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NINE-YEAR RECORD OF *ALNUS* POLLEN DEPOSITION IN THE ROZTOCZE REGION (SE POLAND) WITH RELATION TO VEGETATION DATA

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S u m m a r y

Pollen deposition of alder has been measured at ground level by means of nine modified Tauber traps in different plant communities according to rules of the Pollen Monitoring Programme (http://pmp.oulu.fi). The series of data covers the period 1998-2006. The area under investigation is situated in the Roztocze (surroundings of the Guciów village) within the protective zone of the Roztocze National Park. During nine years of monitoring, significant variations were observed between single years of deposition. The occurrence of peak years (1998, 2001, 2003 and 2006) connected with higher production of *Alnus* pollen was observed at many pollen monitoring sites, but its relationship with different proportions of alder within the surrounding vegetation seems rather weak. The average value of annual pollen deposition of *Alnus* for the whole region was calculated at ca. 1370 grains · cm^{-2}. At the sites situated within the open landscape, pollen influx values ranged from 442 (in 2005) to 6894 (in 1998). It seems that other factors than the proportion of alder within the vegetation control the deposition of *Alnus* pollen. Long-distance transport and meteorological factors such as wind speed and direction should be taken into account in future studies.

Key words: pollen monitoring, *Alnus* pollen, modern pollen deposition, pollen-vegetation relationship, Tauber traps

INTRODUCTION

In Poland three species of *Alnus* Mill. genus occur, from among which the most widespread is common alder *Alnus glutinosa* /L./ Gaertn. (Z a j ą c and Z a j ą c , 2001). As an anemophilous tree belonging to the Betulaceae family, common alder produces a great amount of pollen triggering allergic reactions. For that reason, it arouses interest of aerobiologists and allergists. In our country *Alnus* pollen appears in the air very early, often in the first decade of February (K a s p r z y k et al. 2004; S z c z e p a n e k , 2006; S m i t h et al. 2007; W e r y s z k o - C h m i e l e w s k a and P i o t r o w s k a , 2004; 2006). Due to cross reactivity of alder and birch pollen, not only the concentration of *Alnus* pollen has been analysed, but also the course of pollen seasons and related meteorological factors (G i o u l e k a s et al. 2004; K a s p r z y k et al. 2004; R o d r i g u e z - R a j o et al. 2006; S m i t h et al. 2007). Pollen seasons of early spring flowering taxa, such as *Alnus* and *Corylus*, are quite sensitive to the increase in global air temperature. Thus, these taxa are important in the context of global climate change (E m b e r l i n et al. 2007; R o d r i g u e z - R a j o et al. 2004). There is also a palaeoecological aspect of the studies on alder pollen. Analysis of its deposition at the ground level, in situations analogous to deposition in mid-forest mires in the past, can shed light on the problem of the Holocene expansion of alder. Isopollen maps indicate that it occurred in two stages. The first stage, about 8500 C^{14} years BP, is related to the migration of *Alnus incana* along the Vistula River valley. *Alnus glutinosa* was probably responsible for the second expansion wave about 8000 C^{14} years BP (S z c z e p a n e k et al. 2004). Quantifying the relationship between pollen deposition of *Alnus* and the occurrence of this tree within the vegetation at known distances from a pollen-trapping site can help to solve palaeoecological problems concerning alder communities which are reflected by fossil pollen diagrams. Such studies, based on the rules of the Pollen Monitoring Programme, have been conducted in the Middle Roztocze region since 1998. The project aims at studying pollen dispersal and deposition of different tree, shrub, and herb taxa by means of Tauber traps in the conditions as natural as possible. Diverse natural biotopes of the Roztocze, which is cut by the Wieprz River valley, caused the formation of about 20 forest associations, among which also *Ribeso nigri-Alnetum* association occurs together with initial forms of alder riverside carrs (*Fraxino-Alnetum*) growing along the Wieprz River channel (I z d e b s k i et al. 1992).

The purpose of this paper is to analyse the nine-year series (1998-2006) of data concerning alder pollen deposition, and to relate these data to the proportion of alder in vegetation communities surrounding pollen traps. Such analysis can help to find a solution to a problem to what extent the deposited alder pollen represents local vegetation. This question is essential not only for palaeoecological interpretations, but it can also shed light on the problem of long-distance transport of alder pollen, which is important for allergy sufferers.

MATERIALS AND METHODS

Monitoring pollen deposition

Monitoring of *Alnus* pollen deposition has been conducted by means of nine Tauber traps (Tauber, 1974; Hicks and Hyvärinen, 1986) in the years 1998-2006 in frame of the Pollen Monitoring Programme (PMP). Pollen gathered during the whole calendar year was subjected to laboratory treatment with the use of *Lycopodium* tablets (Stockmarr, 1971) followed by microscopic analysis (Hicks et al. 1996). The PMP method makes it possible to count pollen influx values (PI), i.e. number of pollen grains of a given taxon per 1 cm^2 a year. Detailed guidelines to the PMP method published by Hicks and co-authors (1996; 1999) can be found also at http://pmp.oulu.fi.

In the Roztocze plastic containers were used as modified Tauber traps. Opening of 5 cm in diameter was covered by a wire net with large meshes (*vide* Pidek, 2004). Five *Lycopodium* tablets were added to the trap contents, followed by filtering and standard acetolysis. Microscopic analysis was continued until minimum 500 tree and shrub pollen grains (AP) were counted and minimum 100 *Lycopodium* spores were encountered. Pollen influx values were calculated separately for each taxon – *Alnus* among others.

The calculated annual alder pollen sums per 1 cm^2 (pollen influx values) are presented in Table 2. The table contains pollen influx values for 9 pollen traps in the period 1998-2006. The PI values higher than average ones for at least 30% for a particular site are considered high values and marked in bold. Due to damage of a pollen trap during vegetation season, several data are lacking which have been marked by a horizontal line.

Area under investigation

The area under investigation is situated in the Middle Roztocze region in the surroundings of the Guciów village. The region of the Roztocze forms a belt of elevations in south–eastern Poland, on the border between Poland and Ukraine (Fig.1) and differs from neighbouring regions by its geologic structure, surface relief, climate, waters, soils and vegetation cover (Buraczyński, 2002).

The characteristic feature of the Roztocze region is an extensive forest cover and low degree of anthropogenic changes of landscape due to moderate agrarian activity (Janicki and Wojtanowicz, 1997). About 60% of the Roztocze forests are of natural or semi-natural origin up till now. They can be divided into, among others, coniferous forests, dry-ground forests, alder woods and riverine forests. These communities were classified into 18 associations and two communities (Izdebski, 2002). The forests of the Middle Roztocze are the most precious. They are protected within the Roztocze National Park, founded in 1974. The area under investigation is situated within the protected zone of the Park (Fig. 2).

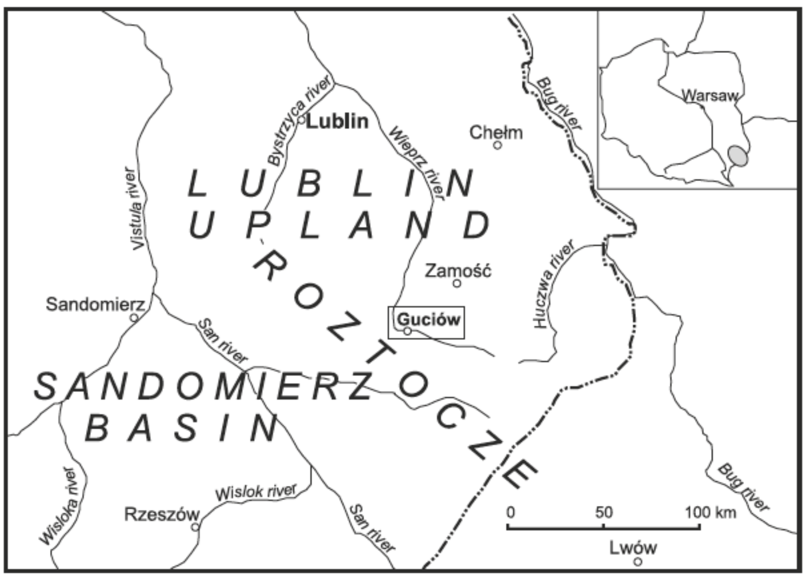

Fig. 1. Location of the area under investigation.

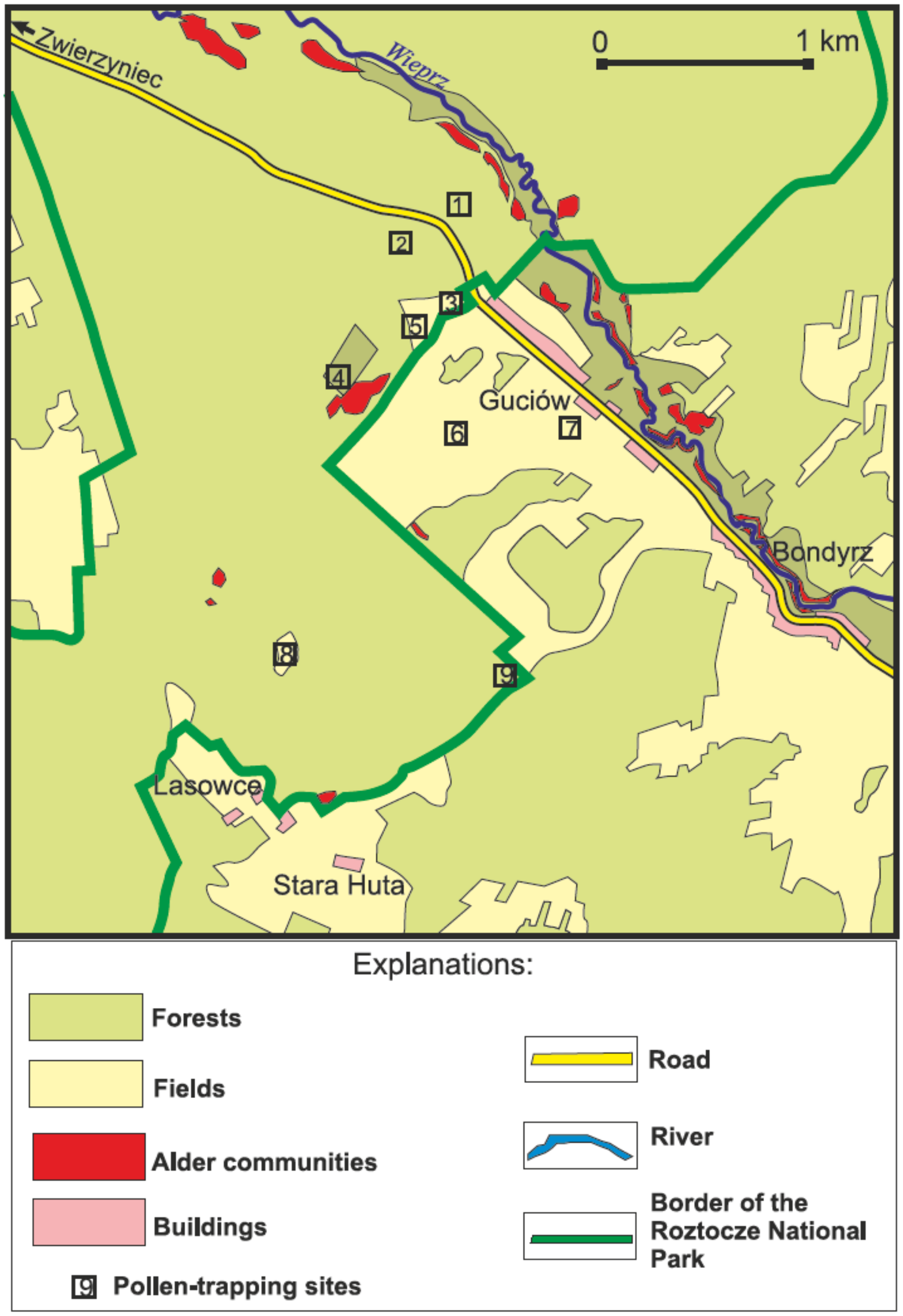

Fig. 2. Pollen-trapping sites in the area under investigation on the background of alder communities.

Alnus glutinosa is the only species of alder occurring in the study area (Izdebski et al. 1992). According to Bałaga (1998), the formation of alder communities in the Roztocze started at ca. 8330 ± 150 C^{14} years BP. This date seems a little earlier than the one considered by Szczepanek and co-authors (2004). Alder communities in the Roztocze grow mainly on peaty soils along the Wieprz River channel as well as in wet hollows without outflow. In the surroundings of the Guciów village, patches of *Ribeso nigri–Alnetum* association as well as riverine alder carrs of *Fraxino-Alnetum* association occur along the lower terrace of the river. They occupy ca. 4 ha in total within the Guciów village itself (Grądziel et al. 2006). The nomenclature of the associations followed Matuszkiewicz (2001).

Figure 2 illustrates the situation of pollen traps on the background of areas overgrown by various alder tree-stands. This map was based on the detailed maps of forest communities of the Roztocze National Park (I z d e b s k i et al. 1992) as well as on the maps of plant communities of the Guciów village (G r ą d z i e l and J a n i c k i , 2002; G r ą d z i e l et al. 2006). Air photos and author's field observations were used, too. Due to the scale of the map, single alder trees along the Wieprz River and in the vicinity of the trap no. 2 were not marked.

RESULTS

Situation of pollen traps against alder communities

The distance between the pollen trap and the nearest flowering *Alnus* trees differs very significantly at individual sites. Alder trees appear the closest to the trap (40 m) at the site 2 (to SE and NE directions from the pollen trap). They grow along the forest edge, in wet meadow. A patch of alder carr of *Ribeso nigri–Alnetum* association occurs also very close (100m) to the trap 4 (Fig. 2). The distances at other pollen-trapping sites are much greater. Table 1 contains a brief description of the sites and the approximate distance from the nearest alder trees.

The two sites (6 and 7) are intended to be "regional" ones to gather not only local but also regional pollen rain coming from outside the local vegetation. They were situated in open landscape within cultivated and abandoned fields.

Pollen data

Pollen deposition of *Alnus* differed very significantly in individual years and between the sites. The differences between the sites were much smaller than between PI values in different years at the same site. The years of high pollen deposition (1998, 2001, 2003 and 2006) were observed, as well as the years of very low

Table 1

Description of pollen-trapping sites in the area under investigation.

Site No	Site description	Distance from the nearest alder trees
1	Small opening within fir forest	250 m – alder communities in the river valley
2	Big, wet meadow within mixed forest	40 m – single alder trees and 650 m – alder communities in the river valley
3	Mixed forest edge	550 m – alder communities in the river valley
4	Big opening within mixed forest	100 m – patch of alder carr
5	Forest edge of beech wood	300 m – alder carr at the site 4
6	Open landscape (cultivated and abandoned fields)	400 m – alder carr at the site 4 and 700 m – alder communities in the river valley
7	Open landscape (cultivated and abandoned fields)	200 m – alder communities in the river valley
8	Big opening within beech wood	500 m – patch of alder carr to the western side
9	Very small opening within beech wood	900 m – patch of alder carr to the western side and 1500 m – alder communities in the river valley

(1999, 2000 and 2005) and average deposition (2002 and 2004). Pollen influx values for alder calculated for all nine trapping sites in the years 1998-2006 are presented in Table 2.

The average value of annual alder pollen deposition for the study area was calculated at 1368 grains×cm^{-2}. It was based on all the results from the pollen-trapping sites during nine years of monitoring. This value is more accurate than the first rough estimates (1419 *Alnus* pollen grains×cm^{-2} annually) based on four years' data (P i d e k , 2004). In the peak years, the PI values significantly surpassed the average deposition. In 1998 the highest among average values was recorded, i.e. over 4300 *Alnus* pollen grains×cm^{-2} (Fig. 3). However, taking into account that only three traps survived the first season of pollen monitoring, the result should be treated with limited confidence. In 2000 the lowest average value (365) of pollen deposition was recorded. In this case, the two regional traps were damaged which could influence the PI values quite significantly.

Taking into account the average values of *Alnus* pollen deposition at each of the monitoring sites (Tab. 2), the highest PI was recorded at the sites 6 and 4 situated quite close to the patch of alder carr. The alder trees

Table 2
Pollen influx values for 9 traps in the period 1998-2006. Values higher than average for at least 30% are marked in bold. Horizontal line means lack of data.

Site no	1998	1999	2000	2001	2002	2003	2004	2005	2006	average
1	--	362	173	**988**	--	**648**	512	319	--	500
2	--	483	363	**1334**	1079	**1137**	**1362**	392	424	822
3	**2294**	863	712	**1440**	1040	**1712**	1167	544	**2004**	1308
4	**3854**	675	209	**3405**	1094	**2261**	1043	--	**2049**	1824
5	--	603	106	**2211**	916	**2776**	681	290	**1882**	1183
6	**6894**	675	--	**3189**	1274	**3151**	1199	389	**3277**	2506
7	--	706	--	**1915**	1337	**1876**	628	442	**2875**	1397
8	--	589	240	--	1283	771	1335	873	**2157**	1035
9	--	1222	755	**2055**	1607	--	735	--	**4049**	1737

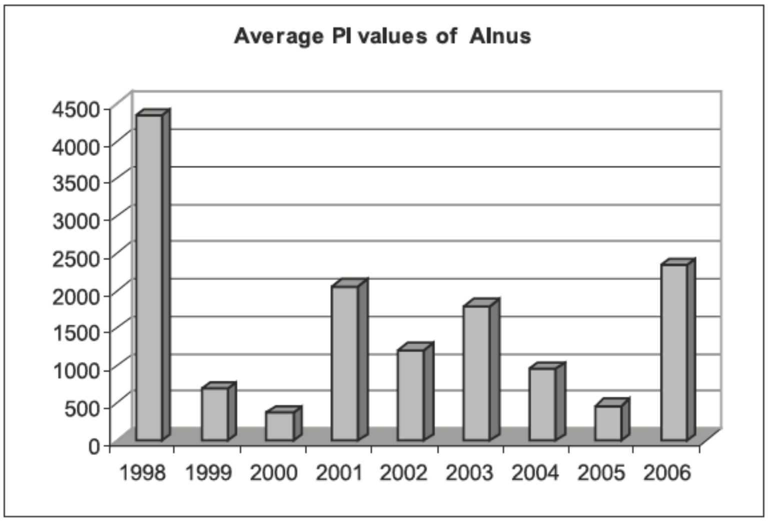

Fig. 3. Average pollen influx values for the period 1998-2006.

were at a distance of 100 m from the trap 4 and ca. 400 m from the trap 6. The third, in terms of average annual deposition, was the site no. 9 which, on the opposite, was situated far away from the nearest alder trees, i.e. 900 m (Fig. 2).

Considering the data obtained in the years of abundant *Alnus* pollen deposition (1998, 2001, 2003 and 2006), it should be stressed that, as a rule, very high PI values were observed at the same site, i.e. 6, frequently also at the site 4 and sporadically at the sites 5 and 7. The lowest values were recorded at the sites 1 and 2, but sporadically also at the sites 3 and 8.

However, deposition during the low years showed another pattern, and the highest values were calculated for the sites 9 and 3, sporadically also for the site 8.

The years 2002 and 2004 were considered average in terms of *Alnus* pollen deposition, but in 2004 the values at several sites were higher than in 2002. For example, at the sites 2 and 8 they surpassed the average values for the nine years period (Tab. 2). In 2002 the highest were the values at the site 9 (1607), while at most of the sites (2, 3, 4, 5, 6, 7 and 8) they ranged from 900 to 1300, i.e. 916 (site 5), 1040-1094 (sites 2, 3 and 4), 1274-1337 (sites 6, 7, and 8).

DISCUSSION

Considerable differences in the values of *Alnus* pollen deposition in particular years are not surprising in the present investigations in the Roztocze region. They undoubtedly result from the diverse pollen production conditioned by many factors. Several years' monitoring of pollen deposition in Cracow by means of gravimetric method indicated that annual pollen sums of *Alnus* fluctuated between 359 and 1749 (Szczepanek, 2006). Peak and low years were recorded also in two cities, i.e. Lublin and Rzeszów, located in the regions adjoining the Roztocze from the north and the south, in which aerobiologic monitoring was conducted by means of volumetric method. The comparison of annual pollen sums recorded in Lublin, Rzeszów and in the Roztocze reveals rather great conformity in the occurrence of years with high and low pollen production of this taxon (Kasprzyk, 2006; Pidek et al. 2006; Weryszko-Chmielewska and Piotrowska, 2006).

Although as a rule the peak years were followed by low or average-deposition ones in the Roztocze, it should be stressed that biannual rhythm of abundant deposition of alder pollen did not unambiguously appear in the analysed period (1998-2006). Its occurrence was discussed among others by Spanish aerobiologists (Rodriguez-Rajo et al. 2004) who suggested that some taxa flowering in winter, such as alder, reveal approximately biannual rhythm of abundant pollen production, though sometimes a year of abundant production of *Alnus* pollen is preceded by two years of low production (Aira et al. 1998).

Analysis of pollen influx in particular sites indicated that the deposition of alder pollen reached the highest values several times at the sites 4 and 6 (mostly during the peak years) and at the sites 3 and 9 (mostly during the low years). The first site is situated close to the association of *Ribeso nigri-Alnetum*, i.e. at a distance of 100 m. Therefore, in this case the proximity of alder carr might be the main factor influencing the PI. At the sites 3, 6 and 9 (situated at a distance of 400-900m from the alder communities), we should search for other explanation of high PI values. Sporadically, the highest PI values occurred also at the sites 5, 7 and 8 where the distance from the nearest *Alnus* communities ranged from 200 to 500 m.

Surprisingly, only twice the highest PI was recorded at the site 2 where the nearest alder trees grow very close to the trap (40 m).

Thus, the relationship between the value of *Alnus* pollen deposition and the proportion of alder in vegetation communities surrounding the pollen trap seems to be rather weak. Alder pollen influx probably represents local trees to a low degree, and it depends largely on regional vegetation. *Alnus* pollen comes mostly from large patches of alder communities growing in the Wieprz River valley. It seems that transport from the valley environs can be the most important factor controlling the spread of alder pollen. This can be favoured by strong winds occurring mostly in colder seasons of the year (Kaszewski et al. 2002). Pollen grains must be transported upslope, as the sites 6, 8, and 9 occur in the highest positions over the valley, i.e. several dozen metres above the upper terrace of the Wieprz River. Both the surrounding vegetation and the distance from alder communities are different in the case of each mentioned site.

Landscape openness certainly favours the spread of pollen. Such situation occurs in the instance of the sites 6 and 7, though pollen reaching the site 7 has to clear a small obstacle of a pine-birch tree patch. However, even the occurrence of beech forest in close (several metres) or more distant (100 m) vicinity of the trap does not seem to be a significant obstacle for penetration of alder pollen. In the period of alder flowering, beech trees are still leafless, so winds of different directions can transport masses of alder pollen to different places. That is why the highest values of PI were recorded in particular years at different sites. The lowest values are usually found in the site 1 that is situated not far from the alder communities, but in a small clearing within dense fir forest which can stop most of penetrating alder pollen. Probably for the same reason, very low deposition was observed at the site 2 in the years 1999, 2001, 2002 and 2006. The importance of long-distance transport concerning plants flowering early in spring was also confirmed by observations from different regions in Poland (Kasprzyk et al. 2004) as well as from other countries where alder pollen was found over 200 km away from its source area (Suszka, 1980).

Pollen grain of alder is much smaller than the grains of coniferous trees, and the difference in fall speed is also considerable. The comparison of pollen productivity estimates after Broström (2002) for *Alnus* (4.2), *Betula* (8.9), and *Pinus* (5.7) shows that alder trees are almost as efficient producers of pollen as pine trees. These values were used in modelling of source areas of pollen (Sugita et al. 1999) and stand in agreement with Andersen's (1970) investigations in Danish forests. The comparison of fall speeds of pollen grains of these three taxa (Eisenhut, 1961), which are for alder – 0.021, birch – 0.024, and pine – 0.031, also shows that alder pollen can be long-distance transported. These distances can be comparable to those at which pine and birch pollen is transported on a large scale. The preliminary estimation of a source area of pine pollen in the Roztocze region indicates that a considerable amount of pollen comes from the areas over 30 km away from pollen traps (Poska and Pidek, 2007). Therefore, it is not surprising that the highest values of alder pollen deposition are recorded not always in the same traps, and not always in traps situated closest to alder trees. Such incidental factors as wind direction, air currents, and precipitation have stronger influence on alder pollen deposition. Analysis of meteorological factors influencing *Alnus* pollen production and dispersal can shed light on the solution of this particular problem.

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Dziewięcioletnie pomiary opadu pyłku *Alnus* w rejonie Roztocza (Polska SE) na tle danych dotyczących roślinności

Streszczenie

Depozycję pyłku olszy mierzono za pomocą dziewięciu zmodyfikowanych pułapek Taubera umieszczonych na poziomie gruntu w zróżnicowanych zbiorowiskach roślinnych zgodnie z regułami stosowanymi przez Pollen Monitoring Programme (http://pmp.oulu.fi). Aktualna seria danych obejmuje lata 1998-2006. Badany obszar zlokalizowany jest na Roztoczu Środkowym w okolicach wsi Guciów w strefie ochronnej Roztoczańskiego Parku Narodowego. Podczas dziewięciu lat prowadzenia monitoringu odnotowano duże różnice w wartościach depozycji pyłku *Alnus* w poszczególnych latach. Wśród nich zaobserwowano lata o bardzo wysokim wskaźniku depozycji (1998, 2001, 2003, 2006), co związane jest ze zwiększoną produkcją pyłku *Alnus*. Zjawisko to odzwierciedla się zwykle na wielu stanowiskach, ale związek depozycji pyłku z udziałem olszy w składzie roślinności wydaje się raczej słaby. Średnia roczna wartość rocznej depozycji pyłku *Alnus* obliczona dla całego regionu wynosi około 1370 ziarn×cm^{-2}. Na stanowiskach znajdujących się w otwartym krajobrazie wartości pollen influx wahały się w analizowanym okresie od 442 (w 2005 roku) do 6894 (w 1998 roku). Wydaje się, że inne czynniki niż procentowy udział olszy w roślinności kontrolują depozycję pyłku *Alnus*. W przyszłych badaniach należałoby wziąć pod uwagę wpływ dalekiego transportu pyłku oraz czynniki meteorologiczne takie jak m.in. prędkość i kierunek wiatru.