm-hornbeam deciduous forest (MC), particularly in the last period (Fig. 2). The similarity coefficient between the beginning and the end of the research reached a very low value (less than 0.5), which is proof of the significant changes in the share of individual tree species in the stand formation in this forest association. The analysed coefficient significantly decreased. Even more visible, similarly oriented tendency was recorded for the mixed coniferous forest association (CP). In the years 1975–1986, small changes were identified, while in the subsequent period the similarity went down, reaching a coefficient value of 0.6. In the fresh coniferous forest (VP), the similarity of the share of individual species slightly fluctuated in the particular research periods, ranging from 0.6 to 0.7. The mean similarity coefficient between the beginning and the end of research was low and was only 0.55, proving a significant dynamic in the stands. Stands in the alder-ash riparian forest, surveyed only in the 1997–2012 period, featured a similar value of the similarity coefficient (0.6), which resulted from a drastic reduction in the share of ash. Therefore, changes in the share of tree species in this association may be described as significant. In the case of typical oak-hornbeam forest (TCt), the similarity was maintained at a similarly high level, approx. 0.8, indicating small changes in the share of particular stand components.

Discussion

In the majority of the analysed forest associations, over a short time period (approx. 40 years) significant changes occurred in the species composition of natural stands of the Białowieża Forest, growing without human interference. It should be emphasised that the research period constituted a small fragment of the forest development history, and the inference and forecasting on this basis may be only approximate. These results fully confirm the results of previous research with a longer duration period, i.e. almost 90 years (Bernadzki et al. 1998, Brzeziecki 2008, Brzeziecki et al. 2012, Drozdowski et al. 2012), emphasising also that the identified regularities refer to the entire Białowieża Forest, including areas subjected to partial protection. Based on the collected long-term research data, with new plots being added regularly, the quoted authors carried out a grouping of species, distinguishing rare ('endangered'), admixture ('relatively safe) and 'expansive' species. It should be noticed that in the group of expansive species only hornbeam is mentioned currently, while in previous periods such a tendency was presented also by linden and ash (Brzeziecki et al. 2012, Drozdowski et al. 2012). In the light of results of the author's own research, hornbeam seems to be very expansive, it not only enters poor habitats of fresh coniferous forest and mixed coniferous forest, but also wetland ash-alder riparian forests. In mixed coniferous forest habitats, it competes, among others, with spruce, while its regeneration is at least as numerous as its competitors. How can the forest association

Calamagrostio-Piceetum look and function, when the key role in the stand should be performed by spruce, but it is replaced by hornbeam having completely different ecological properties? However, unpublished research demonstrate that transitional communities emerge then, strongly referring to oak-hornbeam forests, with still visible elements of coniferous forest and a scarce number of diagnostic species of this association (Paluch, Zin 2013). If the described tendencies would be maintained, those patches taken over by hornbeam will be completely transformed into oak-hornbeam forests. Such a situation is taking place in the case of the thermophilous association of bastard balm-hornbeam deciduous forest (MC), where the vast majority of surveyed patches underwent a transformation into a typical oak-hornbeam forest. In this association, over the last 15 years a multiple increase in hornbeam density was recorded in all layers of the stand, including self-sown seedlings, saplings, and the second storey. That species displaced from the regeneration layer all its competitors, including spruce that dominated there in the beginning of the research period (approx. 40 years ago).

An analysis of the long-term dynamic of linden regeneration and its advancement to the higher layers of the stand allows the statement that the expansion of this species is currently inhibited and limited to optimal and suboptimal habitats (oak-hornbeam forests), whereas several decades ago it was definitely more explicit (Kowalski 1982, Bernadzki et al. 1998).

The dynamic status of ash, more than a dozen years ago regarded as an expansive, dominant or codominant species in the ash-alder riparian forest (Brzeziecki, Żybura 1998, Bernadzki et al. 1998, Paluch 2001, Drozdowski et al. 2012) changed completely. Ash has become a currently heavily threatened species, in regress, just like elm formerly. Early in the 20th century, the unprecedented phenomenon of mass dieback of ash and entire stands with share of this species started, and still continues (Gil et al. 2011). The conducted research proved that ash was naturally eliminated by self-thinning from all stand layers also under natural conditions. Natural regenerations of that species were also missing. It was observed in several cases that all ash trees on a sample plot were naturally eliminated by self-thinning over only 15 years. It is not known when ash will start to regenerate again, as so far there is not the least indication of it occurring. The current health status of ash is a cause of concern, as the condition of the few living specimens is poor. The condition of ash seems to be more critical than in the analyses conducted in the Strict Reserve of the Białowieża National Park (Brzeziecki et al. 2012). The quoted authors found the dieback of that species mainly among young trees, more seldom in the entire population.

In the large group of endangered species, pine and oak may also be found (Brzeziecki et al. 2012), which are very important species for the functioning of many forest communities. The research fully confirmed their decreasing share and the complete lack of pine regeneration, as well as a very small count in the case of oak. A complete retreat of pine from habitats being theoretically optimal for that species, i.e. fresh coniferous forests and mixed coniferous forests, should be noted. Even if a natural regeneration of pine emerged, which happened only once in 1975, then it gradually disappeared. Sporadically, the ingrowth of that species to higher breast-height size classes was noted. On the transects of the Department of Silviculture, pine trees exceeding 5 cm of diameter at breast height (so-called ingrowths) were not recorded throughout the almost 90 years of research (Brzeziecki et al. 2012). Drozdowski (2014) provided that oak regeneration had been regularly emerging in various habitat conditions of the Białowieża Forest, but it had not been finding appropriate conditions for continued growth. In turn, this study showed that self-sown seedlings and low saplings of oak occurred, in particular paradoxically most numerously in poor habitats of coniferous forests and mixed coniferous forests, but they did not advance to higher layers of the stand, which proved the inefficiency of oak regeneration in the current conditions.

Based on the similarity coefficient for the individual research periods, it was ascertained that in the associations of fresh coniferous forest, fresh mixed coniferous forest and bastard balm-hornbeam deciduous forest, the fastest pace of change in the species composition of stands was associated with the last period (1998–2012). At the start of the study, in the years 1975–1986, those changes were usually non-substantive, which suggested an acceleration in the rate of changes over the last 15 years. While comparing all surveyed forest associations, the most considerable changes occurred in the bastard balm-hornbeam deciduous forest. With regard to the pace and extent of changes in the species composition of stands, the surveyed forest communities may be ranked (in decreasing order) in the following way: bastard balm-hornbeam deciduous forest (MC), fresh coniferous forest (VP), fresh mixed coniferous forest (CP), ash-alder riparian forest (FA) and typical oak-hornbeam forest (TCt). It was observed that in the typical oak-hornbeam forest, the slow pace of change in the entire research period was maintained.

It may be stated that hornbeam expansion is the currently dominant phenomenon, having the most significant impact on the image of the forest and ecological conditions prevailing there, which certainly initiates a sequence of changes in the entire forest ecosystem. Hornbeam entry to habitats in which this species has previously not been present or its presence has been very sparse, results in an equalisation of species composition of forest communities and their assimilation to the oak-hornbeam forest (Bernadzki et al. 1998, Paluch 2001, Sokołowski 2004, Brzeziecki 2008, Brzeziecki et al. 2012). The quoted authors state that the hornbeam expansion has yet to end. Brzeziecki et al. (2012), by analysing long-term survey data collected on permanent sample plots in the Białowieża National Park, wondered what had to happen to make hornbeam withdraw. Paluch (2001) supposed that the tendencies of habitat assimilation to the deciduous forest would deepen, and after ten years the situation is in line with this forecast. From the ecological point of view, the stand determines the existence of the remaining strata of the forest community.

The stand, being the most important component of phytocenosis, creates a specific microclimate, making the life of organisms that require particular ecological conditions for their development possible (Obmiński 1977, Szymański 2000). We may state with reasonable assurance that the above-mentioned equalisation of forest communities is not favourable for and will not be favourable for the development of high biodiversity at various levels: of species and ecosystems. Strict conservation, allowing for tracking and conservation of natural processes, not always and not everywhere, guarantees the maintenance of all important species and forest associations for the Białowieża Forest. Currently, a large emphasis is put on the extension of strict conservation areas. Is such a direction of measures correct for the conservation of the entire natural and cultural heritage of the environmentally precious area of the forest?

Long-term studies have indicated that current trends in the development of natural stands and forest communities do not allow the conservation of the entire environmental abundance of the forest with use of passive methods and that we should not focus only on this form of conservation, excluding further areas from any measures (Brzeziecki et al. 2012). It should be strongly emphasised that the present image of the forest woodlands, characterised by a high biodiversity, is resultant not only from natural processes, but also from centuries-long human activity (Kowalski 1982, Bernadzki et al. 1998, Sokołowski 2004). An underestimated role might have been played there by fires, grazing, potash burning, overabundant game populations, and other human activities, so common in the forest in the past centuries and significantly modifying the species composition of stands and the potential of regeneration of tree species. As a result of the overlapping of various historical, global and anthropogenic phenomena, happening in a relatively short time, significant changes were identified, unexpected in previous forecasts by great researchers of the forest of the first half of the past century (Paczoski 1930, Matuszkiewicz 1952). Are we able to forecast now with a significant probability how natural forest stands of the Białowieża Forest will look in the future? It seems that the hornbeam expansion will continue, as well as the gradual decline of other tree species important for biodiversity, e.g. pine or oak.

Conclusions

- A significant increase in the share of European hornbeam in the formation of stands in the entire Białowieża Forest was confirmed. This species indicates expansion to various habitats, including poor and medium-fertile ones. This results in an equalisation of species composition of forest communities, their assimilation to oak-hornbeam forest, which was repeatedly emphasised in previous research based on more long-term studies, in particular on the area of strict conservation. In natural conditions, the forest regeneration in the majority of analysed forest associations was dominated by hornbeam.

- Spruce withdrew to oligotrophic forest communities. In past decades, the share of this species underwent a substantial reduction in stands of mixed coniferous forests and deciduous forests.
- Pine, oak and birch noticeably reduce their share in the formation of stands, including also the regeneration layer, in the entire Białowieża Forest. This phenomenon was recognised in various conditions, of strict and partial conservation provided more than dozen years ago (of limited human interference).
- Over the last 15 years or so, a rapid and strong reduction of the share of ash was registered.
- The pace of change in the composition of stands accelerated in the past 10–15 years.

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Anna Gazda, Stanisław Miścicki

Forecast of changes in the tree species composition of stands in the Białowieża National Park*

Introduction

Changes in the tree species composition of stands or entire forest ranges constitute one of the modern problems of forestry work. It is interesting for practitioners in connection with the rationalisation of silvicultural treatments, formation of the species composition of stands, and sometimes the pursuit of maintaining a relevant quantity of given tree species, particularly of those economically important. On the other hand, within the scope of scientific research, it is connected with the theory of forest dynamics and, increasingly frequently, with nature conservation (Porté, Bartelink 2002, Pretzsch 2009, Burkhart, Tomé 2012).

An important role in the understanding of changes in the tree species composition of stands is played by research conducted in natural forests, as the development processes there are not subjected to direct human impact. With regard to the territory of Poland, studies are known that use contemporary and historical data, e.g. by Dziewolski (1991) from the Pieniny National Park. However, due to the specificity of forests, duration of the time sequence of the measurements and the regularity of repeated observations, the research conducted in the Białowieża National Park should be regarded as the most important. Successive surveys on permanent sample plots were initiated there in 1936 by Professor Tadeusz Włoczewski (Bernadzki et al. 1998). On their basis, changes in the share of all (eleven) significant tree species (Brzeziecki et al. 2012) were identified. The survey results were applied for the development of an equilibrium model of the breast-height diameter structure of individual tree species, as well as for the performance of two variants of a species composition forecast for the year 2088, on the basis of the tree count in the Strict Reserve of the Białowieża National Park (Brzeziecki et al. 2016). In the 1990s, research on the dynamics of that area with the use of the representative sampling method commenced (Brzeziecki et al. 2010, Miścicki 2012). Paluch (2015) presented changes in the natural stands of the Białowieża

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Forest on the basis of data from 120 selected permanent sample plots, measured successively since approx. 1975 at the initiative of Professor Aleksander Sokołowski. Changes in the tree species composition of stands in the Białowieża National Park, determined on the basis of long-term successive surveys, prompt us to ask the question, how will these changes look like in the future, in the next few decades? This paper is an attempt to answer this question.

The objective of this paper was carrying out a medium-term forecast of changes in the tree species composition, expressed by the growing stock of trees, in stands of the Białowieża National Park. Data collected on systematically distributed permanent sample plots were applied, therefore different from those gathered since 1936 on permanent research plots (Brzeziecki et al. 2016). For the calculations used for forecast purposes, an empirical model of growth of tree size classes was used, and the growing stock of merchantable timber for a given forecast date calculated, both for the division into individual species and for their total, while for a given period (between two dates) the volume of ingrowths (trees exceeding the breast-height diameter threshold of d=8cm) and declined trees, and the current periodic volume increment were calculated.

Material and methods

The survey was conducted in the oldest part of the Białowieża National Park, traditionally referred to as the Strict Reserve. In 1921, this area saw the first stirrings of the national park (under the name Reserve Forest Subdistrict). It is comprised of stands measuring 4,584 ha of stands, of which an initial 1,061 ha were subjected to a strict conservation, and then all of them from 1929.

The prediction of changes in stands of the Białowieża National Park was carried out with the size class method (Gazda, Miścicki 2016). As with the quoted paper, four stages were distinguished: calibration, verification, model validation, and performance of the actual forecast.

The empirical material was collected on permanent and temporary sample plots. Measurements of 160 permanent samples were conducted in August 2000, 2002, 2004 and 2011. As their centres, some of the points established by employees of the Białowieża National Park under the process of setting up permanent sample plots in 1999 were used. In three regions where such points did not exist, our own ones supplemented them in order to obtain a regular grid of sample plots. The centres of the samples created a grid with average dimensions of 267 m × 1067 m, with the shorter side having an approximate azimuth of 86°. The data collected on the permanent sample plots were used to parametrise the model of changes in the tree species yield, including calculations of the mortality of trees of individual species depending on their size, periodic breast-height diameter growth for trees of individual species depending on size, and the rate of sapling growth from the lowest class of sapling stand to the next class.

The temporary sample plots were surveyed in June and July 1995 and in August 2005, 460 at each term. Each time the same grid (100 m × 1000 m) of sample plot centres was applied, with their shorter side having an azimuth of 330°. The data collected on the temporary sample plots for both terms, since they were independent data not used in the model calibration, were applied for model validation.

Permanent and temporary sample plots had a concentric form. Each of them was composed of four concentric circles with sizes: 5.31 m^2 (measurement of all trees – including self-sown seedlings at aged ≥2 years), 20 m^2 (measurement of trees h>0.3 m), 50 m^2 (measurement of trees with diameter at breast height d^3 2 cm), 200 m^2 (measurement of trees with d≥12 cm), and 500 m^2 (measurement of trees with d≥36 cm). For all trees included in the sample, the species was defined and the diameter at breast height (or their height if h<1.3 m) were measured. In each stand layer, the height of one to three trees were measured for each species (depending on the share) to plot the height curve. On the permanent sample plots, by measuring the distance and azimuth against the centre, the positions of trees were recorded. On that basis, at subsequent terms, changes in tree sizes and their status (survival, dieback, change in dimensions, emergence) were determined. The volume of merchantable timber of individual trees was calculated according to the formulas by Bruchwald et al. (2000).

The assumption was made, that the size class method-based forecast will be built on the calculation of density of individual tree species in the distinguished 4 cm wide breast-height diameter classes at the subsequent terms, at an interval of 10 years. For the first of them, empirical data were used. The growing stock predicted for the second term created a basis for carrying out the forecast for the third term, etc. The decision was made to run calculations separately for the individual tree species: Norway spruce *Picea abies*, pedunculate oak *Quercus robur*, European hornbeam *Carpinus betulus*, black alder *Alnus glutinosa*, small-leaved linden *Tilia cordata*, European ash *Fraxinus excelsior*, Scots pine *Pinus sylvestris*, silver birch *Betula pendula* and downy birch *B. pubescens*, Norway maple *Acer platanoides*, aspen *Populus tremula,* wych elm *Ulmus glabra* and field elm *U. minor*. Due to their rare occurrence, both species of birch were accumulated into one group, just like elm. In total, the forecast was completed for 11 tree taxa. For the remaining, sparsely represented species, no forecast was carried out. It was assumed that their density in the breast-height diameter classes and the yield are invariable.

In the applied size-class growth model (Gazda, Miścicki 2016), for calculating the predicted density of trees in a given class (here: diameters at breast height), it was necessary to possess data on the periodic mortality of trees in a given class, on the periodic diameter increment of trees in a given class, and on the rate of saplings advancement from the lowest sapling layer to the first size class of the parent tree layer (count of ingrowth trees). The tree count in a given size class and at the end of the forecast period *tj*+1 comes to:

$$n_{i.tj+1} = (n_{i.tj} \cdot (1 - p_i)) \cdot (1 - u_i) + (n_{i-1.tj} \cdot p_{i-1}) \cdot (1 - u_{i-1}) \qquad [1]$$

where:

$n_{i.t}$, $n_{i-1.tj}$ – density of trees in the size class i or in the preceding class i–1 at the date tj at beginning of the forecast,

u_i, u_{i-1} – fraction of declined trees (mortality) in the period Δt_k in the size class i or in the preceding class i–1 (u takes values from 0 to 1),

p_i, p_{i-1} – fraction of trees advancing to the subsequent size class in the period Δt_k from the class i or from the class i–1, calculated e.g. on the basis of the rate of the breast-height diameter increment:

$$p_i = (zd_i \cdot \Delta t_k) / b_i \qquad [2]$$

where:

zd_i – annual breast-height diameter increment in the size class i,

Δt_k – length of the forecast period in years,

b – width of the size class i.

The mortality (probability of death in a given period) u was calculated separately for each species, depending on the tree diameters at breast height:

$$u = (1/(1 + \exp(b_0 + b_1 \cdot \log(d + c) + \ldots + b_n \cdot (\log(d + c))^n)))^{(t/10)} \qquad [3]$$

where:

$b_0, b_1, \ldots, b_n$ – coefficients of the equation,

d – tree diameter at breast height,

c – constant (2 was assumed),

t – period of observation (two or seven years).

Regardless of the results of regression calculations, it was assumed that the tree mortality in the thickest breast-height diameter class was 1.

The periodic tree diameter increment, used to calculate the p rate of tree transfer to the subsequent size class in a given period Δtk was calculated separately for each species, depending on tree breast-height diameter in the beginning of that period:

$$zd = 10^{(b_0 + b_1 \cdot \log(d + c) + \ldots + bn \cdot (\log(d + c))n} \qquad [4]$$

where:

c – constant (2 was assumed),

other symbols as above.

That formula allowed the presentation – within the analysed range of diameters at breast height – of various forms of relation between zd and $d_{1.3}$. It was compliant with the Vanclay's suggestion (1994) that the selected equation should represent well that relation within the entire range of tree sizes.

The volume of ingrowth in a given period was calculated on the basis of the count of trees advancing from the thickest breast-height diameter class of saplings to the first class of breast-height diameter of the parent tree layer (assumed *d*=8−11.9 cm). In order to calculate the predicted density of trees in subsequent size classes in the sapling layer, it was necessary to determine the share, in relation to the initial count, of trees from the first size class in the sapling layer (*h*=0.3−1.3 m), which advanced in the given period to the second class (*d*=0.1−1.9 cm). The following formula was applied:

$$p_{pas\_1.3} = N_{pas\_1.3} / N_{h=0.3-1.3} \quad [5]$$

where:

*Npas*_1.3 – count of trees that grew in the examined period from size class *h*=0.3−1.3 m to size class *d*=0.1−1.9 cm,

Nh=0.3−1.3 – count of trees in size class *h*=0.3−1.3 m in the beginning of the examined period.

Such a solution resulted from the fact that within the ten year period, size class *h*=0.3−1.3 m to size class $d_{1.3}$=0.1−1.9 cm included trees that germinated during the given period, so they did not exist at the commencement of the observation.

The empirical data on tree mortality and the rate of advancement to the subsequent size class were used to verify the model was carried out. To that end, assuming the structure of growing stock in 2000 as the beginning of the forecast, the predicted yield for the individual tree species in 2011 was calculated. Dependent data were used – the same that served for the calculation of the model parameters. In the case of an occurrence of a difference between the forecasted and the measured yield (according to data from sample plots) of the given species in 2011, tree mortality was adjusted. To that end, in each size class *i* the mortality coefficient was raised to the *w* power ($w \geq 0$, identical within each size class): u_i^w. The *w* value was calculated with the method of successive approximations in order that in 2011 the predicted volume was equal to the measured one. The application of the tree mortality adjustment resulted from the assumption that that feature was estimated less accurately than the increment of tree diameter.

The model was validated with use of independent data (not used for the model parametrisation). A forecast for a ten year period was carried out, using the results of measurements of sample plots in 1995 as the initial data. The obtained forecast result in 2005 was compared with the results of surveys of sample plots for that date.

The initial state of the actual forecast was adopted according to the results of the survey of sample plots in 2005. The density of trees in the given size class of the given species, thus the volume of merchantable timber, was predicted for the subsequent four terms at intervals of ten years (at 2015, 2025, 2035 and 2045), and the dynamic of timber growing stock for the periods 2005–2015, 2015–2025, 2025–2035 and 2035–2045.

Results

In the case of the majority of species, the dependence of periodic tree mortality on their breast-height diameter had a typical run, presented by the asymmetric U-shape curve (Fig. 1). The mortality of the thinnest trees in the majority of species (except elm and aspen) was high, and decreasing with increasing diameter at breast height (up to approx. 36−60 cm) and was gradually increasing after exceeding that threshold (except maple).

Due to the type of dependence of the mean periodic (annual) increment of tree diameter on their breast-height diameter, four groups of species were distinguished. The first comprised oak, aspen, spruce, linden, and birch. The curve illustrating that dependence was bilateral, asymmetric (Fig. 2). The increment of diameter of trees rated as the sapling layer (*d*<8cm) was low, as with all other species. In the class of thin trees (*d*=8−35.9 cm), it was increasing together with increasing diameter at breast height and reaching its maximal value in the class of medium-sized trees (*d*=36−59.9 cm) or, as in the case of spruce, even thick trees (*d*≥60 cm). The second group comprised ash, alder and hornbeam; thin and thick trees demonstrated a relatively higher rate of mean diameter increment, while medium trees had a lower rate. This may be explained by the fact that thick trees of those species re-

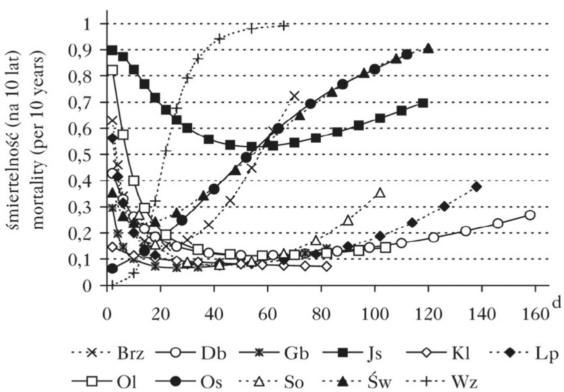

Fig. 1.
Mortality of tree species (curves adjusted) over the ten-year-period depending on the diameter at breast height (*d* [cm])
calculations executed on the basis of surveys in 2000, 2002, 2004 and 2011:
Birch – *Betula* sp., Oak – *Quercus* sp., Hornbeam – *Carpinus betulus*, Ash – *Fraxinus excelsior*, Maple – *Acer platanoides*, Lime – *Tilia* sp., Alder – *Alnus glutinosa*, Aspen – *Populus tremula*, Pine – *Pinus sylvestris*, Spruce – *Picea abies*, Elm – *Ulmus* sp.

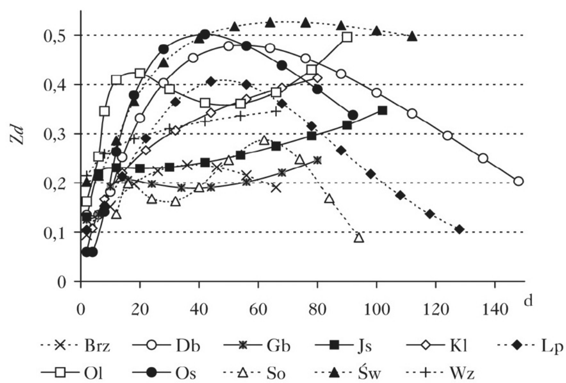

Fig. 2.
Annual increment of diameter (*Zd* [cm]) of species (curves adjusted) depending on the diameter at breast height (*d* [cm]) in the beginning of the period
denoted as in Fig. 1;

sponded with intensified increment when their crown was well-lighted. Pine (third group) differed from the species in the second group by the fact that in the class of thick trees the mean increment of breast-height diameter was lower and lower, following the increase in their dimensions. The fourth group was constituted by maple and elm, whose mean diameter increment was higher the larger the tree diameter.

The rate of tree ingrowth from sapling class h=0.3−1.3 m to class d=0.1−1.9 cm, apart from using it for predicting the development of resources, illustrated the dynamic of that part of regeneration. In the period 2000–2011, trees of only six species advanced from a lower sapling class to a higher one. The rate of ingrowth for alder was 9.1%/year (assuming the same density of trees in the class h=0.3−1.3 m as in 2005: 3.6 pcs/ha/year), for hornbeam 1.5%/year (33.4 pcs/ha/year), for spruce 1.5%/year (3.1 pcs/ha/year), for maple 0.9%/year (1.8 pcs/ha/year), for birch 0.9%/year (1.2 pcs/ha/year) and for linden 0.4%/year (1.0 pcs/ha/year).

The forecasted yield (according to the state as of 2011), calculated for model verification, differed from the yield measured in 2011 (with use of data applied for model parametrisation) for the majority of tree species. Generally, these differences were not large: in seven cases (out of eleven), their absolute value did not exceed 1 m^3/ha. The predicted yield was higher than the measured one in the case of seven taxa: spruce (7.1 m^3/ha, i.e. 8.5%), linden (3.1 m^3/ha, 6.2%), alder (1.2 m^3/ha, 2.4%), hornbeam (0.5 m^3/ha, 0.8%), aspen (0.5 m^3/ha, 4.2%), birch (0.2 m^3/ha, 1.5%) and elm (0.1 m^3/ha, 13.7%), while it was lower in the case of four species: oak (–3.7 m^3/ha, i.e. –3.9%), pine (–0.5 m^3/ha, –2.3%), maple (–0.4 m^3/ha, –2.2%), and ash (–0.3 m^3/ha, –1.8%). Based on those data, the tree mortality of individual species relative to their diameter was adjusted and then applied for model validation.

The mean yield of stands forecasted for 2005 (based on data from 1995), calculated under the process of model validation, was higher than the yield measured only by 1.7 m^3/ha (Table). For six tree taxa, the differences between predicted and measured value were positive, while in five cases they were negative.

Based on the forecast for the years 2005–2045, significant changes in the yield of most tree species should be expected. Already in the period 2015–2020, spruce will no longer be the species with the highest share in terms of the volume of merchantable timber, and by 2045 will become only the fifth species (Fig. 3). Its place on the list will be taken over by hornbeam, whose yield will be the largest by the end of the period covered by the forecast. The highest increase in the yield will be demonstrated by linden, which will become from approx. 2030 the second species in terms of [yield] volume. The yield of oak will continue to decrease, ever more rapidly, from the second species in 2005 to the fourth species at the end of the forecast period. The yield of alder will continue grow, but at decreasing rates. A significant decrease in the yield of ash will occur, by 2045 it will only be larger than aspen and elm. In the case of these two latter taxa, as well as pine and birch, a drop in their yield will also take place. The yield of maple will slightly increase by 2035, and then will decrease.

TABLE

Mean yield [m³/ha] and share (in brackets, [%]) of species measured (Z) in 1995 (used as initial data for the validation of the growth model) and 2005, and forecast (P) for 2005

	1995Z	2005Z	2005P	2005Z–P
Spruce	94.0 (23.7)	77.2 (20.5)	79.9 (21.1)	2.7 (3.5)*
Oak	76.4 (19.3)	67.5 (17.9)	72.3 (19.1)	4.8 (7.1)
Hornbeam	50.5 (12.7)	54.7 (14.5)	57.7 (15.2)	3.0 (5.5)
Alder	41.0 (10.3)	42.9 (11.4)	46.0 (12.1)	3.2 (7.4)
Lindene	42.3 (10.7)	40.9 (11.4)	48.6 (12.1)	7.7 (18.8)
Ash	31.9 (8.1)	31.3 (8.3)	16.3 (4.3)	–15.0 (–47.9)
Pine	28.7 (7.2)	29.7 (7.9)	28.0 (7.4)	–1.7 (–5.8)
Maple	11.3 (2.9)	14.1 (3.7)	12.8 (3.4)	–1.3 (–8.9)
Birch	12.8 (3.2)	12.2 (3.2)	12.7 (3.4)	0.5 (4.4)
Aspen	6.0 (1.5)	5.3 (1.4)	3.6 (0.9)	–1.7 (–31.8)
Elm	1.0 (0.3)	1.3 (0.3)	0.7 (0.2)	–0.6 (–50.0)
Other**	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	–
Overall	396.2	377.3	379.0	1.7 (0.5)

* reference of the difference between the volume forecasted and measured against the measured value.
* the remaining species were not subject to forecast and their yield was presumed invariable.

The predicted changes in the yield of individual species will contribute to changes in the mean yields of stands of the Białowieża National Park. In 2005–2015, it will decrease from 377 to 368 m³/ha. Only at the next term and subsequent terms will it grow to 371 m³/ha in 2025, 379 m³/ha in 2035, and 389 m³/ha in 2045. This means that before the year 2045 a return to the mean yield of stands as of 1995, when it was 396 m³/ha, should not be expected.

The relations between the forecasted volume of tree loss and the increment of volume (to a substantially less extent of ingrowth) explain the expected changes in yield in the next decades (Fig. 4). The increment of volume in the years 2005–2045 will remain at an almost unchanged level, while the volume of tree loss will be reduced. The volume of ingrowth will slightly increase from 2025. The change in volume of tree loss, and consequently in the yield of stands, will be affected by the difference in the dynamic of yield for individual species. Linden and hornbeam, as those species for which tree loss will be relatively small and the increment quite high (Fig. 5), will have a substantial positive effect on the yield changes. In the case of ash, it will be the contrary. In the period 2005–2045, the increment of individual species will be subject to changes. In the 2005–2025 period, the largest portion will be attributed to spruce, but later, in the 2025–2045 period, to linden, and only slightly less (in 2035–2045) to hornbeam. In the entire 2005–2045 period, the largest portion of declined trees will account for spruce. Oak will also represent a high share in them. The share of alder in declined trees will increase in the subsequent decades, while the share of ash (high in the beginning) will decrease together with a decreasing yield in this species. In the entire period 2005–2045, only five taxa will have a significant share in the ingrowth.

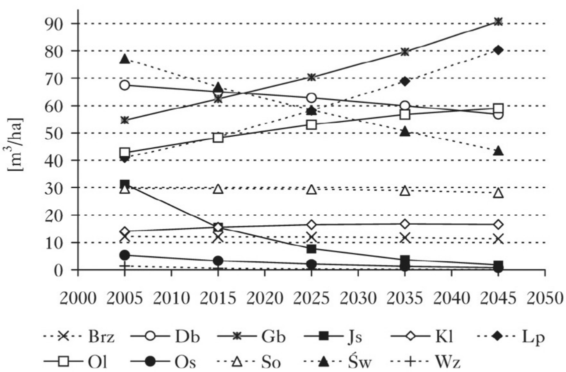

Fig. 3.
Predicted mean yield of individual species. Denoted as in Fig. 1;

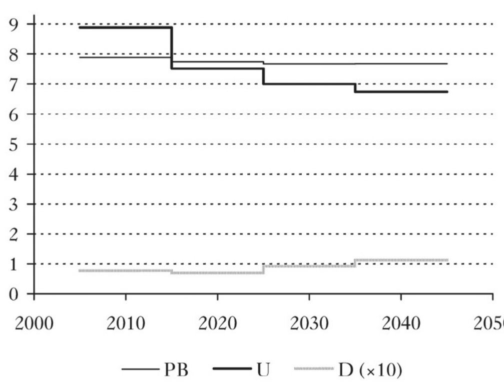

Fig. 4.
Predicted mean annual (over ten-year period) volume [m³/ha/year] of ingrowths to the-breast diameter class d=8.0–11.9 cm (D) and declined trees (U), and current volume increment (PB).

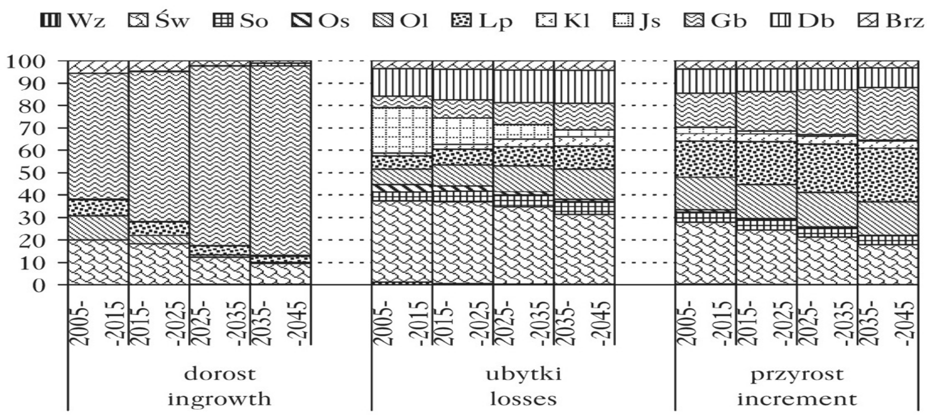

Fig. 5.
Predicted share [%] of tree species in the volume of ingrowths, declined trees and current increment. Denoted as in Fig. 1

Discussion

Changes in the volume of tree species in the Białowieża National Park, forecasted for a period of 40 years, mostly corresponded with trends occurring in the past (Bernadzki et al. 1998). Due to the diverse features used for the description of this process (in the quoted paper: tree count and basal area, and here: volume of merchantable timber), differences may be noticed, particularly in the case of species being rare but featuring large dimensions, as well as of species represented frequently and numerously, but small in size. Due to the difference in the term of the forecast (for the year 2088) and the use of tree count to present the predicted species composition of stands in the paper by Brzeziecki et al. (2016), it was difficult to compare its results with the results of the actual study. However, in both of them it was forecasted that hornbeam and linden would be the dominant species of stands of the Strict Reserve of the Białowieża National Park.

According to the forecast, over the next 40 years the proportion of the share of the five most numerous species will change. Their yields will still be quite high, mainly due to the presence of trees of medium and large diameter. However, by taking into account trees of the sapling layer when forecasting the status and dynamics of trees allowed the judgement that, particularly by the end of the forecast period, the parent part of stands would be supplemented with ingrowth by almost only one species: hornbeam.

It should be born in mind that real changes materialising in the forest may differ from those forecasted. Looking back, in a similar 40-year period, strong and previously not predicted phenomena occurred in the Białowieża National Park: elm dieback in 1966–1967 (Sokołowski 2004), four-fold intensified spruce dieback (Michalski et al. 2004) and ash dieback since approx. 2002. The rates of increments and mortality of individual tree species will probably be subject to fluctuations. However, it is hard to predict that in a quite short, 40-year period, although it would significantly contribute to the increase in their share in relation to hornbeam. In the case of that latter species, probably only mass dieback also affecting thin trees, as the result of a disease or an external factor, may cause a drop in its share.

The forecast of the above-described changes refers to a forest subjected to a strict conservation. That research facilitated the observation of, how dynamic is the forest's response to continuous changes as well as to changes of an incidental nature (distortions). In terms of their reach, they may be customarily divided into global, regional and local changes. Among the global ones, affecting the change in the species composition, there should be indicated climate warming, which contributes to an increase in the rate of biomass increment and to a quicker development of species formerly growing in in warmer zones. In the case of the Białowieża National Park, the local factor was the lowering of the ground water level, having its beginnings in the 1930s and resulting from engineering measures in the vicinity of the Białowieża Forest. Another, still present factor is the excessive impact of herbivorous ungulates on young trees caused by the hunting management near the park. Hornbeam is the best regenerating species under such conditions (Kuijper et al. 2010).

An analysis of the gradual decrease in the share of certain tree species (thus an increase in the share of others) induced Brzeziecki et al. (2012) to express their concern about the possibility of conservation of landscape and environmental values of the Białowieża National Park. The alteration in the species composition of stands, which arose over the last decades, as well as the predicted domination of one species are known also from North America (Salk et al. 2011). Similarly to the Białowieża National Park, the authors considered the excessive impact of ungulates on the young tree generation as one of the more major factors. The authors of the actual study share the opinion that active measures striving to reduce the pressure of these animals are the only ones that may be executed in order to sustain the 'natural' historical dynamic of the forest. The results of the forecast presented here indicate what forest structures may be expected in the Białowieża National Park in the future.

Conclusions

- The results of a forecast built on a tree size-class growth model demonstrated that even if in regard to the mean yield of stands of the Białowieża National Park in the years 2005–2045, only slight overall changes should be expected, but in the case of six species (spruce, oak, hornbeam, linden, alder and ash) these changes will be considerable.
- Predicting changes in the structure of stands several decades in advance may be applied for planning the conservation of forest areas, since the forecast results demonstrate the

future state of a forest in a situation when it is affected by treatments and occurrences with former intensity, and in the case of strict conservation treatments and occurrences affecting this area indirectly.

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The origin of Norway spruce (*Picea abies* L. Karst.) stands in the Białowieża Forest on the background of the area of Regional Directorate of the State Forests in Białystok, based on mitochondrial DNA analyses*

Introduction

Norway spruce (*Picea abies* L. Karst.) is a major forest-forming species in north-eastern Poland (Sokołowski 1993). This species is a constituent part of many forest communities in the Białowieża Forest (Czerwiński 1977, Sokołowski 1993). At the beginning of the 20th century, Paczoski drew attention to the domination take-over by spruce (*Picea abies* (L.) in the woodlands of the Białowieża Forest (Paluch 2001). The forest management conducted in the forest was a factor favourable for the expansion of spruce there. From the 17th to the mid of 19th century, the forest was utilised mainly by felling old pine and oak trees, by which blanks emerged, where the regeneration of spruce occurred. In the second half of the 19th century, the utilisation of the forest by means of clear-cutting was commenced, and in the 1920s and 1930s the devastating exploitation of forests took place (World War I by the German occupation and, in the years 1924–1929, activities of the English company The Century European Timber Corporation) (Więcko 1984).

The woodlands of the Białowieża Forest are situated in the territory of the Białowieża National Park (with an area of 10,500 ha) and three forest districts of the State Forests (52,600 ha): Białowieża, Browsk and Hajnówka. Despite the centuries-old human activity, the woodlands of the Białowieża Forest, including particularly the Białowieża National Park (BPN), belong to the best conserved lowland natural forests in the Central Europe. Against

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other areas, the Białowieża National Park is eminent due to the fact that for more than 100 years no forest management has been conducted there (Paluch 2002). The percentage share of spruce in the forest area counted on the basis of dominant species comes to: 17.6% in the Białowieża National Park, 31.2% in the Białowieża Forest District, 20.6% in the Browsk Forest District, and 27% in the Hajnówka Forest District (http://www.bdl.lasy.gov.pl). Since 1930s, a process of spruce retreat from stands in the fertile habitats of the Białowieża National Park has been observed (Bernadzki et al. 1998). One of factors affecting this phenomenon is constituted by cyclically recurring gradations by the European spruce bark beetle (*Ips typographus* L.) (Michalski et al. 2004, Grodzki 2013). The form of the modern environment of the forest is a resultant of two factors – natural environmental processes (biotic and abiotic) and the history of human impact on nature (e.g. intensive livestock grazing, prohibition of burning the forest floor and fire protection in the beginning of the 19th century) (Samojlik, Jędrzejewska 2004). Palynological studies show that Norway spruce arrived in Poland from two major post-glacial refugia: northern (Baltico-Nordic) and southern (Hercyno-Carpathian) (Szafer et al. 1953, Latałowa, van der Knaap 2006). Both geographical ranges of spruce occurrence are separated by a spruce-free belt, i.e. the so-called disjunction of Central Poland, 50–100 km wide, which traverse the Polish Lowland, Baltic, Wielkopolska and Masurian-Podlasie regions (Szafer 1977; Boratyńska 2007; Boratyński 2007). Most of researchers support the statement that the spruce-free belt emerged as a result of human activity through deforestation for the benefit of farming and cyclic fires caused by meadow and forest floor burning (Lublinerówna 1934, Żybura 1990, Broda 1998, Środoń, Tobolski 1998, 2007, Modrzyński 1999). The presence of spruce in this area over the past millennia is confirmed by pollen analyses (Ralska-Jasiewiczowa et al. 2004).

The studies on the DNA variability threw a new light upon the concept of the geographical range limits presented by Szafer (1977), including also for spruce growing in the Białowieża Forest. The application of molecular genetics in forestry allowed precise identification of forest gene resources to determine their phylogenesis and the level of genetic variation, based on genetic information included in the nuclear, mitochondrial and plastome DNA. The nuclear DNA, inherited from both parents, is a source of information on the level of variability of the gene pool of a given stand, while the organellar DNA in plants inherited maternally allows the recognition of the phylogenesis (i.e. historical origin) of a species on a given area. The absence of recombination processes and conservative transmission of mitochondrial DNA from one generation to another made it possible to track the paths of spruce expansion from major post-glacial refugia in Europe. Based on an analysis of the mitochondrial *nad*1 (intron b/c) gene in spruce populations present within the limits of the northern and southern geographical range of *P. abies* in Europe (Fig. 1), it was ascertained that populations from the north of Europe were described with a dominance of haplotype 'c' of the *nad*1 gene, while spruce populations from the south are marked by the dominance of haplotype 'a' (Sperisen et al. 2001). The examination of the same marker of mitochondrial DNA shows that most spruce trees in the north-eastern part of Poland have genes originating from the northern post-glacial refugium, while a part of spruce population in the south of the Regional Directorate of the State Forests in Białystok stems from the southern geographical range of this species in Europe (Dering, Lewandowski 2009, Nowakowska 2009).

The objective of this paper comprised the determination of the genetic origin of spruce trees present in the territory of the Białowieża Forest, in reference to two main routes of the post-glacial species migration (northern and southern) to Poland. Results of the mitochondrial DNA examinations of seven populations of Norway spruce from the territory of the Białowieża Forest in reference to 24 other populations of this species in the territory of the Regional Directorate of the State Forests in Białystok were presented.

Material and methods

The research encompassed 31 populations of Norway spruce (*Picea abies* L. Karst.) of local origin from the territory of the Regional Directorate of the State Forests in Białystok (Table 1). The material for DNA testing (needle drilling or drilling with a diameter of 3 mm) was collected in the years 2007–2013 from trees randomly spread in the stand, in a way enabling the avoidance of relatedness between the examined specimens, paying attention to their good health condition.

In the Białowieża Forest, the plant material was obtained from two spruce populations (no. 1 and 2 – 81 trees in total) located in the Strict Reserve of the Białowieża National Park, from two populations (no. 3 and 4 – 99 trees) situated in the territory of the Białowieża Forest District, from one population from the Hajnówka Forest District (no. 5 – 49 trees), and two sites from the Browsk Forest District (no. 6 and 7 – 97 trees). The remaining 24 populations were spread over the entire territory of the Regional Directorate of the State Forests in Białystok – from the southernmost stand no. 15 in the Bielsk Forest District to stand no. 28 in the Suwałki Forest District, situated at the border with Lithuania and Russia. In total, 1,390 spruce trees were examined. The mean age of the studied populations fluctuated between 72 and 188 years, the area between 0.7 and 30.17 ha, while the prevalent forest habitat type was the fresh mixed deciduous forest (LMśw) to the south and the fresh mixed coniferous forest (BMśw) to the north of the Regional Directorate of the State Forests in Białystok (Table 1).

The extraction of genome DNA from spruce tissues was executed with the use of DNA isolation sets DNA DNeasy 250 Plant Mini Kit (Qiagen, USA) and Plant Kit (Macherey-Nagel®, Düren, Germany), following the manufacturer's recommendations. The quantity and quality of the obtained DNA were estimated spectrophotometrically, with a wavelength of 230, 260 and 280 nm in the NanoDrop® ND–1000 (Wilmington, USA) device.

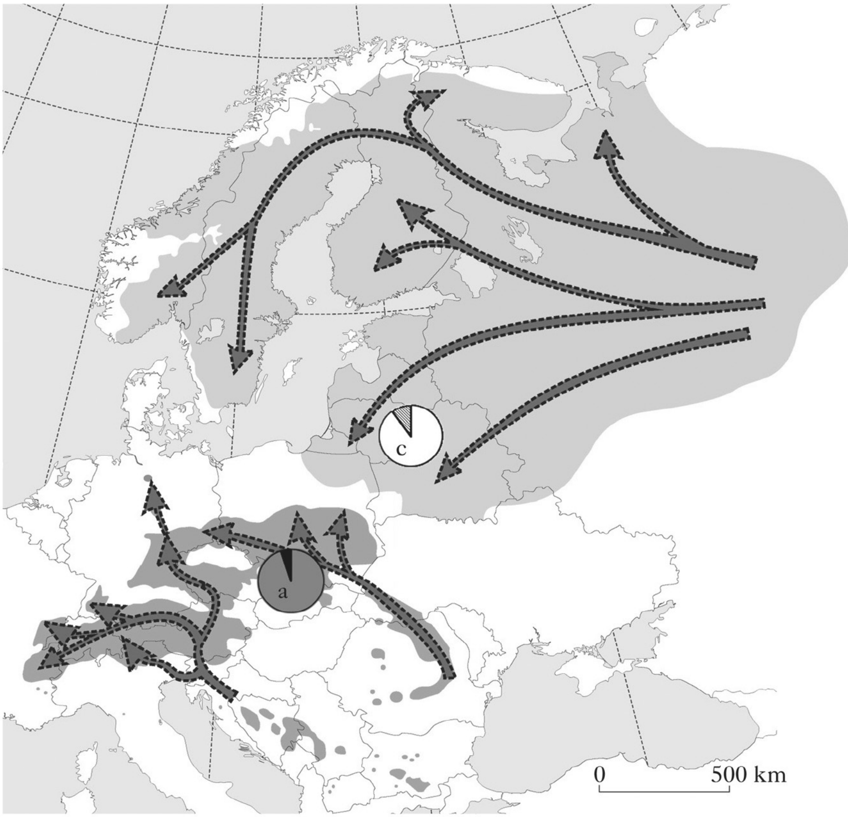

Fig. 1.
Geographical range of Norway spruce in Europe (Schmidt-Vogt 1977) and characteristic haplotypes of mitochondrial DNA ('c' for the northern range and 'a' for the southern range)

TABLE 1
Location, age (W [years]), area of sub-compartment (A [ha]), forest habitat type (TSL) and seed base type (TBN) for examined spruce stands (Population)

	Population		W	A	TSL	TBN
1	BiałowieżaNational Park	52°46'N, 23°50'E	150	30.17	LMw, BMśw	RS
2	Białowieża National Park	52°45'N, 23°51'E	140	25.95	LMśw	RS
3	Białowieża, Teremiski	52°44'52N, 23°46'30"E	188	4.72	Lśw	WDN
4	Białowieża, Grudki	52°40'40"N, 23°47'06"E	149	20.87	LMśw	WDN
5	Hajnówka, Długi Bród	52°38'30"N, 23°37'05"E	162	9.90	LMw	GDN
6	Browsk, Jelonka	52°48'00"N, 23°47'50"E	133	14.21	LMśw	GDN
7	Browsk, Krynica	52°52'46"N, 23°32'E	132	3.96	LMw	WDN

	Population		W	A	TSL	TBN
8	Czarna Białostocka, Czarna Wieś	53°18'N, 23°13'E	72	2.9	BMśw	DG
9	Supraśl, Dworzysk	53°16'N, 23°28'E	103	4.92	LMśw	DG
10	Żednia, Kazimierzowo	53°01'N, 23°34'E	100	14.98	Lśw	GDN
11	Żednia, Sokole	53°03'48"N, 23°32'04"E	113	3.17	BMw	GDN
12	Knyszyn, Kopisk	53°17'N, 23°1'E	102	5.25	LMśw	DG
13	Knyszyn, Kopisk	53°17'N, 23°0'E	87	14.42	BMśw	DG
14	Bielsk, Jodłówka	52°36'16"N, 23°30'42"E	107	8.94	LMśw	GDN
15	Bielsk, Dobrowoda	52°33'33"N, 23°22'18"E	94	0.49	BMw	GDN
16	Rudka, Dołubowo	52°35'N, 22°52'E	101	0.7	LMśw	DG
17	Dojlidy, Antoniuk	53°06'20"N, 23°02'32"E	94	6.83	Lśw	GDN
18	Knyszyn, Karczmisko	53°17'98"N, 23°07'32"E	100	16.57	BMśw	RS
19	Czarna Białostocka, Szyndziel	53°26'58"N, 23°19'34"E	120	4.44	LMśw	GDN
20	Czarna Białostocka, Nowy Dwór	53°32'50"N, 23°27'54"E	117	2.85	LMśw	GDN
21	Augustów, Kozi Rynek	53°47'21"N, 23°20'01"E	134	5.34	LMw	GDN
22	Płaska, Trzy Kopce	53°50'46"N, 23°27'40"E	105	7.45	BMśw	GDN
23	Głęboki Bród, Chylinki	53°58'05"N, 23°16'28"E	128	7.2	BMśw	GDN
24	Pomorze, Wiłkokuk	53°59'10"N, 23°23'25"E	104	18.25	LMśw	WDN
25	Suwałki, Płociczno	54°01'40"N, 22°56'35"E	118	5.07	BMśw	GDN
26	Suwałki, Pijawne	53°59'50"N, 22°56'47"E	133	13.0	BMśw	WDN
27	Szczebra, Koniecbór	54°01'55"N, 22°50'27"E	105	4.86	LMśw	GDN
28	Suwałki, Rutka	52°18'00"N, 22°58'10"E	104	4.86	LMśw	GDN
29	Olecko, Dąbrówka	54°07'10"N, 22°38'57"E	101	14.86	LMśw	GDN
30	Olecko, Gąski	53°57'35"N, 22°29'36"E	105	8.62	Lśw	GDN
31	Ełk, Dąbrowskie	53°45'18"N, 22°29'20"E	111	8.07	Lśw	GDN

LMw – moist mixed deciduous forest, BMśw – fresh mixed coniferous forest, LMśw – fresh mixed deciduous forest, Lśw – fresh deciduous forest, BMw – moist mixed coniferous forest, RS – strict reserve, WDN – selected seed stand, GDN – managed seed stand, DG – managed stand

The haplotypes of spruce were assessed based on the polymerase chain reaction (PCR) designed for the mitochondrial *nad*1 gene intron b/c (Sperisen et al. 2001). The amplification products were analysed based on chip electrophoresis (Bioanalyser®, USA), following the manufacturer's recommendations, with use of the Agilent DNA 1000 kit

(Agilent Techn., Waldbronn, Germany). The alleles were classified into haplotype classes according to the criteria of Sperisen et al. (2001), where the 'a' haplotype corresponded to the gene fragment with length of 320 bp, 'b' – 370 bp, 'c' – 223 bp, 'd – 253 bp, while for alleles with length of 340 bp, 420 bp and 280 bp new classes were created, respectively 'a1', 'b1', and 'd1.

The calculations of genetic parameters, including the observed (*n*a) and effective (*n*e) number of haplotypes, frequency of private alleles (*A*priv) and mean haplotype diversity *h* (Nei 1973) were carried out with the software GenAlEx v.6.5 (Peakall, Smouse 2012). The polymorphism of the examined DNA fragments was determined based on the mean value of the Shannon [Diversity] index (*I*), while the classification of examined specimen into groups representing sets with high genetic similarity – with help of the principal coordinates analysis (PCoA), using the GenAlEx v.6.5 software, in which the standardised covariance matrix of genetic distances of Nei and Li (1979) was considered.

Results

The amplification of the *nad*1 gene generated seven different haplotypes occurring with variable frequency in the examined spruce populations from the territory of the Regional Directorate of the State Forests in Białystok (Fig. 2). In six populations from the Białowieża Forest area, the 'southern' haplotype 'a' dominated, frequency of which was 77.5% in the stand no. 4 from the Białowieża Forest District, 75.5% in the facility no. 5 in the Hajnówka Forest District, and 70.8% on the site no. 1 from the Strict Reserve of the Białowieża National Park, while in the population no. 2 from the Strict Reserve of the Białowieża National Park and in the population no. 6 in the Browsk Forest District it indicated a frequency of, respectively, 51.5% and 46.9%. In five populations (no. 1–5), the 'northern' haplotype 'c' occurred with a frequency below 46%. Two stands (no. 2 from the Białowieża Forest District and no. 3 from the Strict Reserve of the Białowieża National Park) had additionally a 2–3 percentage share of rare 'a1' haplotype, which is the variant similar to the 'southern' 'a' haplotype. That haplotype occurred also in one population from the Regional Directorate of the State Forests in Białystok only, no. 8 (Czarna Białostocka Forest District). A large frequency of the 'a' haplotype was also identified in stands located in the neighbourhood of the Białowieża Forest, to the south of the Regional Directorate of the State Forests in Białystok: 86.0% in the population no. 14 (Bielsk) and 100% in the population no. 16 (Rudka) (Table 2, Fig. 2). Other spruce populations from the Regional Directorate of the State Forests in Białystok were characterised mainly with the occurrence of the Nordic 'c' haplotype: from 75 to 100%. Two spruce populations had a small admixture of the 'b' haplotype: Suwałki (no. 28) and Ełk (no. 31), while four populations contained the 'd' haplotype: Czarna Białostocka (no. 8), Supraśl (no. 9), Szczebra (no. 27) and Suwałki (no. 28). In two latter populations, the presence of two private alleles, i.e. present only in one population, was also noted, i.e. 'd1' haplotype (*A*priv=0.06) and the 'b1' haplotype (*A*priv=0.02). In all examined populations from the Regional Directorate of the State Forests in Białystok, the most frequent haplotype of the *nad*1 gene was the 'c' haplotype (frequency 77.7%) the 'b1' haplotype was the least frequent (0.1%), while the 'a' haplotype occurred with a general frequency of 20.0% (Table 2).

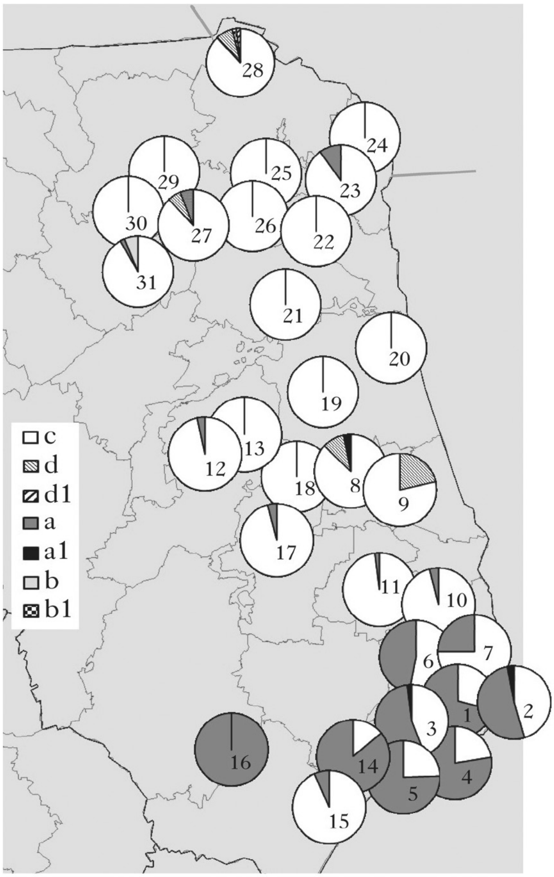

Fig. 2.
Frequency of haplotypes (a–d1) of the mitochondrial *nad*1 gene in examined spruce stands in the Regional Directorate of the State Forests in Białystok. Denoted as in Table 1

TABLE 2

Count of trees (N), haplotype frequency (a–d1), share of private alleles (A_{priv}), count of observed (n_a) and expected (n_e) alleles per locus, Shannon index (*I*), and Nei's haplotype diversity Nei (*h*) for individual spruce stands (denotations as in Table 1)

	N	a	a1	b	b1	c	d	d1	A_{priv}	n_a	n_e	I	h
1	48	0.708	–	–	–	0.292	–	–	–	2	1.704	0.604	0.413
2	33	0.515	0.030	–	–	0.455	–	–	–	3	2.115	0.806	0.527

	N	a	a1	b	b1	c	d	d1	A_{priv}	n_a	n_e	I	h
3	50	0.540	0.020	–	–	0.440	–	–	–	3	0.059	0.772	0.514
4	49	0.775	–	–	–	0.224	–	–	–	2	1.534	0.533	0.348
5	49	0.755	–	–	–	0.245	–	–	–	2	1.587	0.557	0.370
6	49	0.469	–	–	–	0.531	–	–	–	2	1.993	0.691	0.498
7	48	0.250	–	–	–	0.750	–	–	–	2	1.600	0.562	0.375
8	31	–	0.032	–	–	0.871	0.097	–	–	3	1.300	0.457	0.231
9	28	–	–	–	–	0.785	0.214	–	–	2	1.508	0.520	0.337
10	50	0.040	–	–	–	0.960	–	–	–	2	1.083	0.168	0.077
11	50	0.020	–	–	–	0.980	–	–	–	2	1.041	0.098	0.039
12	29	0.034	–	–	–	0.966	–	–	–	2	1.071	0.150	0.067
13	30	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
14	50	0.860	–	–	–	0.140	–	–	–	2	1.317	0.405	0.241
15	30	0.067	–	–	–	0.933	–	–	–	2	1.142	0.245	0.124
16	30	1	–	–	–	–	–	–	–	1	1.000	0.000	0.000
17	49	0.041	–	–	–	0.959	–	–	–	2	1.085	0.171	0.078
18	50	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
19	50	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
20	50	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
21	46	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
22	49	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
23	50	0.100	–	–	–	0.900	–	–	–	2	1.219	0.325	0.180
24	50	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
25	49	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
26	49	–	–	–	–	1.000		–	–	1	1.000	0.000	0.000
27	50	–	–	–	–	0.880	0.060	0.060	0.060	3	1.279	0.450	0.218
28	50	–	–	0.020	0.020	0.880	0.080	–	0.020	4	1.279	0.471	0.218
29	48	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
30	48	–	–	–	–	1.000	–	–	–	1	1.000	0.000	0.000
31	48	0.021	–	0.063	–	0.916	–	–	–	3	1.184	0.334	0.155
M	31	0.200	0.003	0.003	0.001	0.777	0.014	0.002	0.002	1.84	1.261	0.268	0.162

M – mean

The share of the particular variants of the *nad*1 gene in examined stands was correlated with their diversity level. The highest values of the parameters *n*e=2.115 and 2.059 described the population no. 2 from the Strict Reserve of the Białowieża National Park and no. 3 from the Białowieża Forest District (Table 2). The largest count of observed haplotypes was recorded in the Suwałki population (no. 28), where four variants of *nad*1 gene occurred (‘b’, ‘b1’, ‘c’, and ‘d’). In reference to other stands, spruce populations no. 2 and 3 demonstrated also the highest values of the Shannon index parameters (*I*=0.806 and 0.772) and haplotype diversity (*h*=0.527 and 0.514). All examined populations of Norway spruce were described with the mean level *I*=0.268 and total mean diversity 0.162 (Table 2).

The PCoA analysis in the system of two axes (respectively describing 98.53 and 99.97% of total genetic variability) distinguished three major population groups (Fig. 3). The first group is found in the bottom right quadrant and comprises populations with the dominance of the ‘a’ haplotype: no. 1 and 2 from the Białowieża National Park, no. 3 and 4 from the Białowieża Forest District, no. 5 from the Hajnówka Forest District, and no. 6 from the Browsk Forest District, as well as population no. 14 from the Bielsk Forest District adjacent to the Białowieża Forest. The other two groups associated populations with dominance of the ‘c’ haplotype: group 2 composed of three populations: no. 8, 27 and 28, located in the upper left quadrant of the diagram, and group 3 consisting of 18 populations, in the bottom left quadrant of the diagram (Fig. 3).

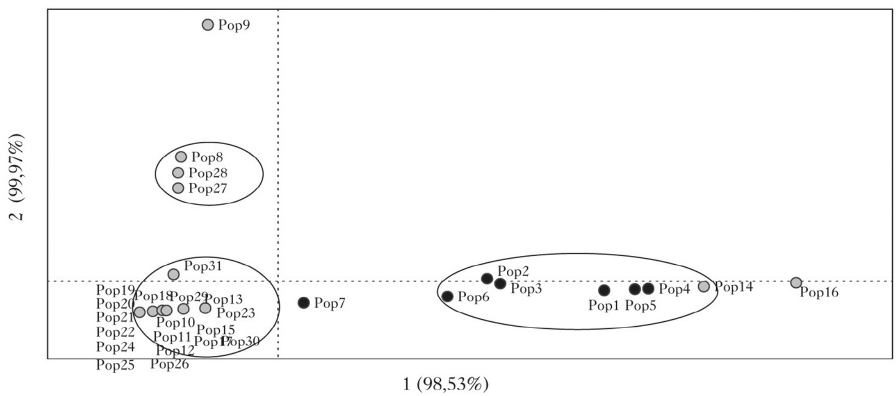

Fig. 3.
Principal coordinate analysis diagram for examined spruce populations based on the analysis of principal coordinates. Population denoted as in Table 1

Discussion

The molecular analysis of the genetic variability on the basis of the mitochondrial *nad*1 gene describes the genetic structure of the examined spruce populations from the territory of the Regional Directorate of the State Forests in Białystok, in reference to the historical origin from two main post-glacial refugia of spruce in Europe. The mitochondrial *nad*1 marker (intron 2 or intron b/c) is used for the determination of genetic relatedness between populations of such species as pine and spruce (Gugerli et al. 2001, Jaramillo-Correa, Bousquet 2005, Milovanović et al. 2007, Naydenov et al. 2007). Research conducted on 20 populations of *P. abies* from 13 various forest districts in Poland showed a distinct geographical division into populations from the south of Poland (with dominance of the 'a' variant of the *nad*1 gene) and north-eastern populations, marked by a high frequency of the 'c' haplotype (Nowakowska 2009). The further to the north-east of the country, the more the frequency of the Hercynian 'a' haplotype in Poland decreases and the dominance of the 'northern' 'c' haplotype increases. These results of research on the spruce populations from the Regional Directorate of the State Forests in Białystok correspond with this trend, as 24 populations out of 31 examined were characterised with a large, over 50-percent frequency of the northern 'c' haplotype. The spruce populations with dominance of the 'c' haplotype are located within the limits of the northern geographical range of spruce, delineated by Szafer in the past century. Also the spruce populations of the Białowieża Forest were situated within the limits of the northern geographical range of spruce in Poland (Szafer et al. 1953, Szafer 1977). As it was demonstrated, five populations from the Białowieża Forest and two neighbouring with the forest, contrary to earlier statements by Szafer, do not belong historically to the northern range of *P. abies* in Europe. Taking into account the high share of the 'southern' 'a' haplotype exceeding 50%, the examined populations belong historically to the southern, Hercyno-Carpathian geographical range of spruce in Europe.

Therefore, it may be supposed that in the Białowieża Forest region, both geographical ranges, the southern and the northern one, met together in the past, which is confirmed by the presence of both haplotypes variants 'a' and 'c'. The occurrence of the 'a' haplotype in spruces from the Strict Reserve of the Białowieża National Park, where the human interference was the lowest in the past, seems to confirm this thesis (Genko 1902, Samojlik, Jędrzejewska 2004). The 'a' haplotype is found also in the Belarussian part of the Białowieża Forest, in the Kamieniuki Reserve (Nowakowska, unpublished data). Additionally, the highest values of parameters of genetic diversity, recorded in four examined spruce populations of the Białowieża Forest District and the Strict Reserve of the Białowieża National Park point at two main historical events: 1) the encounter of two gene pools in the area of the forest as a result of post-glacial migration, and 2) human interference in the composition of spruce forests growing there through the import of seedlings of 'alien' origin. Dering et al. (2012) was similar conclusions for populations of the Białowieża Forest on the basis of a different mtDNA marker of the mt15-D02 gene.

The goal of the aggregation analysis on the basis of the principal coordinates analysis (PCoA) consists in the division of examined units into groupings representing sets with high similarity, based on multidimensional observations with use of two coordinates (Kenkel 2006). The confrontation of the structure of mitochondrial DNA from seven spruce populations from the Białowieża Forest with other 24 analysed populations from the Regional Directorate of the State Forests in Białystok, demonstrated with the help of a PCoA analysis, that the genetic diversity of examined spruce trees correlates with haplotypes of the *nad*1 gene occurring in the examined populations. The stands with a dominance of the 'a' haplotype were significantly grouped in one cluster, in comparison with populations with dominance of the 'c' haplotype.

Based on the examination of pollen preserved in macro-palaeontological petrifactions, it may be assumed that the spruce primarily present in the east of Poland originated from northern Europe and the European part of Russia (Tollefsrud et al. 2008, 2015). This finding is confirmed by the present research, as the majority of analysed stands from the Regional Directorate of the State Forests in Białystok shows a dominance of the 'northern' 'c' haplotype of the *nad*1 gene. However, the analysis of haplotypes of the *nad*1 gene showed individuality of the majority of spruce trees from the Białowieża Forest against other populations from the Regional Directorate of the State Forests in Białystok, due to the prevailing frequency of the 'southern' 'a' haplotype, historically originating from the Hercyno-Carpathian refugium in Europe.

Studies by Dering and Lewandowski (2009) based on the analysis of mitochondrial DNA of *P. abies* in Poland confirm the division of the Polish spruce populations into two groups: north-eastern populations (but without the Białowieża populations) and populations from the south. The spruce populations from the spruce-free belt of the Polish and Mid-Carpathian Lowland demonstrate a higher similarity in the genetic structure of examined haplotypes to the spruce origins from southern Poland (Nowakowska 2009, Dering et al. 2012). It is a confirmation of the thesis by Lublinerówna (1934) and Środoń (1967) assuming that the both geographical ranges of spruce, northern (Baltic-Nordic) and southern (Hercyno-Carpathian), probably encountered in the past in central Poland.

Detailed genetic tests based on microsatellite markers of nuclear DNA, conducted for 58 Polish, approx. 100-year old populations of Norway spruce (mainly from selected seed stands), evidenced that the geographical distribution of spruce genotypes in Poland is random, not dependent on the location against the southern or northern geographical range of that species (Nowakowska 2009, unpublished data). The random distribution of the genetic variability is specific for the majority of forest tree species, which are characterised by longevity, good adaptation to environmental conditions and pollen transmission over long distances. An analysis of 369 examined populations of Norway spruce in Europe on the basis of the mitochondrial *nad*1 gene evidenced that populations originating from the southern geographical range of *P. abies* had a greater genetic diversity (G_{ST}=0.638) in comparison with populations from the north of the continent (G_{ST}=0.277) (Tollefsrud et al. 2008). In connection with a palaeobotanical analysis of distribution of spruce pollen in Europe, these data may indicate two main directions of spruce expansion in central Europe (Ravazzi 2002, Tollefsrud et al. 2015). Considering the conservative inheritance of variants of the *nad*1 gene, it may be assumed that spruce growing in the territory of the Białowieża Forest originate mainly from the Hercyno-Carpathian refugium. This fact may result, apart from natural routes of post-glacial migration, from human interference in the present genotype composition of *P. abies* in the forest, e.g. through bringing propagation material of alien origin (Lewandowski 2014).

The process of adaptation involves the selection of proper genes, the expression of which, conditioned by numerous endogenous (e.g. hormonal) and exogenous (e.g. waste) factors guarantees the continuity of a species. The richness of the species gene pool, expressed in the occurrence of numerous forms of particular genes of which the DNA chain is composed, contributes to a higher probability of occurrence of a beneficial allele combination ensuring the continuity and adaptation of the species to variable environmental conditions.

Based on detailed research within the scope of paleobotanics, molecular biology, silviculture, ecology and climatology, it may be assumed that the present occurrence of Norway spruce in Poland within the limits of the so-called natural geographical ranges according to Szafer has been affected mainly by such factors as historical paths of post-glacial migration of species in the territory of Poland, the conduct of forest management and industrial development, and the competitiveness of certain species, causing the elimination from some habitats (Łukaszewicz 2015).

In the light of presented research, it is very important that the forest management takes actions striving for the conservation of the genetic variability of Norway spruce in Poland. Research on the genetic structure of stands at the molecular level allowed the recognition of the historical origin of Polish populations of *P. abies* in the Białowieża Forest in context of the post-glacial migration of the species.

Conclusions

- The dominant presence of the Nordic ‘c’ haplotype of the mitochondrial *nad*1 gene in 24 of 31 examined spruce populations in the northern and central part of the Regional Directorate of the State Forests in Białystok confirms the historical affiliation of these stands to the northern geographical range of *P. abies* in Europe.
- Five of seven examined populations from the Białowieża Forest (including two units from the Strict Reserve of the Białowieża National Park) and spruce stands from two forest districts neighbouring with the forest are characterised with the dominance of the ‘southern’ ‘a’ haplotype.

- In the Białowieża Forest region, the southern and northern geographical range of spruce met together in the past, which is demonstrated by the presence of both haplotype variants 'a' and 'c'. The results of molecular tests confirmed the uniqueness of spruce from the Białowieża Forest, expressed in a higher diversity of their gene pool comparing with the area of the Regional Directorate of the State Forests in Białystok.
- The geographical range of Norway spruce in Poland presented by Szafer has no justification in the light of presented results of genetic examinations. The research confirms the theory of anthropogenic origin of the mid-Poland disjunction, created due to deforestation linked with the development of farming and settlement over the past millennia.

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Bogdan Brzeziecki

The Białowieża Forest as a mainstay of biodiversity

Introduction

The Białowieża Forest is an extensive (approx. 150,000 ha) forest range, since World War II divided by the state border running firstly between Poland and the USSR, and now between Poland and Belarus. The Forest also comprises deforested river valleys, settlement glades, villages, fields, meadows and communication routes situated inside the forest range or nearby (Faliński 1968). This accentuation is important because various non-forestal elements have a serious impact on the general level of the environmental diversity of the entire area of the forest.

The Białowieża Forest has been eminent for its amazing environmental values for a long time. High diversity, abundance, exceptionality, environmental excellence and rarity are features that may be found practically in all groups of living organisms inhabiting the forest. There has long been a dispute with regard to the most beneficial model, from the point of view of conservation of the entirety of the values of the Białowieża Forest with a particular attention to natural values, for the management (utilisation and conservation) of this site so exceptional in all respects.

For a long time, the participants in this debate has been mainly the representatives of forest sciences and practice, supported by experts from various areas of the life sciences (mainly geobotanists). For example, actions taken up on the initiative of foresters (Polish Forest Society, Committee of Forest Sciences of the Polish Academy of Sciences etc.) – resulted in the issuance in 1975, in a very different political reality, of autonomous principles for the management of the Białowieża Forest, respecting the necessity of maintaining the primeval nature of stands and guaranteeing in a sustainable way the ability of the woodlands of the Białowieża Forest to fulfil both productive and non-productive (environmental, landscape-related and cultural) functions. For more than a dozen years, the agenda of the discussion concerning the Białowieża Forest was being set by representatives of groups and non-governmental organisations, supported by numerous biologists, representing various specialisations, not necessarily related to the nature conservation or forests. The activities of non-governmental organisations also enjoy a substantial support from European institutions responsible for nature conservation and environment protection in the EU states. The main demand and goal of these organisations is the establishment of a national park that covers the entire Polish part of the Białowieża Forest and, ultimately, a complete withdrawal from the economic use of the forests in that area. Representatives of this mainstream make the assumption that the major (the only one?) threat to the environmental values of the Białowieża Forest is the forest management conducted in this area and that the best strategy of protection of these values is the conservation of the natural processes, in other words a strict conservation of practically the entire area of the Białowieża Forest (i.e. of its part located in Poland).

The objective of this study is, starting out from an analysis of selected publications concerning various systematic groups, to identify the most important factors and phenomena posing a threat to the individual elements of the environmental abundance of the forest,. In particular, the author searched for an answer to the question whether the forest management was really the largest problem preventing the sustainable conservation of the high natural values of the forest, as well as whether a strict protection (being the only real alternative for the model of multifunctional forest management, for years implemented in this area) was a strategy allowing for the sustainable conservation of these values.

Long-term trends, threats and extinction of species (examples)

Problems with the understanding of the environmental richness of the Białowieża Forest. In spite of the fact that the Białowieża Forest, and especially the Białowieża National Park, have been for ages the subject of an intense interest of specialists dealing with various groups of organisms, the inventory of all species present here has yet to be completed. For example, previous studies show that approx. 1,500 species of macromycetes are found in the forest, but it is supposed that in reality their number may even exceed 2,000. This results from the fact that large fragments of the forest located outside of the Białowieża National Park are mycologically poorly surveyed (Kujawa 2009). A similar situation concerns the invertebrates, of which approx. 11,700 species have been recorded so far, but probably the real number is approx. 20,000 (Gutowski et al. 2009). Another important problem is the credibility of data concerning the occurrence of many species. Very often information on the presence of various species of plants, animals or fungi in the Białowieża Forest origin from many years ago and it is not known if they are still valid (Adamowski 2009).

The situation is even worse in relation to long-term trends in the counts of individual groups of organisms living in the forest. Most research within this scope was or is random and fragmentary, which makes the assessment of long-term changes in the occurrence of various groups of organisms, e.g. fungi (Kujawa 2009), very difficult. Few exceptions within this scope include long-term research on changes in the species composition of the natural stands in the 'Strict Reserve' of the Białowieża National Park conducted on the basis of the permanent sample plots established in 1936 (Bernadzki et al. 1998a, b; Brzeziecki et al. 2012, 2016), or research on changes in the floristic composition of particular types of forest communities (Matuszkiewicz 2011). Apart from tree species, most information on the long-term changes and dynamics may be found in the case of two groups of organisms present in the forest: vascular plants and lichens.

Vascular plants. Thanks to the long history of floristic and phytosociological research conducted in the Białowieża Forest, the knowledge about long-term changes occurring in the flora and vegetation of the forest is relatively vast. As many researchers emphasise (Sokołowski 1981, 2004; Kwiatkowska, Wyszomirski 1988; Faliński 1994; Paluch 2001, 2003; Adamowski 2009; Matuszkiewicz 2011), the flora and the vegetation of the forest are subject to continuous change, usually adverse.

One of the most important causes of the threat to vascular plants present in the Białowieża Forest are spontaneous successional changes, which perform a particularly important role on areas excluded from economic utilisation and subjected to a strict conservation. It is assumed that changes of that type were the reason, among others, for the extinction of the only site of the largest orchid in Poland, the lady's-slipper orchid, in the Białowieża National Park in the 1960s (Sokołowski 1981 after Adamowski 2009). For the same reason, other species also died out there, such as inundated club moss, white beak-sedge and twinflower, while giant bellflower and lousewort *Pedicularis sceptrum-carolinum* were on the brink of extinction (Sokołowski 1981 after Adamowski 2009). As Adamowski emphasises (2009), from among 65 species of vascular plants under full protection, as many as 32 have less than five known sites in the Białowieża National Park. This obviously translates into a high level of threat to these species. As a result of the spontaneous regeneration processes taking place under the strict conservation conditions, consisting mainly in the expansion of hornbeam (sometimes also spruce), heliophilous species are retreating, e.g. sand milk-vetch, common hedgenettle, creeping bellflower, mountain sedge, bloody geranium, southern sweet grass (bison grass), common club-moss, Eastern pasqueflower, heath grass, globeflower, and wild thyme (Adamowski 2009). The overgrowing and shadowing of peat bogs has resulted in the withdrawal of such species as round leaved sundew and marsh helleborine (Sokołowski 1981 after Adamowski 2009). The same process caused a dieback of downy willow, observed for the last time in the 1950s.

The abandonment of meadow utilisation in the Narewka and Hwoźna River valleys and the successional changes in forest communities constituted the reason for the extinction of marsh saxifrage and the probable extinction of felwort, slender cotton grass and chamomile grape-fern, as well as disappearance of shrub birch and and bearberry (Adamowski 2009). According to Adamowski (2009), the total loss in the flora of the Białowieża National Park flora may amount to even 11 species of vascular plants.

Similar, and even more spectacular, examples concerning the retreat of plant species due to natural succession and regeneration under the conditions of strict conservation are provided by long-term geobotanical studies conducted in the Białowieża National Park by Matuszkiewicz (2011). Matuszkiewicz surveyed how the floristic composition of several major types of plant associations in the Białowieża National Park changed over the last few decades. An example of particularly clear and far-reaching changes is the *Serratulo-Pinetum* association, whose species abundance in the patches continues to decrease, recently slightly less quickly, on average at a rate of 0.6 species per year. Distinct faithful species for the association (saw-wort and common hedgenettle) have completely disappeared, while others are significantly limited in their occurrence (Solomon's seal and mountain-parsley). Species from the *Pyrolaceae* family are becoming rarer, including one-sided-wintergreen, a distinctive species for the association. In total, the current level of these species is 20% of the initial state (from 50 years ago). Negative trends include species specific to the *Querco-Fagetea* class, such as gon lily, spring vetchling, common hepatica, mezereon, mountain melick, and common hazel. Other examples of species, including rare and protected, present 50 years ago but currently absent or increasingly rare, include wood cow-wheat, wood cranesbill, lesser meadow-rue, *Vicia dumetorum*, tormentil, common columbine, devil's-bit scabious, southern sweet grass, wild basil, yellow foxglove, wood vetch, Canadian hawkweed, common bugle, germander speedwell, common dog-violet and European goldenrod. Species that are less frequent include raspberry, and rosebay willowherb has appeared recently. As a conclusion, the author states that the *Serratulo-Pinetum* association, widespread in the area of the Białowieża National Park in the 1950s, disappeared almost completely over 40 years.

According to Matuszkiewicz (2011), it may be certainly assumed that changes occurring in the case of areas covered by strict conservation, consisting in the homogenisation and impoverishment of the floristic composition of communities, are of a natural character and a sign of regeneration of communities previously affected by anthropopressure. In other words, regenerated forms of associations are distinctly poorer with regard to flora than 'distorted' forms (anthropogenic). Therefore, spontaneous renaturation under the conditions of strict conservation leads to a reduction in the floristic diversity of communities, and gradually even to the diminishment of variation at the level of plant complexes.

A serious threat to many species of local flora is posed by expansive alien species. Quaking-grass sedge, a species growing 'naturally' in southern Poland, constitutes a good example (Adamowski 2009). In the Białowieża Forest, it appeared 100 years ago. Very few native plant species tolerate its presence. The retreating species include common hepatica, yellow archangel, and greater stitchwort. Another example is small balsam, which was found for the first time in the region of the forest in Hajnówka in 1965 (Adamowski 2009). Over time the species enters deeply into the forest, especially oak-hornbeam forests. In

1991, its first site in the Białowieża National Park was found, which was removed as part of a long-term active conservation measures consisting in the removal of appearing specimens and inhibiting the plant seed dispersal. Unfortunately, in 2007 another site of that species was found, this time in compartment 399. Currently, this species is widespread in the western part of the forest and enters the Białowieża National Park near Stara Białowieża, where it is so numerous that it is impossible to be controlled (Adamowski 2009).

Lichens. Lichenological research conducted in the Białowieża Forest (including in particular the Białowieża National Park) in the last years of the 20th century and in the beginning of the 21st century have provided a number of facts indicating adverse changes consisting in the disappearance and reduction of species diversity in the lichens present there (Cieśliński 2009). This process concerns mainly epiphytic lichens, forming large thalli. Sparse data from the past make it impossible to draw up a complete list of species that retreated from the analysed areas or are threatened with extinction.

The most worrying examples are provided by the analysis of the modern status of lichens from two genera: beard lichen and horsehair lichen (Cieśliński 2009). In the 1950s, the more than one metre long, threadlike thalli of Methuselah's beard lichen were observable hanging down from tree boughs, mainly of spruce. Now such images belong to the past. Also, other species from this variety became extinct. On the 'Red List' of lichens of the Białowieża Forest, 23 species from the beard lichen genus have been declared extinct, just like seven species from the horsehair lichen genus. At present, the occurrence of only seven species from the beard lichen genus have been identified, with three occurring very frequently. The horsehair lichen genus is currently represented only by three species. The retreat of many species from the beard and horsehair lichen genus, as well as a decrease in the frequency of other existing species have adversely affected the physiognomy of the woodlands of the park and forest. Hair-like and filamentous thalli of those lichens hanging down from trunks and boughs of trees emphasised the natural character of forest communities (Cieśliński 2009).

Currently, the existence of numerous other epiphytic and epixylic species noted by previous researchers is not confirmed, so now they should be considered extinct or so rare that recent surveys have not confirmed their existence. The number of sites and the abundance of many other lichen species have decreased. Lichens, creating currently residual populations, were frequent and common in the past (Cieśliński 2009). Lungwort lichen is a good example. Previous researchers emphasised its abundant presence as a typical primeval forest lichen. This lichen associated, among others, with oak, hornbeam and spruce, is at present still quite frequent in the Białowieża National Park, similarly in the forest. However, on most sites it demonstrates features of a declining species. Individuals producing fruiting bodies are nowadays very rare, if any (Cieśliński 2009).

The impoverishment of the species composition of lichen biota occurring on spruce bark, a forest-forming species in local forest communities, is very clearly marked. Krawiec (1938 after Cieśliński 2009) wrote: 'The most abundant flora (lichens) is featured by spruce'. Today, most of species mentioned by this author have declined or are very rare. Decreasing viability of some lichen species is a sign of the deterioration of living conditions. Previous researchers emphasised the fact of producing fruiting bodies by many species. Currently, no fruiting specimens are identified (Cieśliński 2009). As Cieśliński emphasises (2009), the impoverishment of lichens biota, as in the case of other groups of organisms, is now a common phenomenon, progressing on more and more extensive areas. In reference to the Białowieża National Park and the entire area of the Białowieża Forest, this process has a special aspect. It occurs within a large and compact forest range, including the park, on an area subjected to a strict conservation already for more than 80 years. Many species now declared extinct have been present there still in the mid-20th century.

Diversity and multitude of factors and reasons for the deterioration and decline of environmental values of the Białowieża Forest. Although many authors conducting research on various groups of organisms present in the Białowieża Forest usually emphasise the abundance and environmental variability of this area, as well as the fact of occurrence in the forest area of many rare and protected species, it does not mean that the situation within this scope is secure and stable. It is quite the opposite: practically in reference to any group of organisms (not excluding the flagship species of the forest: bison) there occur certain problems and factors threatening the sustainable occurrence of many local populations of plant, animal and fungi species. It should also be emphasised that the level and scope of threat to various groups of organisms may be determined by various factors and phenomena, whereby things beneficial for one group of organisms may appear to be adverse for another group, and vice versa. Such situations are frequent in the forest.

According to some authors, the best method of conservation of the forest ecosystems of the Białowieża Forest is to 'return them to the nature and minimise the human interference' (Pawlaczyk 2009). However, it appears that natural, spontaneous successional changes are exactly the factor that threatens most vascular plants. Under the conditions of the Białowieża Forest, 'natural, spontaneous successional changes' consist usually in an uncontrolled expansion of one species – hornbeam, a species strongly shadowing the soil, thus causing the vanishing of numerous plant species, in particular those with higher lighting requirements (Kwiatkowska, Wyszomirski 1998; Paluch 2001, 2003; Sokołowski 2004; Matuszkiewicz 2011). Such changes play a particularly important role on areas excluded from economic use and subjected to strict conservation (Bernadzki et al. 1998a, b; Brzeziecki et al. 2012, 2016) (Fig.).

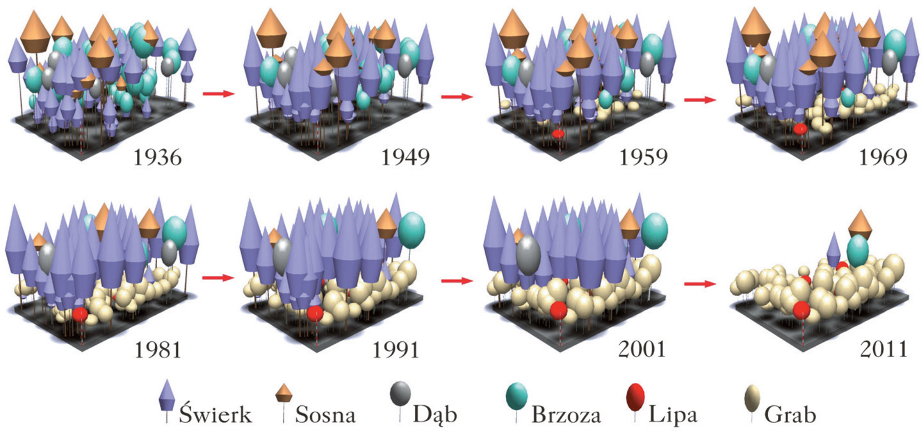

Fig.
Hornbeam expansion on a patch of the *Serratulo-Pinetum* association as a reason for the decline of the floristic diversity of ground cover (on an example of permanent research plot of the Department of Silviculture in compartment 319 of the Białowieża National Park)
Computer visualisation of long-term development of an example fragment of a stand measuring 40 × 60m, carried out with use of BWINPro software (Nagel, Schmidt 2006)

(Świerk – Spruce; Sosna – Pine; Dąb – Oak; Brzoza – Birch; Lipa – Linden; Grab – Hornbeam)

The problem related to this is the long-term retreat process and adverse alterations in the demographic structure of many tree species, particularly strongly and well-documented on areas excluded from economic activity, such as the 'Strict Reserve' of the Białowieża National Park (Bernadzki et al. 1998a, b; Brzeziecki et al. 2012, 2016). These changes have a huge impact on the functioning of primeval forest ecosystems, because trees are the components of forest ecosystems on which the sustainable existence of all remaining elements of biocenosis depends (Ellison et al. 2005). A showpiece example in this regard is the process of spruce retreat from the stands of the forest. In the 'Strict Reserve' of the Białowieża National Park, this process has been continuing for a long time, as a result of which the number of spruce in this area has decreased to a little more than a dozen percent of its state from several decades ago (Brzeziecki et al. 2012, 2016). This happened before the occurrence of the current wave of dieback of spruce stands, whose extent has now encompassed practically the entire forest. It should be noted that the very significant role of spruce is frequently emphasised, as a tree species with which numerous species of fungi (Kujawa 2009), lichens (Cieśliński 2009), insects (Gutowski et al. 2009) and birds (Walankiewicz 2009) are associated. The retreat of spruce causes species associated with it to disappear, as has happened with many of the earlier mentioned species of lichens (Cieśliński 2009).

However, negative trends are associated not only with spruce, but with many other tree species: aspen, birch, pine, oak, maple, elm and, recently, ash. As with spruce, the adverse effects of such processes may be expected for other elements of the natural richness of the forest that are directly related to the above-mentioned tree species. The reasons for the retreat of many tree species under the strict conservation conditions are complex and sometimes difficult for an unambiguous explanation. Certainly, an important role in this process is performed by global environmental changes, including climate warming and drying, as well as industrial pollution of the atmosphere (including, in particular, the deposition of nitrogen compounds), which do not leave the Białowieża Forest untouched (Malzahn et al. 2009). It may be assumed that the 'climatic' factor is responsible for the deterioration of the health condition and the weakening of the viability of spruce stands present in the forest, as well as for the increase in their susceptibility to attacks by European spruce bark beetle.

Apart from the changes occurring in the abiotic environment, a very important role is also played by the pressure, originating from the excessively propagated populations of ungulates (mainly red deer), on the natural regeneration of many tree species (Kuijper et al. 2010, Churski 2014). Most do not withstand this pressure well and only few of them (such as hornbeam) are able to advance to the tree layer of the stand under the conditions of intense game browsing. This results in a regular impoverishment and homogenisation of the species composition of stands, especially on areas under strict conservation, i.e. where no measures are taken to protect regenerations from game pressure. The lack of efficient control of the number of ungulates indirectly results in adverse effects for the entire forest biocenosis. In the literature, such an event is referred to as the negative cascade effect (Côté et al. 2004).

Air pollution is certainly (co)responsible for alterations in the lichen biota. As commonly known, lichens are highly sensitive to any changes in habitat conditions, especially those resulting from human activity. Lichens are a good indicator (bioindicator) of air pollution with gaseous compounds (mainly SO_2, NO_x) and heavy metals (Cieśliński 2009).

Another reason for the impoverishment of the natural richness of the forest is the general process of disappearance of open spaces of various kinds, both natural, semi-natural, and anthropogenic. As already mentioned before, the Białowieża Forest does not only mean closed woodlands, but also various roads, compartment division lines, meadows, peat bogs, sedge meadows, river valleys, glades and timber yards. Due to settlement within the forest, there are still some larger and smaller deforested areas, including the Białowieża Glade. The existence of these various open and semi-open spaces, both permanent and temporary, allows the existence of many species of plants, animals, and fungi. It appears that practically in every group of organism living in the forest, species related to open and semi-open spaces have their significant share. For example, in the case of land snails it amounts to approx. 10%, for springtails to approx. 15%, and for various families of beetles it ranges from a fraction of a percent to over 50% (Gutowski et al. 2009).

In the case of lichens, the situation is similar. Non-forested areas of any type found in the forest (villages, meadows, fields, uncultivated land) constitute the site of many specialised species. Some of them even use various substrates of a typically anthropogenic origin (concrete, plaster, brick, eternit) (Cieśliński 2009). As a consequence, the number of lichen species present in the entire forest significantly exceeds the number of lichen species present in the Białowieża National Park, where this type of habitat and conditions are absent by nature.

Bird species associated with open spaces play an important role in the forest (Walankiewicz 2009). The lesser spotted eagle constitutes one good example. Over the last 20 years, 20 pairs of lesser spotted eagle disappeared from the Białowieża Forest and its neighbourhood. One of the most important reasons for this phenomenon was the diminishment of open spaces (meadows, pastures and fields), extensively utilised in the past. The process of regression of open and semi-open areas in the forest has already lasted for many years. It has adverse effects for practically all groups of organisms living there.

Another problem is imposed by the small number of sites and the low density of populations of many species. This problem also concerns the 'Strict Reserve' of the Białowieża National Park, encompassing a relatively large area (the largest domain of its type in Poland), practically under strict conservation for 100 years. It is some kind of curiosity that, in the woodlands of the Białowieża National Park, populations of birds achieve quite a low density in comparison to other forests in the moderate zone. The total density of birds, at a maximum of approx. 150 pairs/ 10 ha in riparian forests and approx. 50 pairs/ 10 ha in coniferous forests, is several times lower in the Białowieża National Park than in Western Europe, where it may reach 400 pairs/ 10 ha (Tomiałoić et al. 1984, Wesołowski et al. 2003 after Walankiewicz 2009). Only 17 bird species, thus less than 10%, exceed the number of 1,000 breeding pairs in the Białowieża National Park. Almost 70% of species occur as 100 breeding pairs or less (Walankiewicz 2009). Such a low density translates into a high level of threat to many species. In any case, this problem does not concern birds only, but also many other species of plants, fungi and animals.

The problem of invasive species should be mentioned as well, which is also observed in the area of the Białowieża Forest. Two representative examples from the plant world include quaking-grass sedge and small balsam (Adamowski 2009). Among the mammals, American mink plays a similar role of an invasive species, and is commonly found in the Białowieża National Park. This species is highly expansive, and in a relatively short time it has controlled all environments appropriate to it, constituting a serious competition for weasels and indirectly for stoat (Zub 2009).

Summary

There is no doubt that the (still) extensive natural richness of the Białowieża Forest is mainly a result of two factors: 1) specific, transitional geographical location (at the intersection of Eastern and Western Europe) and the favourable environmental conditions of this area (high diversity of geological, pedological, topographic conditions, hydrological relationships), and 2) the unique history of this territory, for centuries being subject to many various influences and forms of human impact, however generally described with moderate intensity and strength, which translated into a generally good condition for conservation and a considerable variation in ecosystems.

However, the environmental richness of the forest is not given once and for all, as the above random examples illustrate. Over the last couple of decades, many species associated with the forest have significantly decreased in count or completely died out. Many of them are now considerably threatened and often on the brink of complete extinction. The problem of a threat to or complete disappearance of various, often very precious (such as lady's slipper) elements of biodiversity of the Białowieża Forest does not concern only those areas that are or have recently been exposed to forest management measures. Equally, but sometimes it may feel that to a greater extent, this problem concerns those areas excluded from use and subjected to strict conservation. Either way, many cases of disappearance of precious elements of the nature in such areas have been well-documented. Events of this type suggest that strict conservation (absence of forest use), following the superior principle of protection of natural processes, does not guarantee the preservation of all elements of the natural richness of the forest (and non-forest) ecosystems of the Białowieża Forest. Even if it is beneficial for some groups of species (mainly the so-called saproxylic species, i.e. dependent on dead wood), it simultaneously leads to a deterioration of living conditions of many other species (including rare, precious and endangered), up to their elimination.

The awareness that strict conservation often fails to meet the expected goals is becoming more common in the world. For example, Cole and Yung (2010) describe examples from the United States and other countries in the world of environmental degradation and the decline of precious natural values, occurring in the case of natural parks and so-called wilderness areas, the functioning of which is based on the principle of conservation of the natural processes. In the conclusion, they write: 'some time ago, a popular belief was that strict conservation was the method of preservation for all environmental values occurring in national parks and wilderness areas, but (currently) it is more clearly noticeable that leaving nature to act alone does not ensure the protection of biodiversity and other values associated with the protected areas', (therefore) 'we cannot protect parks and wilderness areas by drawing a line around them and leaving them alone.' Cole and Yung (2010) indicate also

that 'the objectives and results (of conservation) should be clearly defined, achievable, and desired, (meanwhile) most concepts based on the concept of 'naturalness' do not meet these requirements', as well as that 'the key challenge for the management of [national] parks and wilderness areas is now the issue of deciding where, when, and how should physical and biological processes be influenced, to sustainably preserve the things about which we care for such places.'

O'Hara (2016) also thinks in a similar way, as he observes that 'the fundamental assumption (paradigm) on which forest management is based, is that managed forests are able to provide people with a wider range of assets and benefits than non-managed forests (natural forests).' He also states that 'forest management purposes may be diverse and proper activities within the scope of forest management may strengthen the ability of forests to perform these functions (not excluding environmental functions), which we consider important in a given place and time.'

As even a brief and introductory description of the subject shows, the problem of the environmental abundance of the Białowieża Forest and its sustainable conservation is much more complex and complicated than is presented nowadays in many areas. One thing seems to be sure: since there is no single reason for the general decrease in the biodiversity of the forest over recent years, on one simple receipt exists for the sustainable conservation and preservation of all environmental values of the forest. On the contrary to what is suggested today, strict conservation of the entire Polish part of the Białowieża Forest is not such a recipe. Just the opposite, the maintenance of the natural richness and other values of the forest in as good condition as possible for future generations requires an active, smart, comprehensive strategy and a range of well-considered silvicultural and protective measures, which take into account all previous experience and the entire available knowledge about the processes taking place in the forest and in its vicinity. The need for such measure may be concluded from examples of many negative phenomena occurring in these parts of the forest that have been excluded from direct human impact for a long time, as well as from examples and experience from many other environmentally precious areas from all over the world (Cole, Yung 2012).

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Problem of mass dieback of spruce stands in the Promotional Forest Complex 'Białowieża Forest'

Introduction

The Białowieża Forest is a domain of unique character and high significance for the nature conservation and forest management, not only in our country. In addition, it plays an important role in the sustainable development of the region and in ensuring prosperity of the local community. Recently, a serious threat to the forest and its miscellaneous values has been posed by the gradation of European spruce bark beetle, *Ips typographus*, since 2012, and resulting in the dieback of spruce stands with a total volume of approx. 1.4 million m^3 (www.bialystok.lasy.gov.pl).

The objective of this paper is to present the actual situation in the sixth year of gradation by the bark beetle in the Białowieża Forest. This paper has the nature of an overview and uses the published results of research, expert's reports, economic data, legal acts in force and administrative orders. Also considered were the opinions of authorities of the Podlaskie Voivodeship and Hajnówka poviat, the representatives of local governments, as well as of representatives of the Regional Directorate of the State Forests in Białystok and of forest service officers from the forest districts of the forest. The scope of the paper encompasses an attempt to determine the reasons for the present situation, develop guidelines and suggestions striving for the limitation of the adverse effects of bark beetle gradation in the present, as well as an indication of methods (at various levels of central and regional authorities) aiming at the maintenance of the miscellaneous values of the Białowieża Forest in the future.

An outline of the economic and natural history of the Białowieża Forest

For centuries, the Białowieża Forest was subjected to various forms of utilisation by humans. In the period of Royal Poland, when it was within the territory of the Grand Duchy of Lithuania, from the end of the 14th century to the end of the 18th century it mainly performed a hunting function (Więcko 1984). Towards the end of the period of Partitions, the forest was transformed into a tsarian menagerie, the result of which was a large population of cervids and bison, with catastrophic consequences for the forest, in particular for the natural regeneration processes (Seferyniak 1925; Faliński 1986, 1988). The exploitation of the forest's wood resources on an industrial scale began during World War I, when over 4 million m^3 of timber were harvested there in a plundering manner and 6,500 ha of clear-cutting areas were established. That process continued in the inter-war period. Based on an agreement signed with the Polish government, the company The Century European Timber Corporation in the years 1924–1929 harvested 2.5 million m^3 of timber, not meeting the obligation of regenerating the clear-cut areas (Więcko 1984). These areas were regenerated by the Polish forest administration, with the use of spruce of alien origin. By the 1960s, intensive cattle grazing was being conducted in many stands of the forest.

The period of World War II contributed to further damage caused by excessive and uncontrolled tree felling. Even in the period immediately after the war, due to demands resulting from the need to rebuild following war damage, intensive timber harvesting was conducted in the territory of the current forest districts of the forest, often in the form of clear-cutting regenerated mainly with coniferous species.

In the light of information concerning the history of the human impact on the forest's ecosystems, the statement that it apparently constitutes 'the last primeval forest in the lowland part of Europe' is untrue (Bernadzki et al. 2012). Even stands on the area of the oldest part of the Białowieża National Park (in the Strict Reserve) are falsely deemed primeval (Konieczny 2016). They were cut down by tsarist Partition power, mainly in the years 1898–1910 and then by German occupants in the years 1915–1918 (Paczoski 1930, Zaręba 1958, Michalczuk 2001). Even in the first years of existence of the national park (until 1929), individual dead trees were felled there (Michalczuk 2001). Therefore, the Białowieża Forest is not a 'primeval forest' and not a 'fully natural forest', but there is the occurrence of biocenoses similar to natural ones (Matuszkiewicz 2016). Nevertheless, arguments emphasising the apparent primeval character or the naturalness of the forest are used by supporters of the idea of subjecting its entire area to strict conservation.

The vast majority of the present stands in the forest embodies the result of human impact. Thanks to the consequent work of many generations of foresters, the average stand yield has increased in the forest from 187 m^3/ha in 1930 to 340 m^3/ha at present. A significant turn in the approach to the problem of managing the forest's resources was accomplished when the Forest Act (1991) came into force. Since that time, balanced and multifunctional forest management has been conducted in the forest districts of the forest. In 1994, by the decision of the Minister of Environmental Protection, Natural Resources and Forestry, the Promotional Forest Complex 'Białowieża Forest' was established, encompassing the Białowieża, the Browsk, and the Hajnówka forest districts, and having as its major objective the implementation of a pro-ecological model of forestry, to protect the biodiversity, and to carry out the education of society in forest-related matters.

The need for subjecting selected fragments of the Białowieża Forest to special form of conservation has been considered for a long time. In 1919, the idea to protect the most precious and the best preserved fragments of the forest emerged, and in 1921 the Forestry Department decided to establish the Reserve Forest Subdistrict (approx. 4,700 ha), which was fully covered by strict conservation in 1929. In 1932, the Minister of Agriculture and Agrarian Reforms issued a regulation on the establishment of the National Park in Białowieża. In 1947, the Council of Ministers confirmed the status of a national park named the Białowieża National Park (BPN). In 1977, the Białowieża National Park was appointed the World Biosphere Reserve by UNESCO, while in 1979 it was inscribed on the UNESCO World Heritage Site list. In 1996, the Council of Ministers extended the Białowieża National Park to 10,502 ha, with a buffer zone of 3,224 ha. In 2004, the Białowieża Forest was considered the Natura 2000 Site PLC200004 'Puszcza Białowieska' [The Białowieża Forest]. In 2005, the entire Polish part of the forest acquired the status of a Biosphere Reserve. In 2014, the entire Białowieża Forest (in its Polish and Belarussian part) was considered a UNESCO World Heritage Site.

Present sanitary condition of spruce stands and related threats

Dynamics of the European spruce bark beetle population in the Białowieża Forest. Over the last 100 years, gradations by European spruce bark beetle have occurred in the forest many times: the largest taking place in the years 1919–1922, 1950–1957, 1960–1966, 1983–1988, and 1994–1997 (Michalski et al. 2004).

Practically each year, spruce trees in stands in the managed part of the Białowieża Forest become infested by bark beetle (Fig. 1). Since until 2007, the most infested spruce trees have been removed under protective procedures, their volume per vegetation season at an average of approx. 20,000 m^3.

The situation changed after 2008. An increasingly large part of active spruce snag [snag infested by secondary pests] was left in stands (mainly in the nature reserves). Particularly few trees were removed in 2012 (only around half of the infested trees), which resulted in an increased volume of trees infested by bark beetle in subsequent years: to approx. 100,000 m^3 in 2013, approx. 200,000 m^3 in 2014, approx. 270,000 m^3 in 2015, and more than 480,000 m^3 in 2016. Simultaneously, due to existing limitations and bans, in that period only a small number of infested trees (approx. 14%) was harvested under protective treatments (Fig. 2).

Only in 2017, thanks to the decision of the Minister of Environment, the possibility of more decided bark beetle control in the Promotional Forest Complex 'Białowieża Forest' appeared. As of 31 October 2017, the total volume of trees infested by bark beetle from the beginning of the year was approx. 360,000 m^3, while the volume of trees removed for the sake of improvement of public and fire safety was approx. 150,000 m^3.

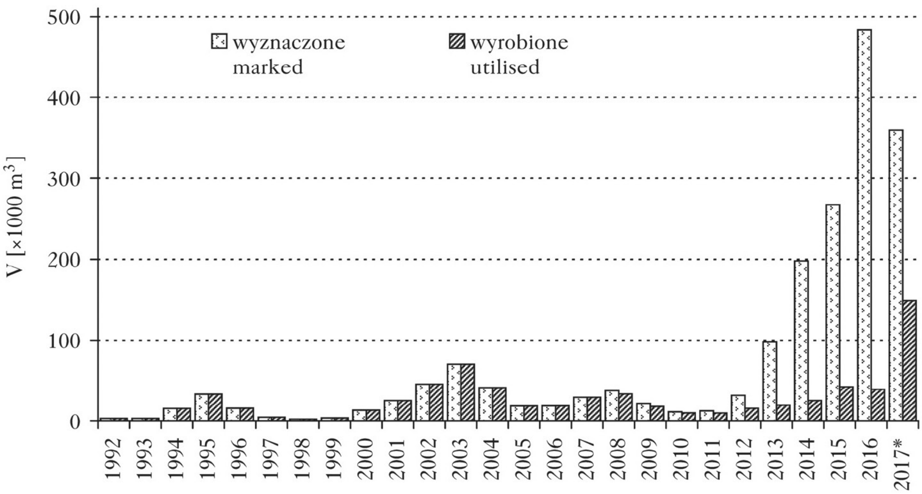

Fig. 1.
Volume of spruce trees infested by European spruce bark beetle (assessment on the basis of marking and measurements of trees by the forest service personnel), and removed within the framework of protective treatments conducted in the managed Polish part of the Białowieża Forest in the years 1992–2017
*until 31 October based on data from the Regional Directorate of the State Forests in Białystok

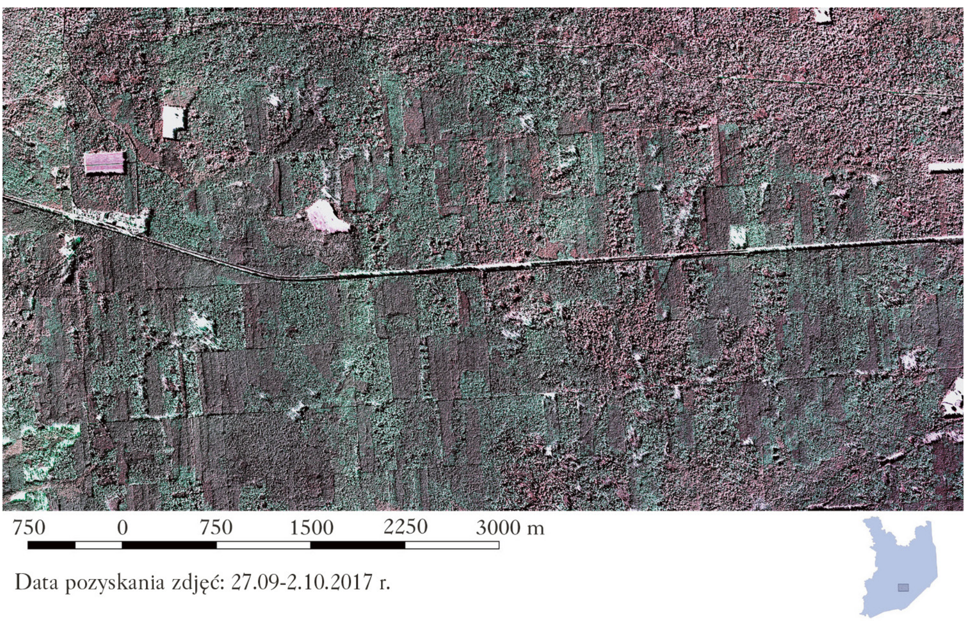

Fig. 2.
Fragment of the Białowieża Forest with dead spruce trees (blue and green) on colour aerial images in infrared, taken under the project LIFE+ ForBioSensing PL 'Comprehensive monitoring of the dynamic of stands of the Białowieża Forest with use of remote sensing data' LIFE13 ENV/PL/000048

(Data pozyskania zdjęć: – Date of obtaining pictures:)

Although spruce dieback occurs most frequently in stands of older age classes, particularly valuable from the point of view of biodiversity conservation, currently this problem increasingly concerns also young stands, representing even age class II. The main reason for the rapid increase in the number and volume of spruce trees declined as a result of mass propagation of European spruce bark beetle over the past years was the reduction, pursuant to a decision of the Minister of Environment (Decision 2012a–c), of the annual allowable cut from 107 to 48,500 m^3 and the introduction of many diverse bans. This meant that the possibility of performing sanitation treatments on areas affected by the large-scale gradation of that insect was restricted.

In 2012, upon the commencement of the current gradation of the European spruce bark beetle in the Białowieża Forest, the forest districts in Białowieża, Browsk and Hajnówka belonging to the Promotional Forest Complex 'Białowieża Forest', following the provisions of Instruction… (2012), attempted to take actions striving to at least slow down the process of spruce stand loss, if not stopping it. However, limitations concerning the allowable cutting volume, introduced together with approved forest management plans, accompanied by a long list of stands excluded from any maintenance and protective measures, blocked the possibility of performing effective protective treatments against bark beetle. Such treatments were permitted only in spruce stands of less than 100 years old, where stands in which only 10% of the trees exceeded that age limit were deemed 100-year-old stands. Protective treatments were not conducted in bog and moist habitats either. All stands remaining without protective treatments covered an area of 22,838 ha, which constituted 46% of the wooded area of the districts of the Białowieża Forest. The control of European spruce bark beetle gradation was not carried out on the area of nature reserves either, covering in total an area of 12,054 ha, i.e. another 24% of the wooded area of forest districts of the forest. As a consequence of the above-mentioned restrictions, a large number of infested spruce trees were left in the stands.

It is possible that the problem of calamitous dieback of The spruce forests would not exist today if in 2011 the foresters were permitted to remove 5,000 m^3 of wind-broken and wind-thrown spruce trees and to take actions not to allow the gradation of European spruce bark beetle. Since a significant part of the damaged trees exceeded the age of 100 years, the forest districts of the Promotional Forest Complex 'Białowieża Forest' applied to the Chief Nature Conservator for a consent for protective actions. In the face of a lack of reaction on his part, the Regional Directorate of the State Forests in Białystok submitted a similar request, but did not receive a positive answer either.

Importance of the European spruce bark beetle for the dieback of spruce stands. European spruce bark beetle *Ips typographus* (*Coleoptera*, *Curculionidae*, *Scolytinae*) feeds on the inner bark and cambium of spruce, which leads within a short time to the tree's death, and which is why it is their most dangerous cambiophage. When its population is small, it usually infests weakened, wind-thrown, broken or felled trees. However, in the gradation period, it attacks fully healthy trees, not showing any signs of weakening, and causes a dieback of whole stands (Grodzki 2016). This concerns in particular single-species spruce forests of older age, growing in improper habitats, both on the lowland and in the mountains. Over the last decades, large-scale and several-year-long gradations by European spruce bark beetle happened not only in Poland, but also in other countries of Central Europe (Grodzki et al. 2013; Grodzki, Kolk 2013). Each gradation of European spruce bark beetle, a species with a high reproductive capacity, capable of reproducing two main generations and one to two sister generations within one year, usually leads to calamitous effects and significant economic losses on the entire area of spruce occurrence.

An increase in the population of European spruce bark beetle often occurs as a result of leaving in the forest large numbers of not debarked wind-broken and wind-thrown trees, which contributes to the infestation of living standing trees (Starzyk 2013a). The development and reproduction of the European spruce bark beetle population is stimulated by such factors as high temperature, lack of precipitation, adverse soil conditions and damage to spruce stands from wind and snow, as well as shock by fungi of the honey and *Heterobasidion* genera. Susceptibility to infestation by European spruce bark beetle increases in the case of older stands and stands weakened by drought. Spruce has a shallow root system, and when there is a lack of water, production is inhibited of the resin used to cover any injuries, including insect bites. All these factors act synergistically, causing rapid changes in the size of population of European spruce bark beetle and other species accompanying it (Starzyk 2013b).

It is sometimes argued that the previously applied methods of limiting the size of the bark beetle population and reducing the amount of damage caused by them are ineffective and pointless, because they stimulate gradation development, and when all snag trees are removed, the stand dies back much faster. The results of long-term observations and the experience acquired in combatting European spruce bark beetle in Poland and in many other European countries indicate a different picture (Capecki et al. 1998, Grodzki 2016). Therefore the prophylactic treatments described in detail in the *Instructions on Forest Protection* (2012) and methods verified in practice related to limiting the size of the European spruce bark beetle population (Hilszczański, Starzyk 2017) should not be ignored.

Gradation of the European spruce bark beetle and the need for active protection of valuable species and habitats. The need for the active protection of species and natural habitats imply the necessity of taking actions aimed at the limitation of the adverse effects of European spruce bark beetle gradation in commercial stands. The objective of the active protection measures includes the initiation and protection of the proper course of the regeneration processes, with the inclusion of all tree species important for the Białowieża Forest, as well as the creation of a spatially and species-wise diversified forest structure, and the conservation of existence continuity of all ecosystem components, not only those associated with dead spruce trees.

Pursuant to the Act… (2004) in force, as well as to the Habitats Directive of the EU, the priorities that should determine the performance of actions in the forest related to the active protection, consisting among others in an active control of European spruce bark beetle, include the maintenance of ecological processes and stability of ecosystems, maintenance of biodiversity, provision of the continuity of existence of plant, animals and fungi species together with their habitats through the maintenance or restoration of their proper state of protection, conservation of landscape values, and maintenance or restoration of a proper state of habitat protection. In the Białowieża Forest, the maintenance of these priorities under the conditions of the present bark beetle gradation and without a radical change in the approach to the management on this area, in particular in remaining live spruce forests and stands with share of spruce, will be very difficult, if not impossible.

The example of the Strict Reserve of the Białowieża National Park indicates that the spontaneous regeneration of stands after large-area distortions, partly due to their frequent overgrowing by weeds and the turf creation process (small reed, blackberry, raspberry, common bracken, etc.), as well as the strong, selective pressure of large herbivores, is a very slow process. In such conditions, decades or even centuries must past before that forest ecosystems regenerate fully. Research conducted in the territory of the park also show that under the present conditions many tree species do not advance from the layers of self-sown seedlings and saplings to the higher layers of the stand, and that support by humans is necessary in this case (Matuszkiewicz 2011; Brzeziecki et al. 2012, 2016, 2017; Gazda, Miścicki 2016).

Impact of large quantities of timber from dead spruce trees on forest soils. The processes of decomposition of timber from dead trees lead to a large volumes of undecomposed lignin covering the forest floor. Contrary to cellulose, it is very resistant to degradation, while some products of its decomposition remain in the soil undecomposed for centuries (Zabel, Morrell 1992). The different parts of lignin decomposes over various lengths of time, depending on the species, temperature and humidity. In the case of spruce, 95% of the substance decomposes in ten years. Phenolic compounds created after lignin decomposition may limit the growth of soil microorganisms participating in processes of mineralisation of the organic substance. In the lignin oxidation process, numerous compounds are produced (e.g. vanillin, acetic acid, vanillic acid), which also cause alterations in the soil properties. Earlier studies have confirmed the significance of wood from dead trees in the increase of carbon accumulation in the soil environment, with a simultaneous increase in the soil biological activity (Lajtha et al. 2005; Kim et al. 2017).

In comparison with deciduous species, the wood of conifers is poorer in macroelements, such as nitrogen, phosphorus, potassium, calcium and magnesium. A greater concentration of resinous substances and a different chemical composition of lignins may slow down the microbiological processes of wood decomposition of non-coniferous species (Kögel-Knabner 2002). Leaving spruce wood may result in various consequences, depending on habitat conditions, under particular soil conditions. For permeable sandy soils without a strong infiltration of rich ground water (fresh mixed coniferous forest and mixed deciduous forest habitats), an acidification of the surface soil levels may be expected. In the case of soils with high buffer capacity and affluent in water containing dissolved mineral salts (fresh deciduous forest, moist deciduous forest, riparian forest and alder carr habitats), no adverse impact of spruce wood occurs. According to Matuszkiewicz (2016), leaving a large quantity of dead spruce trees (down and standing) in deciduous forest habitats dominating in the forest is unjustified from the environmental point of view. Research by Lasota et al. (2017) concerning the composition of the filtrates released from decomposing wood into the soil indicates that spruce wood delivers relatively large quantities of phosphate and sulphate anions to the soil. The quantity of base cations (calcium, magnesium, potassium) released from decomposing spruce wood is comparable with the quantity of cations released from wood of deciduous species (oak, alder and aspen).

Threat from pathogenic fungi. Pathogenic fungi are also important for the health condition of spruce. European spruce bark beetle is a vector for at least 25 pathogenic fungi species, especially ophiostomatoid, which it transfers to newly infested spruce trees. In the Białowieża Forest, the most important ones include *Ceratocystis polonica* (=*Endoconidiophora polonica*), *Grosmannia penicillata*, *Ophiostoma ainoae,* and *O. bicolor* (Jankowiak, Hilszczański 2005; Kirisits 2010). A special significance for the deterioration of the health condition of spruce stands can be attributed to *C. polonica* fungus. It is characterised by very high virulence and is able to cause spruce dieback without the participation of bark beetle.

On boles of dead spruce trees the fruiting bodies of *Fomitopsis pinicola* occur numerously. This species may also attack other coniferous and deciduous trees. Fungi from the *Armillaria* and *Heterobasidion* genus pose a large risk. They commonly develop in the root systems and butts of spruce and, by weakening them, facilitate the development of European spruce bark beetle gradation.

Problem of fire hazard. Fire hazard increases in the summer period, when dead boles and withered branches with a loose, spatial structure cover the forest floor. About 99% of fires occur under such conditions. In comparison to the conditions before the outbreak of gradation by European spruce bark beetle, the volume of dry and flammable biomass increased after 2012 in many places of the forest, by a factor of several to more than a dozen. Snag trees left by public roads pose a fire risk for the forest and breaches § 39, section 1 of Regulation… (2010). This fact was pointed out by the Poviat Commander of the State Fire Service in Hajnówka, who issued on 9 June 2014 a decision directed to district forest managers of the Białowieża and Hajnówka forest districts obliging them to clean a 30-metre wide strip along the Hajnówka–the voivodeship road from branches, branchwood and not delimbed fallen trees. The execution of works by forest districts according to the commander's decision led to the accumulation of branches 30 m behind the cleaned strip and to the formation of piles (banks) of flammable snag posing a high fire risk. Fire spread on areas where a breakup of stands took place (thus flammable small reed has occurred) constitutes a considerable fire risk in early spring and in autumn. It may also occur during extended summer drought periods (Szczygieł, Kwiatkowski 2015).

Public safety issue. The impact of a very large number of standing dead trees for the safety of people staying in the territory of the forest (residents and tourists) is an important issue. Several years after the spruce dieback, their boles began to break at a height of several metres. Trunk breaking is related to tree colonisation by fungi, mainly by *Fomitopsis pinicola*. It causes brown rot of wood, which consists of the decomposition of cellulose and hemicellulose, while the lignin remains almost intact. Wood free of cellulose is crisp, brittle, and may be triturated at the final stage. The highest risk from breaking dead spruce trees emerges in the case of main roads, communication routes and touristic paths; however the side roads and forest trails used by tourists, local resident and forest staff are not free of it either.

Economic aspect. The economic issues of the region and forest districts of the Promotional Forest Complex 'Białowieża Forest', directly related to the elimination of the effects of European spruce bark beetle gradation in spruce forests, are also important. The opinion, popularised by some 'ecological' groups, that the managers of the area, 'foresters', want to conduct cutting because of a willingness to earn income from sold timber, is not only false but also highly harmful to the environmental, social and economic interests of the local community. A comparison of forest management costs in the The, Hajnówka and Browsk forest districts indicates that they receive large financial means annually from the forest fund. The data from the Regional Directorate of the State Forests in Białystok show that since 2010 subventions for the districts of the forest have been growing regularly. In total, on the scale of three forest districts, the subventions (in PLN) came in 2010 to 5.4 million, in 2011 to 13.7 million, in 2012 to 15.8 million, in 2013 to 16.2 million, in 2014 to

16.7 million, in 2015 to 21.2 million, and in 2016 to 21.4 million. The level of subventions to the forest management in the Promotional Forest Complex 'Białowieża Forest' proves that foresters do not profit from management of the forest.

A cost analysis of timber harvesting, processing and extraction on the example of the Białowieża Forest District in 2015 indicated that the sale price for raw material originating from dead spruce trees was at the gross level of PLN 91.80/m^3, with simultaneous cost of timber harvesting, processing and extraction at the gross level of PLN 64.40/m^3. This means that after almost one hundred years of forest management and stand maintenance, a revenue at the level of PLN 27/m^3 is obtained. With the annual allowable cut reduced to 48,500 m^3, the difference between the timber sales revenue and the harvesting cost (without consideration of other costs, e.g. administration and taxes) in these forest districts is approx. PLN 1.315 million per year. This amount cannot be compared and balanced with the amounts of subventions from the forest fund. It should also be emphasised that a complete cessation of cutting and turning commercial stands into protected ones would not solve the problem of subventions. A national park covering such a large area would require significant regular financial means (which can be only estimated today) for its administration, operations and protection.

Conditions for functioning of forest districts in the Promotional Forest Complex 'Białowieża Forest'

The multitude of legal acts valid in the Białowieża Forest results from the variety of protection forms, often interpenetrating and sometimes contrary to each other (Białowieża National Park, protected landscape site, nature reserves, nature monuments, ecological land, species conservation of plants, fungi and animals, Natura 2000 site, UNESCO World Heritage Site). With this complicated legal status, even lawyers find the interpretation of laws difficult and this state hampers employees of nature conservation or the forest service, and can make it impossible to take reasonable decisions. In the area of the forest, 23 international legal acts (including 6 EU acts), 28 acts of the Polish law (including 16 acts of parliament and 9 regulations of the Minister of Environment) and many other apply, e.g. regulations of local authorities (Perkowski 2015).

Apart from nature conservation forms valid upon Act… (2004), additional conservation regimes have been introduced to the Białowieża Forest, having no legitimacy in the Polish nature conservation law. Examples within this scope include decisions of the Minister of Environment on the exclusion from management practices of stands aged more than 100 years, distinguished on the basis of a definition not used anywhere else, or implementation of an annex to the forest management plan consisting, for example, in a significant reduction of the annual allowable cut (Decision 2012a–c).

An example of the lack of consequence in the 'conservation-oriented' approach to the forest as a site encompassed in full in the Natura 2000 programme is the prohibition of the removal of spruce trees infested by European spruce bark beetle, justified with the argument that in the case of the forest, natural processes should not be counteracted. On the other hand, it is required to remove vegetation overgrowing in the process of the natural succession some habitats present in the forest, stating that they should be maintained in an unchanged form (Ksepko, Porowski 2015; Kapuściński 2016).

Recommendations resulting from the analysis of the problem of dieback of spruce stands

The proper management of the Białowieża Forest requires an integrated action plan, considering simultaneously the Białowieża National Park, three forest districts and all communities adjacent to it. The implementation of such a plan requires sufficient funds, which should come to a large extent from the European funds, due to the international rank of this domain. The implementation of such a plan, apart from state institutions, should also involve non-governmental organisations, which would entail taking responsibility for the tasks entrusted to them.

Both passive conservation (essentially the conservation of natural processes) and multifunctional forest management considering the necessity for the active conservation of habitats and species (mainly interventions to preserve the objects of protection) have their advantages. In the case of forest districts in the Białowieża Forest, the advantages of the multifunctional management prevail definitely. It allows a gradual conversion of commercial stands and the formation of a diversified structure, in terms of species, age and space, allowing at the same time to prevent the adverse effects of passive conservation and rationally use the habitat and wood raw material. A petition appealing for the establishment of multifunctional and sustainable forest management in the forest districts of the Promotional Forest Complex 'Białowieża Forest', which was directed in 2016 to the Prime Minister Beata Szydło, was signed by five thousand people (approx. 33% of the local population).

In order to catalogue the proposals and suggestions addressed to the various levels of governmental authorities, local governments and forest authorities, the rescue actions in the stands of the forest were divided into three groups, depending on the task urgency:

A. Immediate and short-term activities:
   1. Timely performance – before spring swarming of European spruce bark beetle – of sanitation cutting in stands where currently active snag trees exist, in order to slow down the further decline of spruce stands.

2. Ongoing marking and removal of active spruce snags appearing in commercial stands of all age classes, in order to limit the pace of decline of the stands and, as a result, to limit European spruce bark beetle gradation.
3. Rejection of the arbitrary definition of stands aged more than 100 years, not grounded in forest sciences, and cancellation of the ban on conducting intervention cuts in such stands.
4. Granting a consent by the Minister of Environment to conduct sanitation cutting in all stands of the 'Białowieża Forest' Promotional Forest Complex in accordance with the needs of European spruce bark beetle control, which shall allow:
   a) removal of most trees infested by European spruce bark beetle, thus limiting the gradation growth rate,
   b) improvement in the conditions of direct safety of people staying in this area,
   c) reduction of fire risk.
5. Execution of active conservation measures for environmental habitats and species being subject to protection in the area of the Natura 2000 site.
6. Development of a comprehensive action plan for the forest districts of the 'Białowieża Forest' Promotional Forest Complex, following the example of forests in Beskid Śląski and Beskid Żywiecki (Małek 2015).

B. Measures with a medium-time horizon:
1. Implementation into the practice of forest environment management of legal mechanisms preventing from making wrong decisions, contrary to the present state of forest knowledge (with particular consideration of knowledge concerning the approach to insect gradations), by bodies in charge of environmental protection in our country.
2. Carrying out an assessment of the level of threat to valuable habitats and species for which a sudden dieback of a spruce stand and soil exposure shall cause adverse environmental effects threatening their existence.
3. Taking actions preventing from the further deepening of the generation gap in the Norway spruce population in the forest, as well as containing its retreat in appropriate habitats.
4. Counteracting the emergence of the lack of continuity in the stock of dead spruce trees being at the initial decomposition stage, posing a threat to the existence of many species of saproxylic organisms (living in decomposing timber).

5. Making a decision on the removal of excessive dead spruce trees in deciduous forest habitats requiring a species conversion, to prevent their degradation in the longer term.
6. Designation of stands for conversion and commencement of the introduction of species appropriate for deciduous forest habitats, based on propagating material of local origin, ensuring preservation of the gene pool of species and the ecotypes of trees of the Białowieża Forest (Bernadzki et al. 2012).

C. Long-term measures:
1. Return to the idea of sustainable and balanced development in the management conduct in the area of the 'Białowieża Forest' Promotional Forest Complex, based on scientific grounds, taking into account the needs of the local community.
2. Transformation and enrichment of stands, adjustment of their species composition to habitat conditions and carrying out functions of a protective character and associated with the recognition of the Białowieża Forest as a UNESCO World Heritage Site.
3. Commencement of works on a parliamentary act on the Białowieża Forest ensuring the conservation of its values in the aspects of environment, landscape, tourism and leisure, water protection, and protection of unique fauna and flora species, and providing the local community (highly dependent on activities in the sector of forestry and environmental protection) with conditions for its development and dignified life.

Summary

The Białowieża Forest is an area where humans have been living for centuries and satisfying their social, cultural and economic needs. The current shape and position and role of the forest is also a merit of the local community. In recent years, decisions concerning the management of this area have been made without consideration of the opinion of this community. The lack of a coherent and accepted by the local population vision of management of the Białowieża Forest area led to the accumulation of many problems and the socio-economic stagnation of that region, the consequence of which is the highest rate of depopulation in Poland. The Białowieża Forest, which is a brand recognised all over the world, needs special support and commitment from the governmental side related to actions for the sake of sustainable development of the region and to the search for a compromise between human and environmental needs.

The current problem of European spruce bark beetle gradation in the forest districts of the Promotional Forest Complex 'Białowieża Forest', which appeared almost immedi-

ately after the implementation of the concept of leaving the forest to the 'forces of nature', indicate unambiguously that it is a poor concept in reference to so large area, affected for centuries by human activities of various kinds. The results of long-term research conducted in areas subjected for a long time to strict conservation also prove that this concept is harmful for the forest. They demonstrate that, under the conditions of strict conservation, the state of preservation of many valuable elements of natural richness of the forest deteriorate significantly.

The Forest is a domain where the necessity of integrating the main postulates of nature conservation within the framework of a multifunctional forest management is best illustrated. The solutions implemented in the forest, developed mutually by foresters and naturalists, and accommodating the needs for the utilisation and conservation of various forest resources, can form a model for the management of other forests in Poland and abroad. The broadest possible implementation of such solutions constitutes a basic condition for the effective protection of natural resources of our country and the condition for accommodating different needs and social expectations towards forests.

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1. **O Puszczy Białowiezkiey przez Juliusza Barona Brinken** [About the Białowieża Forest by Baron Juliusz Brinken] (*Sylwan. Dziennik Nauk Leśnych i Łowieckich*, Vol. 4(3), 1827, p. 298–319)
2. **Puszcza Białowieska (Urywki z pracy pt. „Białowieża w albumie") [The Białowieża Forest (Extracts from the work entitled** *Białowieża in Pictures*)] (Gloger Z., *Sylwan. Czasopismo miesięczne dla leśników i właścicieli ziemskich. Organ Galicyjskiego Towarzystwa Leśnego*, Vol. 32(8/12), 1914, p. 318–329)
3. **Opis puszczy białowieskiej wedle dzieła E. Eichwalda** [Description of the Białowieża Forest according to the work by E. Eichwald] (A.K., *Sylwan. Czasopismo miesięczne dla leśników i właścicieli ziemskich. Organ Galicyjskiego Towarzystwa Leśnego*, Vol. 34(1/6), 1916, p. 1–16)
4. **Puszcza białowiezka w czasie wojny** [The Białowieża Forest in the time of war] (*Sylwan. Czasopismo miesięczne dla leśników i właścicieli ziemskich. Organ Galicyjskiego Towarzystwa Leśnego*, Vol. 35(7/9), 1917, p. 166–175)
5. **Z Puszczy Białowieskiej. Wrażenie z wycieczki odbytej w kwietniu b.r.** [From the Białowieża Forest. Impressions from a trip taken in April this year] (Szafer, W., *Sylwan. Czasopismo miesięczne dla leśników i właścicieli ziemskich. Organ Małopolskiego Towarzystwa Leśnego*, Vol. 37(4/6), 1919, p. 125–139)
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8. **Użytkowanie Puszczy Białowieskiej** [The use of the Białowieża Forest] (Kochanowski, C., *Sylwan. Organ Małopolskiego Towarzystwa Leśnego*, Vol. 40(1), 1922, p. 12–14)
9. **Odpowiedź p. Klosce na artykuł zamieszczony w Nr. 2 Lasu Polskiego pt. Obecny stan przemysłu drzewnego w Puszczy** [Reply to Mr. Kloska to the paper published in No. 2 of *Las Polski* journal titled 'The current status of wood industry in the Forest] (Kochanowski, C., *Sylwan. Organ Małopolskiego Towarzystwa Leśnego*, Vol. 40(11), 1922, p. 252–254)

10. **Odpowiedź na artykuł 'Z puszczy Białowieskiej' p. Wacława Rossińskiego [nr 3 Lasu Polskiego z marca 1922 r.]** [Reply to the paper 'From the Białowieża Forest' by Wacław Rossiński (No. 3 of *Las Polski* of March 1922)] (Kochanowski, C., *Sylwan. Organ Małopolskiego Towarzystwa Leśnego*, Vol. 41(6), 1923, p. 139–141)
11. **Studia nad opadem pyłków drzew leśnych w Puszczy Białowieskiej** [Studies on the pollen fall of forest trees in the Białowieża Forest] (Bremówna M., Sobolewska, M., *Sylwan*, Vol. 56(3/4 Ser. A), 1938, p. 121–139)
12. **Znaczenie Białowieskiego Parku Narodowego dla leśnictwa [Skrót referatu]** [The importance of the Białowieża National Park for forestry (Paper abstract)] (Trampler, T., *Sylwan*, Vol. 100(1 Ser. A), 1956, p. 58–59 [From the conference 'National parks and reserves as centres for scientific, teaching and educational activities', 2–4 June 1955, Białowieża])
13. **Zakres i kierunki dotychczasowych badań na terenie Białowieskiego Parku Narodowego [Skrót referatu]** [Scope and directions of previous research in the Białowieża National Park (Paper abstract)] (Graniczny, A., *Sylwan*, Vol. 100(1 Ser. A), 1956, p. 59–61 [From the conference 'National parks and reserves as centres for scientific, teaching and educational activities', 2–4 June 1955, Białowieża])
14. **Swoistość badań Białowieskiego Parku Narodowego w ogólnokrajowej sieci parków narodowych i rezerwatów [Skrót referatu]** [Specificity of research of the Białowieża National Park in the nationwide network of national parks and reserves [Paper abstract] (Dehnel, A., *Sylwan*, Vol. 100(1 Ser. A), 1956, p. 57–58 [From the conference 'National parks and reserves as centres for scientific, teaching and educational activities', 2–4 June 1955, Białowieża])
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19. **Obserwacje nad rozwojem wegetacji roślinnej w Białowieskim Parku Narodowym** [Observations of plant vegetation development in the Białowieża National Park] (Graniczny, A., *Sylwan*, Vol. 101(4), 1957, p. 36–45)
20. **Najstarsze świerki w Puszczy Białowieskiej** [The oldest spruce trees in the Białowieża Forest] (Ząbek, J., Zaręba, R., *Sylwan*, Vol. 101(5), 1957, p. 46–59)
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25. **1st Scientific Session of the Forest Sciences Committee of the Polish Academy of Sciences on the regeneration of the Białowieża Forest. 15–18 October 1958, Białowieża** (Dunikowski, A., *Sylwan*, Vol. 104(4), 1960, p. 73–78)
26. **Ogrody do polowania w Puszczy Białowieskiej w czasach Stanisława Augusta Poniatowskiego** [Hunting gardens in the Białowieża Forest in the times of Stanisław August Poniatowski] (Zaręba, R., *Sylwan*, Vol. 106(2), 1962, p. 81–83)
27. **Próby pomiaru rosy w grondzie (*Querceto-Carpinetum medioeuropaeum* Tuxen 1936) w Białowieskim Parku Narodowym** [Attempts at the measurement of dew in oak-hornbeam forest (*Querceto-Carpinetum medioeuropaeum* Tuxen 1936) in the Białowieża National Park] (Olszewski, J., *Sylwan*, Vol. 107(1), 1963, p. 21–29)
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30. **Częstotliwość temperatur maksymalnych i minimalnych gleby w zespole boru mieszanego *Pineto Querceto serratuletosum* Białowieskiego Parku Narodowe-**

go [Frequency of maximal and minimal soil temperatures in the mixed coniferous forest *Pineto Querceto serratuletosum* community in the Białowieża National Park] (Bednarek, A., *Sylwan*, Vol. 109(5), 1965, p. 55–63) **Próba wyróżnienia i charakterystyka klimatologiczna fenologicznego okresu wegetacyjnego w Białowieży** [An attempt to distinguish and climatologically describe phenological vegetation period in Białowieża] (Bednarek, A., *Sylwan*, Vol. 110(6), 1966, p. 39–46)

31. **Specyfika mikoflory nadrzewnej Białowieskiego Parku Narodowego, ze szczególnym uwzględnieniem grzybów rzędu *Aphyllophorales*** [Specificity of tree microflora of the Białowieża National Park, with particular reference to fungi of the *Aphyllophorales* order] (Domański, A., *Sylwan*, Vol. 111(1), 1967, p. 17–27)
32. **Układ i charakterystyka klimatologiczna pór fenologiczncyh w Białowieży** [The system and climatological description of phenological seasons in Białowieża] (Bednarek, A., *Sylwan*, Vol. 111(10), 1967, p. 71–76)
33. **Obecna i przewidywana jakość drewna tartacznego iglastego z Puszczy Białowieskiej** [Present and predicted quality of softwood sawmill timber from the Białowieża Forest] (Żakowski, H., *Sylwan*, Vol. 112(1), 1968, p. 41–50)
34. **Jodła pospolita (*Abies alba* Mill.) w Puszczy Białowieskiej** [Silver fir (*Abies alba* Mill.) in the Białowieża Forest] (Gunia, A., Kowalski, M., *Sylwan*, Vol. 112(3), 1968, p. 59–66)
35. **Park Narodowy w Puszczy Białowieskiej (Uwagi do monografii) [recenzja]** [The National Park in the Białowieża Forest (Comments on the monograph) (review)] (Graniczny, A., *Sylwan*, Vol. 113(6), 1969, p. 89–96 [Park Narodowy w Puszczy Białowieskiej, ed. J.B. Faliński, PWRiL, Warsaw 1968])
36. **Report from the field conference in Białowieża on 5 and 6 April 1968 on the 'Management of the Białowieża Forest' [and] Conclusions from the meeting titled 'Management of the Białowieża Forest' held on 5 and 6 April 1968 in Białowieża** (developed by: Gierliński, T., [and] Graniczny A., *Sylwan*, Vol. 113(7), 1969, p. 75–79, p. 80–83)
37. **Nasze puszcze** [Our forests] (Zaręba, R., *Sylwan*, Vol. 114(8/9), 1970, p. 224–234 [Jubilee issue published on the occasion of 150th anniversary of *Sylwan* journal])
38. **Gospodarstwo rezerwatowo-łowieckie Biełowieżskaja Puszcza na terenie BSRR** [The reserve and hunting holding *Bielowieżskaja Puszcza* in the territory of the Belarussian Soviet Socialist Republic] (Okołów, C., *Sylwan*, Vol. 114(12), 1970, p. 77–82)
39. **Planowanie hodowlane w rębni gniazdowej przerębowej na przykładzie obiektu położonego w Puszczy Białowieskiej** [Silvicultural planning in patch selection cutting system on the example of a unit located in the Białowieża Forest] (Bernadzki, E., *Sylwan*, Vol. 115(1), 1971, p. 79–85)

40. **Produkcja nasion różnowiekowego i wielogatunkowego drzewostanu zbiorowiska grądu w Białowieskim Parku Narodowym** [Production of seeds in the uneven-aged mixed-species stand of oak-hornbeam forest community in the Białowieża National Park] (Falińska, K., *Sylwan*, Vol. 115(6), 1971, p. 17–23)
41. **Gospodarka w Puszczy Białowieskiej w ostatnim pięćdziesięcioleciu** [The economy in the Białowieża Forest for the past fifty years] (Więcko, E., *Sylwan*, Vol. 116(2), 1972, p. 29–46)
42. **O konieczności przebudowy rezerwatu pokazowego żubrów w Białowieskim Parku Narodowym** [About the necessity of conversion of the European bison show reserve in the Białowieża National Park] (Kawecka, A., *Sylwan*, Vol. 116(10), 1972, p. 77–80)
43. **Monument of Professor J. J. Karpiński, PhD, [unveiled on 26 October 1972 at entrance to the Białowieża National Park]** (E.W., *Sylwan*, Vol. 117(4), 1973, p. 81–83)
44. **Puszcza Białowieska (Uwagi o monografii)** [The Białowieża Forest (Comments on the monograph] (Okołów, C., *Sylwan*, Vol. 118(2), 1974, p. 64–70 [Puszcza Białowieska – E. Więcko, PWN])
45. **O nowych zasadach gospodarowania w Puszczy Białowieskiej** [About the new management principles in the Białowieża Forest] (Graniczny, S., *Sylwan*, Vol. 120(5), 1976, p. 37–41)
46. **Uszkodzenia systemów korzeniowych drzew spowodowane nadmiernym ruchem turystycznym w Białowieskim Parku Narodowym** [Damage to tree root systems caused by excessive touristic traffic in the Białowieża National Park] (Okołów, C., *Sylwan*, Vol. 122(11), 1978, p. 63–71)
47. **Przegląd zbiorowisk leśnych Puszczy Białowieskiej** [Review of the forest communities of the Białowieża Forest] (Sokołowski, A.W., *Sylwan*, Vol. 123(4), 1979, p. 21–29)
48. **Zmiany zasad zagospodarowania lasów Puszczy Białowieskiej w latach 1929–1976** [Changes in the principles of woodland management of The Forest in the years 1929–1976] (Graniczny, S., *Sylwan*, Vol. 123(11), 1979, p. 27–37 [Abstract of the lecture given at the conference organised by the Polish Forest Society and the Regional Board of the State Forests in Białystok, held in Białowieża on 23 and 24 June 1978]
49. **Conference in the Białowieża Forest on the principles of forest management and directions of forest management planning methods in the Białowieża Forest [23–24 June 1978, Białowieża]** (Graniczny, S., *Sylwan*, Vol. 123(11), 1979, p. 55)
50. **Gospodarka łowiecka w Puszczy Białowieskiej z uwzględnieniem hodowli żubra** [Game management in the Białowieża Forest with regard to bison breeding] (Miłkowski, L., *Sylwan*, Vol. 123(11), 1979, p. 45–54 [Abstract of the lecture given at the conference organised by the Polish Forest Society and the Regional Board of the State Forests in Białystok, held in Białowieża on 23 and 24 June 1978.])

51. **Drzewostany o niewłaściwym składzie gatunkowym w Puszczy Białowieskiej i propozycje ich przebudowy** [Stands with improper species composition in the Białowieża Forest and proposals of their conversion] (Kutrzeba, M., *Sylwan*, Vol. 123(11), 1979, s. 39–44 [Abstract of the lecture given at the conference organised by the Polish Forest Society and the Regional Board of the State Forests in Białystok, held in Białowieża on 23 and 24 June 1978])
52. **Gospodarka w Puszczy Białowieskiej w ostatnim pięćdziesięcioleciu** [The economy in the Białowieża Forest for the past fifty years] (Więcko, E., *Sylwan*, Vol. 124(8), 1980, p. 55–65)
53. **Rozległość niewiedzy o faunie Puszczy Białowieskiej** [The breadth of ignorance about the fauna of the Białowieża Forest] (Gutowski, J., Wołk, K., *Sylwan*, Vol. 125(6), 1981, p. 37–41)
54. **Puszcza Białowieska jako teren badań przyrodniczych** [The Białowieża Forest as an area of natural research] (Sokołowski, A.W., *Sylwan*, Vol. 125(6), 1981, p. 31–36)
55. **Filmowa kariera Puszczy Białowieskiej** [Film career of the Białowieża Forest] (Bajko, P., *Sylwan*, Vol. 127(9/10), 1983, p. 121–124)
56. **Stan zapasu Puszczy Białowieskiej i możliwości jego stopniowego podwyższania** [The state of growing stock in the Białowieża Forest and the possibilities of its gradual increase] (Zabielski, B., *Sylwan*, Vol. 128(3), 1984, p. 1–8)
57. **Puszcza Białowieska. Kalendarium – część I** [The Białowieża Forest. Timeline – part I (Więcko, E., *Sylwan*, Vol. 129(8), 1985, p. 49–56)
58. **Puszcza Białowieska. Kalendarium – część II** [The Białowieża Forest. Timeline – part II] (Więcko, E., *Sylwan*, Vol. 129(9), 1985, p. 43–52)
59. **Stan ścisłego rezerwatu Białowieskiego Parku Narodowego w świetle narastających zagrożeń lasów Polski** [The state of strict reserve of the Białowieża National Park in the light of increasing threats to Polish forests] (Sokołowski, A.W., *Sylwan*, Vol. 130(8), 1986, p. 21–28)
60. **Białowieski Park Narodowy – bilans 65-lecia** [The Białowieża National Park – a summary of 65 years] (Okołów, C., *Sylwan*, Vol. 130(12), 1986, p. 1–10)
61. **Granica swawoli w badaniach dzikich zwierząt** [Limits of freedom in the research of wild animals] (Kossak, S., *Sylwan*, Vol. 138(8), 1994, p. 49–60)
62. **Zmiany składu gatunkowego lasów na tle zmian klimatu w ostatnich dwóch stuleciach** [Changes in the species composition of forests on the background of climate change in the last two centuries] (Kowalski, M., *Sylwan*, Vol. 138(9), 1994, p. 33–44)
63. **Ekonomiczny model gospodarki leśnej obszaru Puszczy Białowieskiej** [Economic model of forest management of the Białowieża Forest area] (Płotkowski, L., *Sylwan*, Vol. 138(12), 1994, p. 17–38)

64. **Opinion of the Polish Forest Society on the principles of conservation and management of the forest ecosystems of the Białowieża Forest** (*Sylwan*, Vol. 139(1), 1995, p. 111–113)
65. **Opinion of the Council of Forestry to the Minister of Environmental Protection, Natural Resources and Forestry on the Białowieża Forest conservation** (Klocek, A., *Sylwan*, Vol. 139(8), 1995, p. 127–131)
66. **Liczebność zwierzyny w Puszczy Białowieskiej i proponowane sposoby prowadzenia gospodarki łowieckiej** [The game population count in the Białowieża Forest and proposed methods for game management] (Kossak, S., *Sylwan*, Vol. 139(8), 1995, p. 25–41)
67. **Przegląd pasożytów wybranych gatunków ssaków łownych i chronionych Puszczy Białowieskiej** [Review of parasytes of selected game and protected mammals in the Białowieża Forest] (Miniuk, M., *Sylwan*, Vol. 140(2), 1996, p. 87–95)
68. **Wpływ lasu na wilgotność powietrza (na przykładzie niektórych fitocenoz leśnych)** [The impact of forest on air humidity (on the example of selected forest phytocenoses] (Ożga, W., *Sylwan*, Vol. 140(5), 1996, p. 17–28)
69. **Gospodarka łowiecka i ochrona zwierzyny w Puszczy Białowieskiej w latach 1991–1997** [Game management and game protection in the Białowieża Forest in the years 1991–1997] (Kossak, S., *Sylwan*, Vol. 141(9), 1997, p. 55–61)
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