Studia Quaternaria, vol. 20: 73–82.

PALAEOECOLOGY OF BASINS OF ORGANIC SEDIMENT ACCUMULATION IN THE RESERVE DURY

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Abstract

The Reserve Dury, Tuchola Pinewoods, Poland, includes five depressions with no outflow filled up with biogenic sediments. They undergo terrestrialization processes to a high degree. In four of the basins there are still some open water areas surrounded by floating mire with raised and transitional bog plants. For the needs of protection service officers some palynological and geological research were carried out. All the geological cores were described in detail following the Troels-Smith system. The deepest core Dury I was selected for pollen analysis. Ten Local Pollen Assemblage Zones (L PAZ) show the history of regional and local plant communities. On the basis of two air photographs, modern dynamics of floating mire in four basins were evaluated. The results allow us to correlate the geological layers, to describe the Late Glacial and Holocene succession of plant cover at Dury I site, and to show the stages of filling-in of basins with lacustrine sediments and peat.

Key words: floating mire, pollen analysis, lacustrine sediments, shoreline changes, postglacial and Holocene succession

Manuscript received 10.07.2003, accepted 12.11.2003

INTRODUCTION

The area of "Reserve Dury" is located in the outwash-plain in the Tuchola Pinewoods region, Poland (Kowalewski 2002). In the network of protected areas, it is a part of the Wdecki Landscape Park (Fig. 1A). Water and mire plants are the main reason for the protection by law of the Reserve. The Reserve includes five depressions without run-off filled up with biogenic sediments. Their total area is 12.9 ha (Fig. 1B). They undergo terrestrialization processes to a high degree, but in four of the basins there are still some open water areas, surrounded by floating mire with raised and transitional bog plants. The floating mire consists mainly of bottle-sedge swamp *Sphagno-Caricetum rostratae*, rarely bog-sedge hollow *Caricetum limosae* and white beak-sedge community *Rhynchosporetum albae*. *Sphagnum* red hummocks *Sphagnetum magellanici* occur farther from the shoreline. These communities are surrounded by bog pine woods *Vaccinio uliginosi-Pinetum* (Boiński 1996). One of the basins is completely overgrown.

The subject of interest of the protection service officers was the nature and timing of hydroseral succcession of mire-lake ecosystem. They needed to prepare a protection plan for the Reserve, so a general geological investigation of the basins was carried out. Samples for pollen analysis were taken from one of the geological cores (Dury I). A pollen diagram allows us to describe the regional and local vegetation history.

The subject of this article is the description of the Late Glacial and Holocene succession of plant communities at the Dury I site, correlation of sediment layers and stages of filling in of the basins with lacustrine sediments and peat.

MATERIALS AND METHODS

General, stratigraphic-lithological research was done in all the five basins of organic sediment accumulation in the Reserve Dury. In every basin one core was taken from the floating mire area, except Dury III, which is filled up with sediments so the core was taken in the central part of the basin (Fig. 1B). The cores were described following the Troels-Smith system (1955), which is characterized also by Tobolski (1995, 2000). The description was done in the field and only a few, single samples were taken for laboratory identification. The longest core (9.80 m) from Dury I site was selected for palynological research.

Palynological samples of 1 cm^3, taken at every 10 cm were prepared in a standard way for microscopic analysis (Berglund, Ralska-Jasiewiczowa 1986). Peat samples were boiled in 10% KOH, purified with acetolysis and then mounted in glycerine. Microscopic slides were examined under 400x magnification and counted to at least thousand of pollen grains of trees and shrubs with all the accompanying sporomorphs and *Pediastrum*. Pollen data were processed with the programme Tilia. The pollen diagram constructed with Tilia-graph (sum AP+NAP=100%) shows trees and shrubs as AP (Arboreal Pollen) and herbs (excluding aquatic and wetland plants) as NAP (Non Arboreal Pollen). Only taxa used in the discussion are shown.

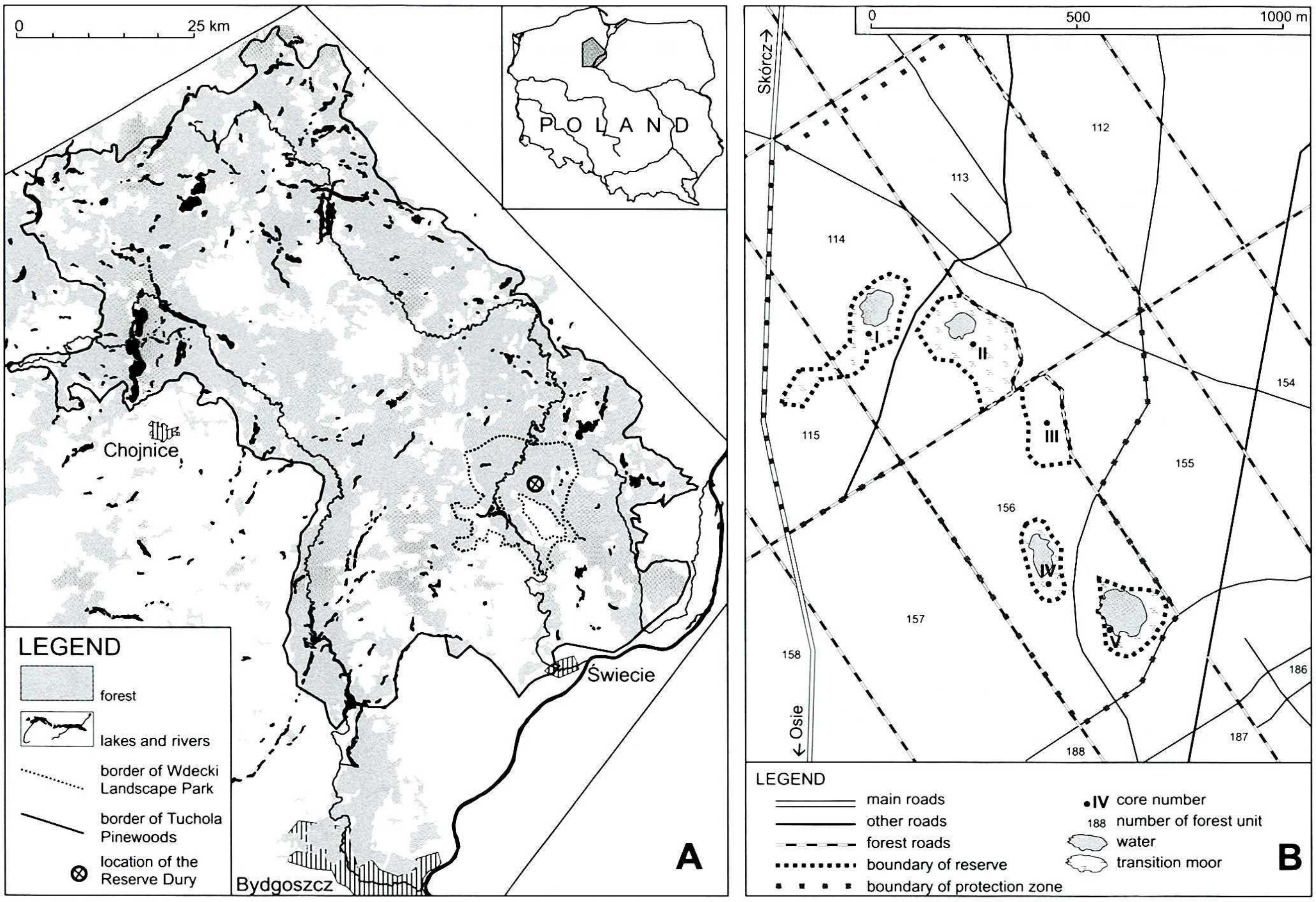

Fig. 1. Location of a study site (A) and location of geological and palynological cores in organic sediments accumulation basins in Dury Reserve (B).

RESULTS

Lithology

The lowest organogenic layer in all the basins is a thin layer of highly decomposed, organic material mixed with a large amount of sand (mostly it is described as Sh2Gmin2), which overlays a mineral base (Fig. 2). Strongly compacted peat is the main element of this layer.

Accumulation process was the most differentiated in core IV. On top of the mixed layer, gyttja with *Bryales* and silts was found. This was overlain by 21 cm of sand without clear traces of organic sedimentation (Gmin4). The conditions for accumulation of lake sediments were gradually established, which is confirmed by the overlying layer of gyttja containing still some sand. The sedimentation of this layer took place from the beginning in shallow water, as is shown by a 2 cm thick moss layer of *Drepanocladus*. Only then a 1 m layer of gyttja was accumulated. The higher variety of sediments in core IV (and V as well) was probably caused by the location of these cores closer to the margins of the basin, where inwash of slope deposits played a more important role.

In the other cores (Dury I, II and III) gyttja has been accumulated directly on the mixed layer. Its thickness ranges from 66–212 cm. Moss remains were found in the gyttja. *Calliergon* sp. remnants are the main element in 57 cm of gyttja in Dury I (6.27–6.84 cm) and 12 cm of gyttja in Dury III (6.22–6.34 cm). This gyttja changes upwards. The proportion of the herbal element (*turfa herbacea* Th) increases at first. Then the proportion of moss increases and *turfa bryophytica* (Tb) appears in which *Sphagnum* sp. remains dominant. Moss dominates in the uppermost part of the cores. In cores IV and V the moss layer has no other components (Tb4). In cores I and III, it contains some herbal remains (Th), mainly *Eriophorum* roots.

A very low degree of decomposition is observed in all the sediments except the deepest, mixed layer of the Late Glacial age. According to the Troels-Smith system this is humo 0–1, sometimes 2 in a 5-degree scale. The low decomposition indicates a permanently high water level during the deposition. The peat contains a lot of water as well (*siccitas* 0–1, seldom 2). It is neither laminated (*stratificatio* 0), nor elastic (*elasticitas* 0, seldom 1). Complete description of the cores, following the Troels-Smith system, is shown in Table 1.

Pollen analysis

The pollen diagram of core Dury I is divided into ten local pollen assemblage zones on the basis of trees and NAP curves (L PAZ) (Fig. 3). They show the stages of vegetation

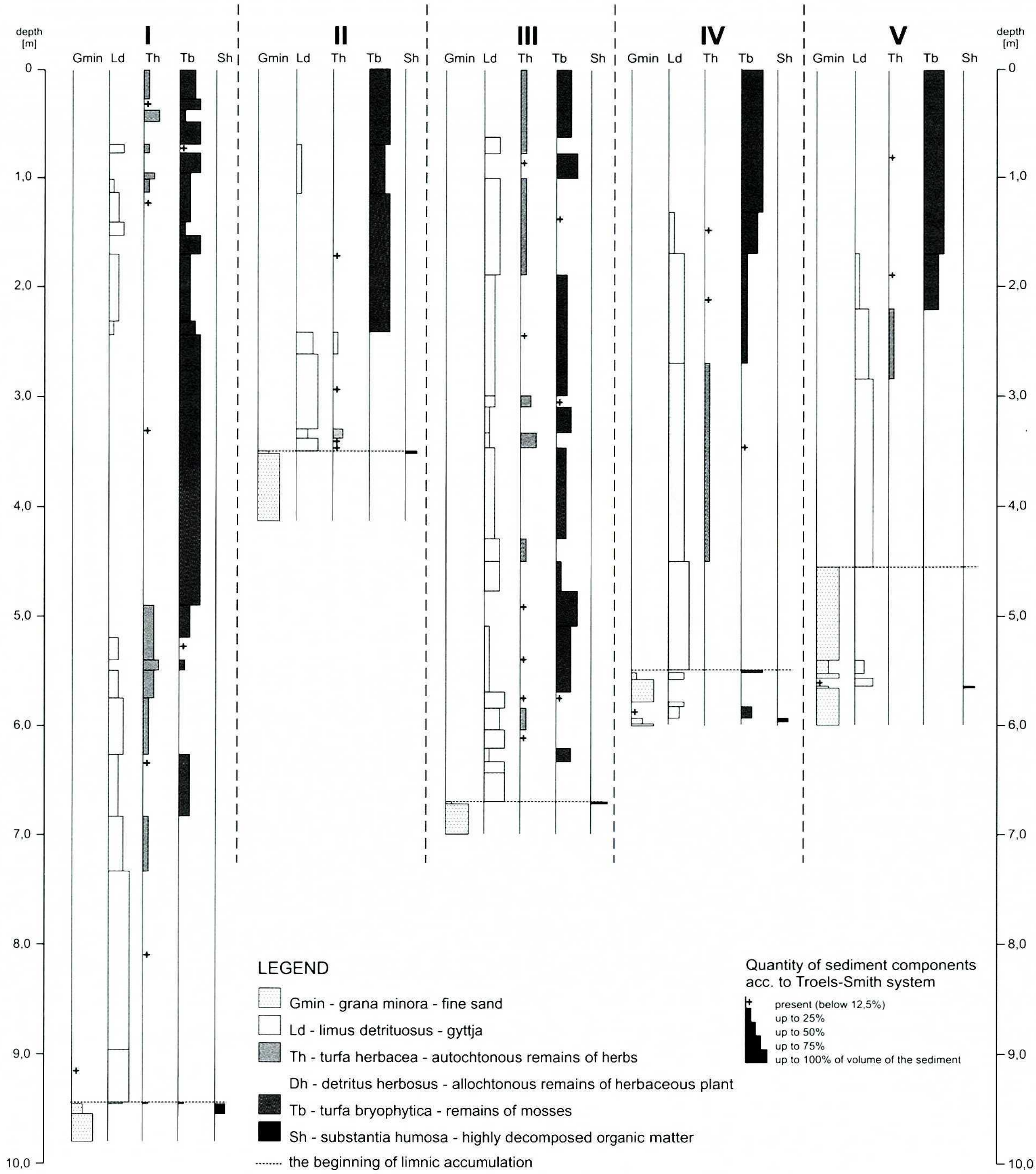

Fig. 2. Lithology of the researched cores in the Reserve Dury.

succession around the lake as well as local changes in the history of the basin (Fig. 4). To confirm the rationality of the L PAZ a Coniss dendrogram was prepared. A detailed characteristics of the pollen zones and their limits will be published (Milecka in press), so this article contains only a short, general description.

Regional succession of the forest surrounding the Reserve Dury

The bottom layer of the core Dury I shows a *Pinus-Betula* forest at the end of Alleröd. The high proportion of herbs and light demanding elements like *Juniperus* or *Artemisia* indicates low density of the forest. A more detailed interpretation however is not possible, because there is no complete representation of this period.

The last cooling of climate in the Younger Dryas caused a decrease of *Pinus* and a greater role of *Betula*. Low temperatures and the lack of forest caused development of light demanding shrub and herb communities with *Juniperus*, *Artemisia*, *Chenopodiaceae* and *Rumex acetosa/acetosella*. *Helianthemum*, an indicator of cold periods of the Late Glacial, was found as well. *Salix* occupied wet areas.

The beginning of the Holocene is marked by decreasing

Table 1

Lithology of cores in the Reserve Dury

depth [cm]	thickness [cm]	humositas	nigror	stratificatio	elasticitas	siccitas	limes	formula (record)	comments
Core I									
0.00-0.27	0.27	1	3	0	0	1	-	Tb(Sph)^{0}3Th^{0}1Dl+	root remains of *Eriophorum*, *Pinus* wood
0.27-0.38	0.11	0	2	0	0	1	0	Tb(Sph)^{0}4Th^1+	Sphagnum of sectio *Cymbifolia*
0.38-0.48	0.10	2	3	0	1	2	4	Th^{1}3Tb(Sph)^{1}1	peat with many *Eriophorum* remains
0.48-0.69	0.21	0	2	0	1	1	4	Tb(Sph)^{0}4Th^1+	Sphagnum of sectio *Cymbifolia*
0.69-0.77	0.08	-	3	0	0	1	3	Ld^{4}3Th^{2}1Tb(Sph)^2+Dl+	layer of detritous gyttja
0.77-0.95	0.18	1	2	0	0	1	3	Tb(Sph)^{1}4Dl+	
0.95-1.01	0.06	2	3	0	0	1	1	Th^{3}2Tb(Sph)^{1}2	Eriophorum remains are dominat
1.01-1.13	0.12	-	3	0	0	1	0	Tb(Sph)^{1}2Th^{2}1Ld^{3}1	gyttja mixed with numerous remains of moss and herb roots
1.13-1.41	0.28	-	3	0	0	1	0	Ld^{3}2Tb(Sph)^{2}2Th1+	
1.41-1.53	0.12	-	3	0	0	0	0	Ld^{3}3Tb(Sph)^{2}1	wet gyttja
1.53-1.70	0.17	1	2	0	0	2	4	Tb(Sph)^{0}4	
1.70-2.32	0.62	-	3	0	0	0	2	Ld^{2}2Tb(Sph)^{0}2	
2.32-2.44	0.12	-	3	0	0	2	0	Tb(Sph)^{1}3Ld^{1}1	
2.44-4.90	2.46	0	2	0	1	1	3	Tb(Sph)^{0}4Th^2+Dl+	wood and bark of *Pinus*
4.90-5.20	0.30	1	3	0	0	1	0	Tb(Sph)^{1}2Th^{3}2Tl+	rhizome and roots of *Vaccinium*, seeds of *Menyanthes*
5.20-5.40	0.20	-	3	0	0	1	2	Ld^{1}2Th^{2}2Tb(Sph)^2+	
5.40-5.50	0.10	1	2	0	0	1	0	Th^{2}3Tb(Sph)^{1}1	*Carex* radicels
5.50-5.75	0.25	-	3	0	0	1	0	Ld^{2}2Th^{2}2	
5.75-6.27	0.52	-	3	0	0	1	3	Ld^{2}3Th^{2}1	
6.27-6.84	0.57	-	3	0	0	1	0	Ld^{3}2Tb(Bryal)^{2}2Th^3+	*Calliergon* sp.
6.84-7.35	0.51	-	3	0	0	1	0	Ld^{3}3Th^{2}1	
7.35-8.97	1.62	-	4	0	1	2	2	Ld^{4}4Th^1+	endocarps of *Potamogeton* sp.
8.97-9.46	0.49	-	3	0	0	-	3	Ld^{2}4Ag+Gmin+	
9.46-9.47	0.01	-	3	0	0	1	0	Ld^{3}2Th^{3}1Tb(Bryal)^{2}1	
9.47-9.56	0.09	4	4	1	0	2	4	Sh2Gmin2	highly decomposed peat with a big amount of sand
9.56-9.80	0.24	-	2	0	0	2	4	Gmin4	sandy base
Core II									
0.00-0.70	0.70	0	2	0	0	1	-	Tb(Sph)^{0}4	wet moss layer
0.70-1.15	0.45	-	3	0	0	1	0	Tb(Sph)^{1}3Ld^{2}1	detritous gyttja with Sphagnum
1.15-2.40	1.25	1	2	0	0	1	0	Tb(Sph)^{1}4Th^2+Tl+	*Vaccinium*, vaginae of *Eriophorum*
2.40-2.60	0.20	-	3	0	0	1	3	Ld^{3}3Th^{3}1Dl+	remains of *Pinus*: wood, bark and needles
2.60-3.28	0.68	-	3	0	0	1	0	Ld^{3}4Th^3+Dh+	*Vaccinium* leaves
3.28-3.36	0.08	-	3	1		1	1	Ld^{3}2Th^{2}2	
3.36-3.48	0.12	-	3	0	0	1	0	Ld^{4}4Th^3+anth+	charcoals in a bottom part
3.48-3.50	0.02	4	4	0	0	2	4	Sh2Gmin2Th^3+Dl+	peat and sand
3.50-4.10	0.60	-	1	0	0	2	4	Gmin4	sandy base
Core III									
0.00-0.62	0.62	0	2	0	0	1	-	Tb(Sph)^{1}3Th^{2}1	
0.62-0.78	0.16	-	3	0	0	1	3	Ld^{3}3Th^{2}1	detritus gyttja
0.78-1.00	0.22	1	3	0	0	1	4	Tb(Sph)^{1}4Th^2+	
1.00-1.89	0.89	-	3	0	1	1	3	Ld^{3}3Th^{2}1Tb(Sph)^2+Dl+	
1.89-3.00	1.11	-	3	0	0	1	0	Ld^{3}2Tb(Sph)^{1}2Th^1+	
3.00-3.10	0.10	-	3	0	1	1	1	Ld^{3}2Th^{1}2Tb(Sph)^1+	
3.10-3.34	0.24	-	2	0	0	1	1	Tb(Sph)^{1}3Ld^{1}1	
3.34-3.47	0.13	-	3	0	0	1	2	Th^{2}3Ld^{3}1	
3.47-4.30	0.83	-	3	0	0	1	1	Ld^{3}2Tb(Sph)^{1}2	

Table 1 (continued)

Lithology of cores in the Reserve Dury

depth [cm]	thickness [cm]	humositas	nigror	stratificatio	elasticitas	siccitas	limes	formula (record)	comments
Core III									
4.30-4.51	0.21	-	3	1	0	1	2	Ld^{4}3Th^{2}1	
4.51-4.78	0.27	-	3	0	0	1	0	Ld^{4}3Tb(Sph)^{2}1	
4.78-5.10	0.32	1	2	0	1	1	3	Tb(Sph)^{1}4Th^{2}+	
5.10-5.70	0.60	-	3	0	0	1	0	Tb(Sph)^{2}3Ld^{3}1Th^{2}+	
5.70-5.85	0.15	-	3	0	0	2	4	Ld^{3}4Th^{1}+Tb(Sph)^{3}+	
5.85-6.05	0.20	-	3	0	0	1	0	Ld^{3}3Th^{1}1	
6.05-6.22	0.17	-	4	0	1	2	4	Ld^{4}4Th^{1}+	
6.22-6.34	0.12	-	3	0	0	2	4	Tb(Bryal)^{3}3Ld^{3}1	
6.34-6.45	0.11	-	3	0	1	2	0	Ld^{3}4	
6.45-6.71	0.26	-	2	0	2	2	3	Ld^{2}4Ag+	gyttja with addition of silt
6.71-6.73	0.02	4	4	0	0	2	4	Sh3Gmin1Dl+	
6.73-7.00	0.27	-	1	0	0	1	4	Gmin4	sandy base
Core IV									
0.00-1.32	1.32	0	2	0	0	1	-	Tb(Sph)^{0}4	
1.32-1.70	0.38	-	3	0	0	1	0	Tb(Sph)^{1}3Ld^{1}1+Th^{2}+	
1.70-2.70	1.00	-	3	0	0	1	0	Ld^{2}3Tb(Sph)^{1}1Th^{1}+Tl+	roots of *Vaccinium*
2.70-4.50	1.80	-	3	0	0	1	0	Ld3^{3} Th^{3}1Tb(Sph)^{1}+Tl+Dl+	seeds of *Scheuchzeria palustris*, endocarp of *Potamogeton*
4.50-5.50	1.00	-	4	0	1	2	0	Ld^{4}4	
5.50-5.52	0.02	0	2	2	0	2	4	Tb(Bryal)^{1}4	*Drepanocladus*
5.52-5.58	0.06	-	2	0	0	2	4	Ld^{2}3Gmin1	
5.58-5.79	0.21	-	1	0	0	1	1	Gmin4	
5.79-5.83	0.04	-	2	0	1	2	4	Ld^{2}3Ag1	highly compacted gyttja
5.83-5.95	0.12	-	3	0	1	2	4	Ld^{3}2. Tb(Bryal)^{2}2Gmin+	highly compacted gyttja
5.95-5.97	0.02	-	4	0	0	2	4	Sh2Gmin2Dl+	mixed organic-mineral layer
5.97-6.00	0.03	-	1	0	0	2	4	Gmin4	
Core V									
0.00-1.70	1.70	0	2	0	0	1	-	Tb(Sph)^{0}4Th^{1}+	
1.70-2.20	0.50	-	3	0	0	1	1	Tb(Sph)^{1}3Ld^{1}1Th^{1}+	
2.20-2.84	0.64	-	3	0	0	1	0	Ld^{3}3Th^{2}1Dl+	wood and bark of *Pinus*
2.84-4.55	1.71	-	3	0	0	1	4	Ld^{3}4	
4.55-5.41	0.86	-	1	0	0	1	4	Gmin4	
5.41-5.54	0.13	-	2	0	0	2	4	Gmin2Ld^{2}2	
5.54-5.57	0.03	-	2	0	0	2	4	Gmin4	
5.57-5.65	0.08	-	3	1	1	2	4	Ld^{3}4Gmin+Ag+	highly compacted gyttja, slate structure
5.65-5.67	0.02	-	4	0	0	3	4	Sh2Gmin2	mixed organic-mineral layer (highly decomposed peat is possible)
5.67-6.0	0.33	-	1	0	0	2	4	Gmin4	

proportion of open plant communities and development of forest. At first *Betula* was the most important component, then as a light demanding tree, it had to decrease and *Pinus* took over. Birch was still present, but under an increasingly dense canopy its development was hampered and it became restricted to the margins of forest and clearings.

Immigration and spread of mesophilous species is reflected in the Boreal Period (9000 – 8000 ^{14}C years BP). It caused a rapid decrease of pine dominance. Hazel was the first deciduous immigrant. Its abundance preceded the development of mixed, deciduous forest during the climatic optimum. Then, a growing importance of *Quercus*, *Ulmus*, *Tilia and Fraxinus* caused almost complete disappearance of *Betula* and rapid decrease of *Pinus* at the beginning of the Atlantic Period, about 8000 ^{14}C years BP.

The elm decline, ca. 5000 ^{14}C years BP was the next stage of forest succession. It resulted in an increasing number of *Quercus* and *Corylus* tree stands. The presence of climatic indicators like *Hedera* and *Viscum* confirms still good climatic conditions and dominance of mixed, deciduous forest in the older part of the Subboreal Period. *Carpinus betulus* was the next element of the forest. It appeared *ca.* 4000 ^{14}C years BP as the "late immigrant" together with *Fagus sylvatica*, which is of less importance in Tuchola Pinewoods.

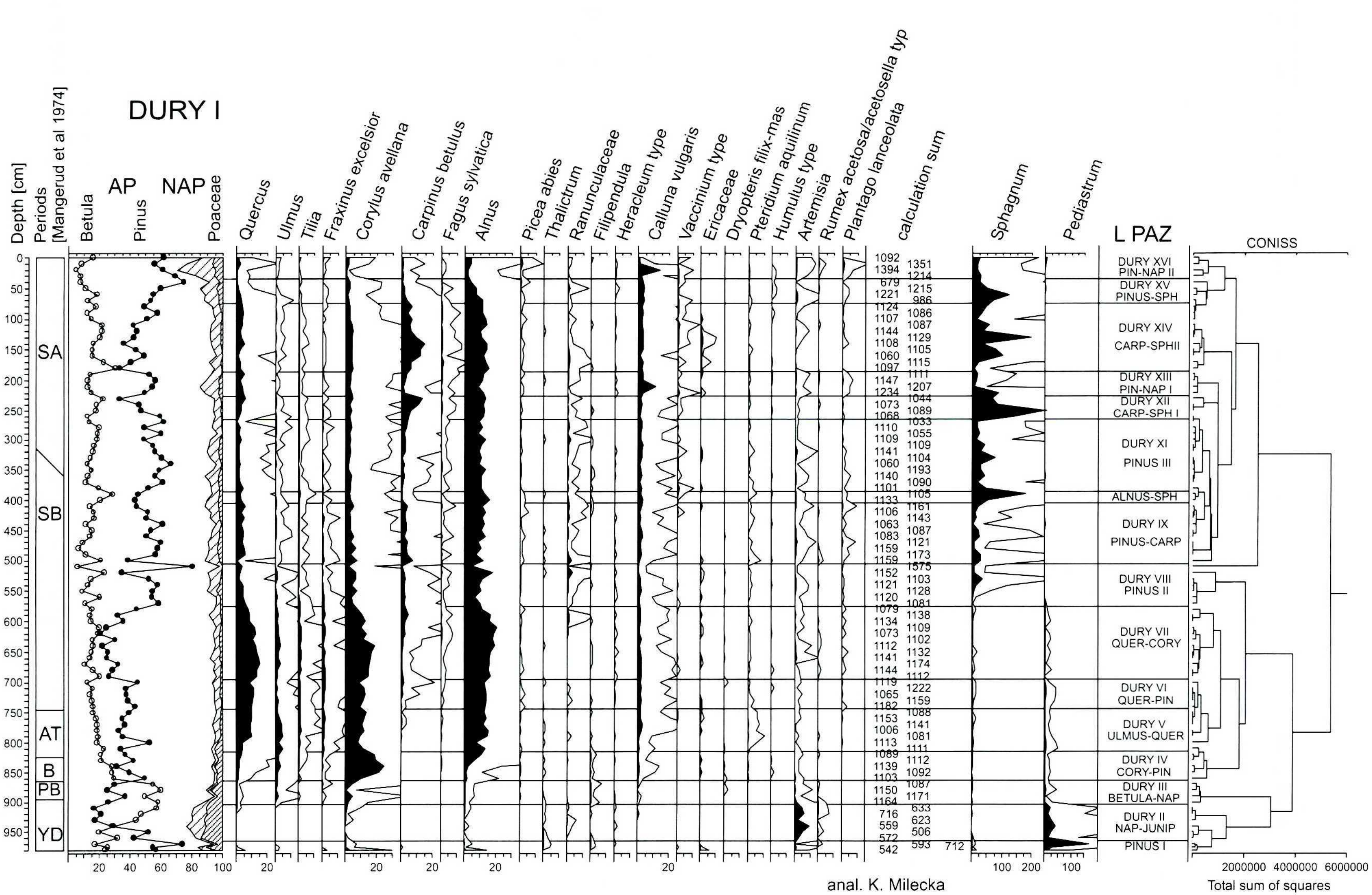

Fig. 3. Percentage, pollen diagram of Dury I with selected taxa, L PAZ and chronostratigraphy after Mangerud et al. (1974).

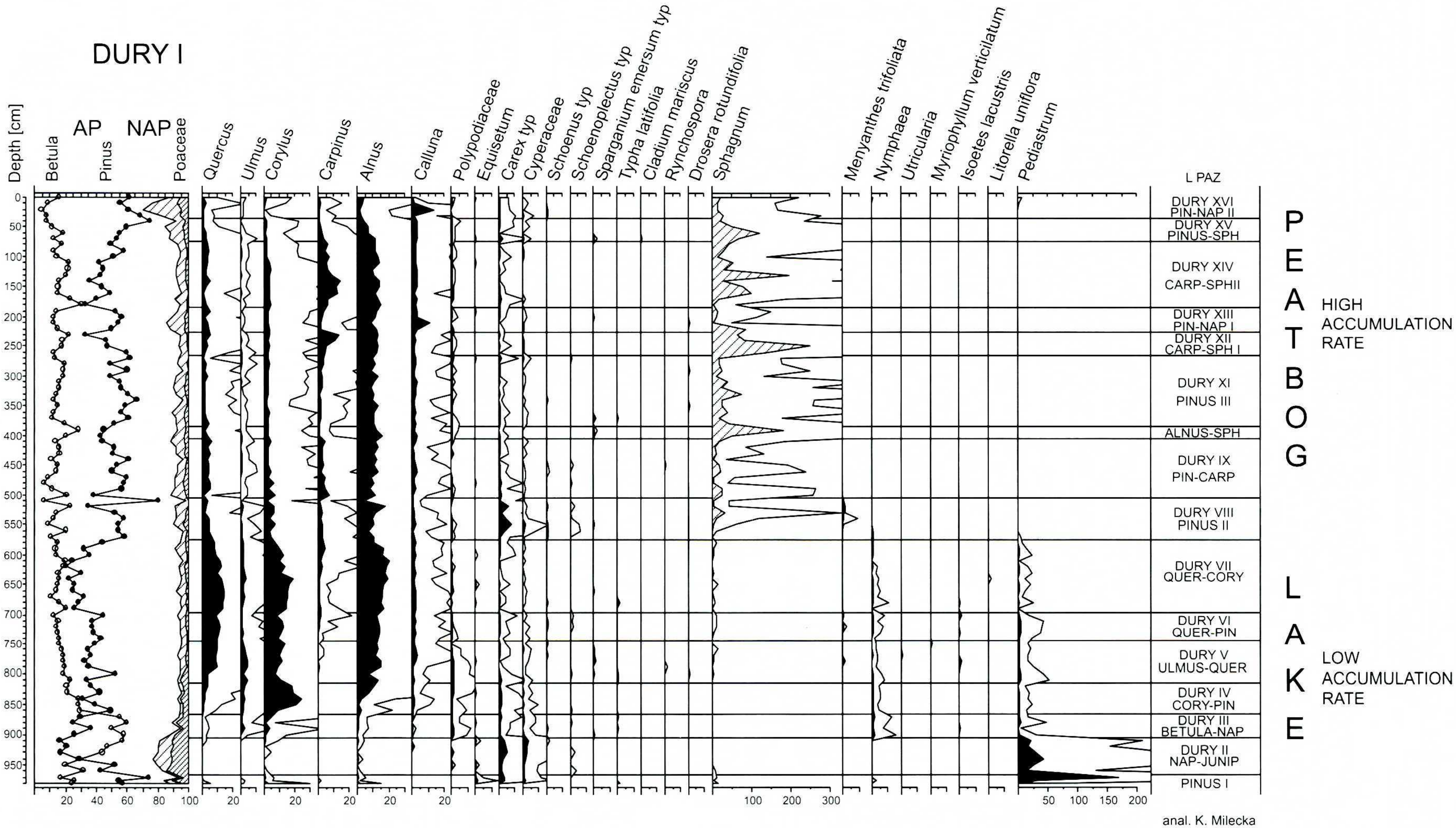

Fig. 4. Percentage, pollen diagram of Dury I with selected local taxa showing the stages of lake and mire succession.

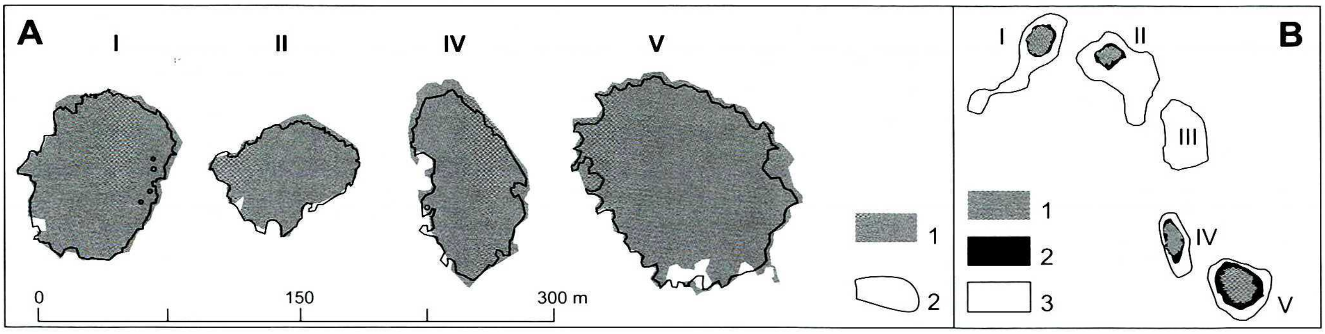

Fig. 5. Dynamics of the floating mire spread over lakes in the Reserve Dury in 1951, 1996 and present state. A: 1 – open water area according to air photograph from 1951; 2 – open water area according to air photograph from 1996; B: Present state (2001) 1 – water; 2 – floating mire; 3 – boundary of mires.

Such forest is the most important plant community in the area surrounding the Dury site up to the Middle Ages.

The last few centuries differ from the previous periods by: 1. Increasing area of the open plant communities; 2. Decreasing proportion of deciduous trees; 3. Increasing pine in the forest. Human activity caused changes in the surrounding plant communities and development of large areas of coniferous forest with dominant *Pinus sylvestris*.

Modern dynamics of floating mire on the basis of aerial photographs

The dynamics of horizontal growth of the floating mire across lakes in the Dury Reserve was studied on the basis of two air photographs from 1951 and 1996 (Fig. 5, Table 2). The process of spread of the floating mire dominated in some areas, its range did not change in other areas and exceptionally it diminished. The largest spread during 45 years reached 15 m, but apart from this single case it was not greater than 10 m. During the analysed time the loss of open water surface was 6–16% (average 10%). If this trend is similar in future, the overgrowing will be completed in 300–750 years (average for the 4 lakes is 450 years).

DISCUSSION

Cores of lacustrine sediments, especially those from large lakes, document first of all regional changes in plant succession. The cores from mire basins show us the history of the mire itself. Plants growing at the mire are the source of increasing mass (volume) of the peat. In the accumulated layers, besides the remains of decomposed mire plants there are also pollen grains and spores which provide information about the mire and its nearest neighbouring and regional communities as well. At the Dury I site the *Sphagnum* curve is the most important to show the "local" character, because its changing content of spores confirms the history of the lake and mire and fluctuations of the water level.

General information concerning succession of the basin is provided by the curves of herbs of local communities, *i.e.* aquatics and telmatophytes, and macroscopic components of the sediment, which often can be identified already in the field. Analysis of trends in the curves of pollen grains and spores together with the macroscopic elements allows us to establish the timing of lake and mire functioning. In the pollen diagram, the deeper part reflecting lake sedimentation and the upper part corresponding to peat accumulation, can be clearly distinguished.

SUCCESSION OF THE MIRE-LAKE ECOSYSTEM DURY

The first accumulated layer of the peat indicates that "[....] the initial accumulation of biogenic sediments took place at the mineral base as a result of its paludification" (Karcz, Kowalewski, Schubert, unpublished). It shows its beginning as a result of melting out of dead ice blocks. The originally shallow basin of Dury I became distinctly deeper,

Table 2

Dynamics of open water area in the lakes of the Reserve Dury. Numbers of the lakes follow Fig. 5. The areas of lakes and lengths of shorelines were derived from the air photographs taken in 1951 and 1966

Lake	Area in 1951 (m^2)	Area in 1996 (m^2)	Length shoreline in 1951 (m)	Length shoreline in 1996 (m)	Area ratio 1996/1951 (%)	Rate of floating mire spread 1996-1951 (%)	Predicted time of complete lake overgrowing (years)
I	5376	4913	308	364	91.39	8.61	533
II	3026	2848	249	271	94.12	5.88	765
III	0	0	0	0	-	-	
IV	4477	3779	337	346	84.41	15.59	289
V	9366	8490	533	506	90.65	9.35	481
TOTAL	**22245**	**20030**	**1427**	**1487**	**90.04**	**9.96**	**452**

allowing gyttja sedimentation and the development of aquatic fauna and flora.

As deep as in the lowest layer of the sediments (L PAZ Dury I) numerous planctonic algae of *Pediastrum* were found as well as single pollen grains of *Nymphaea* and *Potamogeton*. It shows that communities of floating and submerged aquatics existed already at that time. Components of the bottom pollen spectra indicate that they were accumulated during the warm period of the Late Glacial, probably at the end of the Alleröd. This proves the pre-Alleröd age of melting of dead ice blocks. The mean annual temperature at that time allowed for development of sensitive aquatic communities with *Nymphaea* and *Potamogeton* (cf. *e.g.* Ralska-Jasiewiczowa 1991, Ralska-Jasiewiczowa *et al.* 1998). Most of these species (*Nymphaea* and species of *Potamogeton*) live at medium (T 3-4) temperature conditions (Zarzycki *et al.* 2002). The presence of *Typha latyfolia* tetrad indicates mean July temperature of about 15°C (Wasylikowa 1964).

The development of the lake flora was interrupted by cooling of the climate at the beginning of the Younger Dryas (L PAZ Dury II). No pollen grains of aquatic macrophytes were found. The lake existence is proved by relatively high number of *Pediastrum* algae. Presence of *Pediastrum angulosum* confirms a low trophy of the lake. It usually appears in cool climatic periods and in lakes poor in nutrients (Jankowska, Komarek 2000 and personal observations of the co-author).

Climatic warming at the beginning of the Holocene, *ca.* 10000 ^{14}C years BP resulted in a relatively quick and clear change in the lake flora (L PAZ Dury III – Dury VII). Once again aquatic macrophytes appeared: *Nymphaea*, *Potamogeton* and probably bur reed (pollen grains of *Sparganium emersum* type). In the oldest part of the Holocene single spores of *Isoëtes lacustris* were found, which is a component of oligotrophic lake plant communities. Some spores of *Sphagnum* came from the small mires developing along the shore of the lake. They coexisted with typical telmatophytes like sedges (*Carex* sp.), ferns (Polypodiaceae, *Thelypteris palustris*) and reed-mace (*Typha latifolia*). In the plankton flora there were some changes during the warmer stage of development of the lake in the Preboreal, Boreal and Atlantic and during its final overgrowing in the Subboreal. At the beginning *Pediastrum boryanum* var. *boryanum* and var. *brevicorne* had their maxima. Then, their frequencies decreased and *Pediastrum angulosum* was the most important taxon, indicating lowering of lake trophy again.

At 575 cm depth a change of the accumulation process occurred and peat was formed on the surface of gyttja. A growing volume of the herb component (Ld2, Th2) is observed in the layer 550–575 cm (site Dury I). The percentage pollen diagram shows the beginning of L PAZ Dury VIII at this level, which we can correlate with the younger phase of the Subboreal. Disappearance of *Nymphaea*, absence of *Pediastrum* algae, beginning of *Menyanthes* and local culmination of Cyperaceae pollen are the most characteristic features of this L PAZ. Between 540–550 cm, the herbal component (like radicels of Cyperaceous plants) is dominant. There are also some *Sphagnum* remains (Th3Tb(Sph)1). Presence of turfa elements (Cyperaceae radicels and Ericaceae roots) indicates sedentation as the process of sediment accumulation. This means that the exact location of the core Dury I was not any more a lake but a floating mire has formed or the lake was filled up.

Nymphaea usually exists in lakes down to 1.5 m water depth. It takes part in filling up of lakes and it could be an element of reed-swamp and mire communities, taking a landform of the plant (Podbielkowski, Tomaszewicz 1996). In the diagram Dury I, pollen grains of *Nymphaea* disappeared at the same time as the open water area did. So the plant was present untill the overgrowing of the lake stage as the last aquatic in the basin. In the overlying layers of the transitional stage there were almost no *Pediastrum* algae. Some single coenobia could be the result of exceptionally high water levels covering the mire with water. However, the development of micro-flora was rather weak, probably because of a low pH in the mire.

A relatively high proportion of Cyperaceous pollen (*Carex* type, Cyperaceae) and *Sphagnum* indicates spreading of wet plant communities. *Menyanthes trifoliata*, an element of overgrowing basins, appeared. Its seeds were found between 490 and 520 cm, where *Sphagnum* and herbs are the main elements of the sediments (Tb(Sph)2Th2). The high water level on the mire made an intensive development of *Sphagnum* communities possible. Later they became the most important community on the mire, while the importance of the Cyperaceous plants decreased and *Menyanthes trifoliata* was not found in the overlying layers as well.

Wetland plant communities show some variability during the youngest phase of basin existence. Curves of *Sphagnum* and Cyperaceae fluctuate while the fern spores content (Polypodiaceae) seems to be relatively stable. The reason was in changes of hydrological conditions. Raising and falling water levels caused spread and decrease of the area of reed-swamp plants. Covering the *Sphagnum* stands with water eliminated some species. The survived ones were well adopted for living under the water. This process is reflected in the Dury sediment cores by numerous layers of peat with gyttja elements. This type of sediment occurs at different depths in different cores, the largest in Dury I (471 cm, gyttja layers of depths of 74 cm, 52 cm and 8 cm). This part is also a transition layer between the lake sedimentation and terrestrial accumulation and it seemed to be a feature of filling up those basins where a floating mire with transitional bog plants exist today. The similar stages of the succession were found in the mire at Jelenia Wyspa in the Reserve "Bagna nad Stążką" where open water area has already disappeared (Kowalewski, Schubert, Tobolski 2002).

The bottom layers of the mire contain only a few pollen grains of Cyperaceous, ferns and *Sphagnum*. The rare pollen types like *Drosera* are lacking, though they were noticed earlier. *Sphagnum* section *Cymbifolia* and macroremains of *Eriophorum* are dominant elements of the sediments (Karcz, Kowalewski, Schubert unpublished).

The change of the process of sediments accumulation and replacement of the lake by the mire caused a big change in the accumulation rate. The older, lacustrine part (400 cm in Dury I) represents the Late Glacial and Holocene up the older part of the Subboreal Period (together *ca.* 7000 ^{14}C years). The younger, terrestrial part (575 cm) has been accumulated during the Subboreal and the Subatlantic (*ca.* 4000 ^{14}C years)

At present the basins are still overgrowing. The dynamics of the process is not high but in the light of air photographs we can predict a complete overgrowing in the coming hundreds of years (Table 2). However it must be stressed, that the phenomenon of spreading of floating mires is poorly investigated. A description of the dynamics of this process in the recent past would need a more detailed lithological research based on a precise grid of cores, macrofossil analysis and a good, absolute chronology based especially on flora and fauna bioindicators. Nonetheless, we tried to evaluate this phenomenon in a longer time perspective. As mentioned above, the initial spread of the floating mire probably took place at the time of initiation of terrestrial accumulation (540 cm depth). The *Menyanthes* curve confirms that (beginning at 550 cm, and a small maximum at 560 cm) as this plant usually develops most abundantly within the margins of the mire. The process began in the older part of the Subboreal (*ca.* 4000 ^{14}C BP) and the location of the core is 10 m distant from the present margin of the mire. So the average rate of spread of floating mire is 0.25 cm/year. Modern dynamics of the floating mire is much larger and amounts on average 1–3 cm/year with a maximum up to 10 cm/year in Dury I lake (the largest 33 cm/year in Dury V lake) (Fig. 5).

Some authors referred high dynamics of such processes, especially in historical times as a result of human activity (*e.g.* Warner 1993). The question about anthropogenic influences at the Reserve area is open in the light of the presence of a drainage ditch connecting Dury I and Dury II basins. A wider comparative analysis of the process of overgrowing of lakes in the south part of Tuchola Pinewoods has been prepared recently (Kowalewski 2003).

Acknowledgements

We thank Professor Kazimierz Tobolski for supporting our work with his ideas and great knowledge about mires. We also wish to thank dr Tomasz Schubert and mgr Grzegorz Karcz for the cooperation in field work and the detailed sediment description. Careful revision of the manuscript and improving the English by dr Pim van der Knaap, prof. Tomasz Goslar and an anonymous reviewer is gratefully acknowledged.

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