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CHAPTER 36

THE LIBOŘEZY BOG PRIOR TO EXTRACTION

L. Soukupová, V. Bauer, J. Jeník, L. Klimeš, S. Kučera and K. Prach

The size and diversity of 50 mires in the Třeboň Basin Biosphere Reserve (TBBR) attract numerous paleo-ecologists interested in Postglacial development of Central European landscapes, however, the value of these ecosystems for (actuo)-ecological studies is also substantial. Five peatlands in the TBBR are dominated by old-growth stands of bog pine (*Pinus rotundata* Link), a tree of broad environmental range, yet, of exceptional tolerance to waterlogged soil (see Figure 30.1). These stands offer an opportunity to examine structural differentiation of a resistant tree population in relation to other woody plants commonly participating in Central European hydroseres.

Ecological studies of the bog pine mires in the TBBR were initiated by Ambrož (1927, 1948) and continued after World War II by Březina (1956, 1957). Palynological examination of peat deposits has been summarized in Jankovská (1980), Chapter 31. Human activities have affected these stands to different degrees: Borkovice Bog was fully extracted and only a marginal strip was preserved. Červené Blato (see Chapter 32) and Žofinka bog have been marginally influenced by preceding drainage and plantations of Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) but their bog pine stands were finally preserved by declaration of the areas as nature reserves. Široké Bog, situated on the Czech/Austrian border, remained mostly untouched and was ultimately declared a nature reserve in 1994. Until recently, Libořezy Bog had remained undisturbed by humans due to its distance from the nearest village; however, at the beginning of the 1980s this locality was licensed for extraction, drained, clear-cut and heavy machinery was used to exploit the peat.

Legislative protection for Libořezy Bog was not forthcoming, due to its unfortunate position astride the boundaries of the TBBR; only recently a smaller part of this mire has been designated Losí Blato Nature Reserve. In view of the irreversible destruction to this unique ecosystem, an opportunity arose to analyse the bog pine forest by dendrometric methods, including destructive procedures. A group of ecologists from the Institute of Botany, formerly Czechoslovak Academy of Sciences, undertook this research in summer 1983. Evaluation of some data was performed within the GAČR project 206/99/1411.

STUDY SITE AND METHODS

Libořezy Bog is situated 14 km east of Třeboň town, close to the eastern boundary of the TBBR (Figure 30.1). An extensive mire complex filled a narrow valley from north to south for about 6 km. The bedrock is mainly Proterozoic granite, covered by an extensive layer of Tertiary sands and gravel-sands. The altitude is between 460 and 470 m, mean annual precipitation is 655 mm, and mean annual air temperature is 7.5 °C. The growing season, expressed in meteorological terms, lasts for 148 days, from May 1st to September 25th.

Prior to extraction, the depth of peat deposits in the centre of the bog reached 4 m. Macroscopic layering of the peat strata was in the following sequence: the basal layers contained remnants of reed-like plants, above were mixed layers of sedges, cotton-grass, brown mosses and peat mosses. All layers were penetrated by pieces of wood from broad-leaved trees in the lower section, and coniferous by pieces in the middle to upper layers. In terms of phytosociology, the mire species in the middle to upper layers. In terms of phytosociology, the mire developed from a minerotrophic fen, through willow or alder carr, to treeless oligotrophic bogs and stands with coniferous trees – pines and Norway spruce. The age of the bottom layers is unknown, but analyses from a neighbouring mire complex (Jankovská, 1980) suggest a period close to the beginning of the Postglacial. Time of immigration of the bog pine remains unknown.

Phytosociological relevés were recorded in accordance with standard methods of the Zürich–Montpellier School (Ellenberg, 1956). Nomenclature of syntaxa is given according to Rybníček *et al.* (1984) and Moravec *et al.* (1995). Bryophytes were identified according to Pilous and Duda (1960), and nomenclature of vascular plants followed Ehrendorfer (1973).

Detailed studies in the central section of Libořezy Bog were undertaken on six experimental plots (P-1 to P-6), of 25 by 25 m. Based on the preceding measurement of peat depth, groundwater table and the phytosociological survey, each plot represented a different type of bog pine stand. In each plot, standing live and dead trees more than 5 cm in diameter at breast height (dbh) were recorded and plotted on a map by means of rectangular coordinates. Height, dbh and crown projections were measured for each tree. Basal area, density, Simpson's index of dominance (Odum, 1983) and spatial pattern R (Clark and Evans, 1954) were also assessed. In addition, a profile diagram of a belt, 5 m in width, was measured and plotted on graph paper. To evaluate radial increment and age of individual trees, tree borings were performed at breast height in all live trees thicker than 5 cm; in the description of radial increment, the 'age' refers to annual rings recorded at breast height.

RESULTS

Phytosociological identity of Libořezy Bog

Three vegetation types were distinguished along the environmental gradient of the forested section of Libořezy Bog. An inner belt adjacent to the central treeless zone, situated on the deepest peat sediment, was occupied by single-dominant

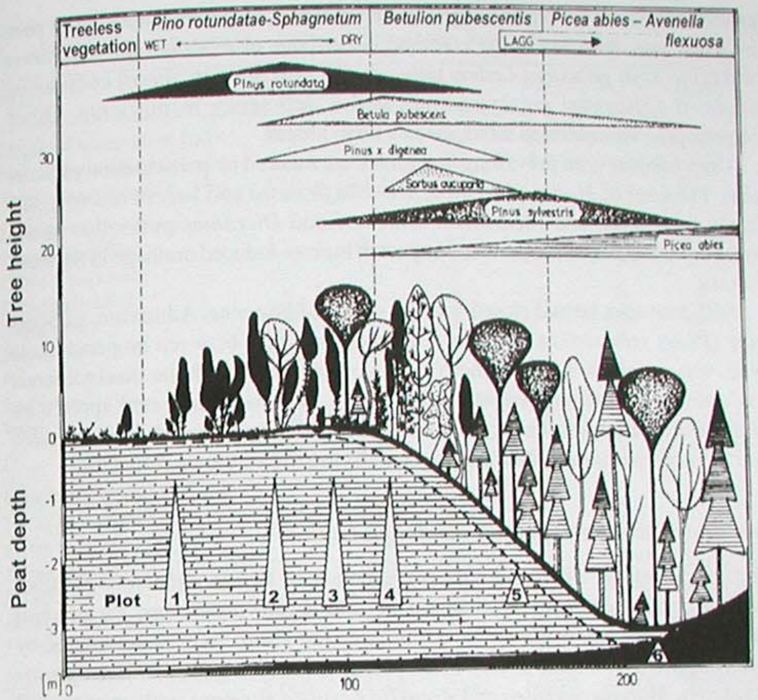

Figure 36.1 Cross section through Libořezy Bog showing the situation of plots P-1 to P-7, distribution of tree species and range of phytosociological units are described in Table 36.1

bog pine stands belonging to the *Pino rotundatae-Sphagnetum* Kästner et Flössner 1933 corr. Neuhäusl 1969, an association from oligotrophic bogs summarized within the *Oxycocco-Sphagnetea* class. The wet variety of this community on the outer bog expanse was analysed within the P-1 and P-2 plots; drier variety (P-3 and P-4) showed some transitional characters towards the *Betuletum pubescentis* Tüxen 1937, an association of the *Vaccinio-Piceetea* class, which prevailed over the marginal slopes of the bog and was well developed in P-5. The lagg zone was marked by a shallow peat layer and the proximity of mineral ground (P-6) and was covered by a Norway spruce forest with *Avenella flexuosa* in the herbaceous layer. Distribution of tree species along a transect crossing the bog is illustrated in Figure 36.1.

Bog pine woodland

The wettest sites of the *Pino rotundatae-Sphagnetum* had an open tree canopy composed of rather short and even-volume specimens of predominantly bog pine, with a few less vigorous specimens of Scots pine. Full saturation of peat by water was reflected in the common occurrence of *Eriophorum vaginatum* and *Oxycoccus palustris*; *Ledum palustre* was also present; almost continuous cover of *Sphagnum recurvum* indicated a deficiency in nutrients. Other oligotrophic vascular and moss species were absent.

Drier habitats with prevailing bog pine were marked by participation of Scots pine. Presence of *Molinia caerulea*, *Avenella flexuosa* and *Vaccinium myrtillus* in the herb layer, and *Pleurozium schreberi* and *Dicranum polysetum* in the moss layer, suggested the previous impact of human-induced drainage in adjacent forests.

Still drier sites hosted closed-canopy stands of bog pine. Admixture of Scots pine (*Pinus sylvestris*) and *Pinus* x *digenea*, a hybrid between bog and Scots pine, was apparent. A patchy herb layer corresponded with the discontinuous tree canopy. *Sphagnum magellanicum* and *S. recurvum* indicated spots with higher water saturation, but occurrence of *Vaccinium myrtillus*, *Molinia caerulea* and *Avenella flexuosa* indicated seasonal drying out of the peat surface.

Transitional woodland towards coniferous taiga

The canopy of the woodland with participation of *Betula pubescens* is rather loose. *Pinus sylvestris* is more abundant, and *Betula pubescens*, *Picea abies* and *Pinus rotundata* make up the admixture. The shrub layer is dominated by black dogwood (*Frangula alnus*). In the patchy herb layer, grasses *Calamagrostis canescens*, *Molinia caerulea* and *Avenella flexuosa* alternate with species well adapted to waterlogging, such as *Carex canescens*, *Oxycoccus palustris*, *Sphagnum recurvum* and *S. magellanicum*.

On the periphery of the bog, swampy spruce–pine taiga belonging to the *Betulion pubescentis* alliance was established. Patchy soil moisture was reflected in the interlacing of Scots pine, birch and Norway spruce. Vigorous regeneration of Norway spruce was visible in the shrub layer. Finally, the outer lagg zone of the bog was occupied by coniferous taiga with Norway spruce. The closed-canopy stand developed over a thin layer of peat drained by shallow ditches. In the shade of spruce, Scots pine was evidently suppressed, and beside *Avenella flexuosa* and *Vaccinium myrtillus* typical companions of taiga appeared: *Oxalis acetosella*, *Maianthemum bifolium* and *Sphagnum girgensohnii*.

Structure of experimental stands

Table 36.1 summarizes some important characteristics of the experimental plots and Figures 36.2 to 36.4 illustrate the vertical and horizontal structure of the pertinent stands in experimental plots P-1 to P-6. The dominance estimated by Simpson's index D_s was also related to the distribution of density. The value of D_s was lowest in P-3 where the occurrence of *Pinus rotundata* considerably overlapped other species commonly found on rather drier sites. The total basal

Table 36.1 Characteristics of tree structure in experimental plots on Libořezy Bog; E_{3a} – height of trees > 8 m, D_s – index of dominance, R – spatial pattern

PLOT	*P-1*	*P-2*	*P-3*	*P-4*	*P-5*	*P-6*
Depth of water level [m]	–0.10	–0.15	–0.20	–0.25	–0.30	–0.35
Mean peat thickness [m]	2.5	2.2	3.2	2.9	0.8	0.7
Tree canopy cover E_{3a} [%]	42.0	44.3	72.8	71.4	76.0	88.5
Density of live trees						
Pinus rotundata	132	89	20	28	8	–
Pinus x *digenea*	–	3	3	2	–	–
Pinus sylvestris	1	3	6	2	16	9
Picea abies	–	1	7	10	78	47
Betula pubescens	1	5	3	5	9	10
Frangula alnus	–	2	–	–	3	–
Sorbus aucuparia	–	–	–	1	–	–
Total	134	103	39	48	114	66
D_s	0.97	0.75	0.33	0.40	0.50	0.55
Live basal area [10^{-4}.m^2]						
Pinus rotundata	13262	10467	6120	9960	1613	–
Pinus x *digenea*	–	978	599	933	–	–
Pinus sylvestris	75	1411	5188	2026	8225	8182
Picea abies	–	31	564	2495	5510	9009
Betula pubescens	179	896	521	1259	2457	3017
Frangula alnus	–	15	–	–	40	–
Sorbus aucuparia	–	–	–	4	–	–
Total	13516	13798	12992	16677	18245	20208
R	0.64	0.82	0.99	1.08	0.88	0.96

area of the trees was lowest in the wetter part of the gradient and on deeper peat deposits, and increased gradually towards the drier and nutrient-richer plot marked by the increasing presence of Norway spruce. However, even the lowest basal area of the trees was five times higher than that of fertilized forested bogs in southern Finland (Vasander, 1982). The spatial pattern R of trees in the plots was mostly random, only in the wettest plot P-1, was it clustered. This pattern reflected the variation in surface soil moisture that is modified by hummock-and-hollow microrelief. Successful establishment of seedlings of *Pinus rotundata* apparently requires drier microhabitats. The hybrid *Pinus* x *digenea* occurs in the middle part of the soil moisture gradient in P-2, 3, and 4. These plots are situated in an intermediate position with regard to their parental species.

In the innermost bog pine woodland with the highest water level (Figure 36.2: P-1), tree density was high (0.214 m^{-2}), in spite of canopy cover of only 42%. The index of dominance D_s was high (Table 36.1) reflecting prevalence of *Pinus rotundata*. Basal area of the dominant species reached 0.0021 m^2 m^{-2}

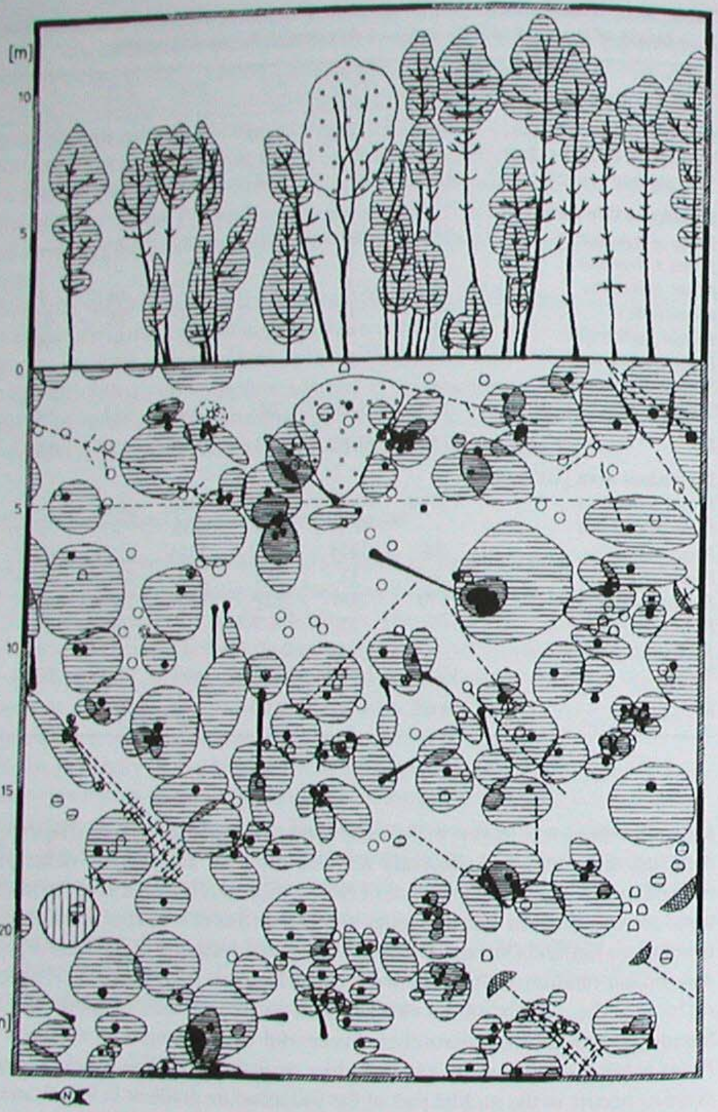

Figure 36.2 Horizontal and vertical structure in sample plot P-1 representing the less vigorous stand of the *Pino rotundatae-Sphagnetum* in the transition zone between the treeless zone and forested zone of Libořezy Bog; for explanation of symbols, see Figure 36.3

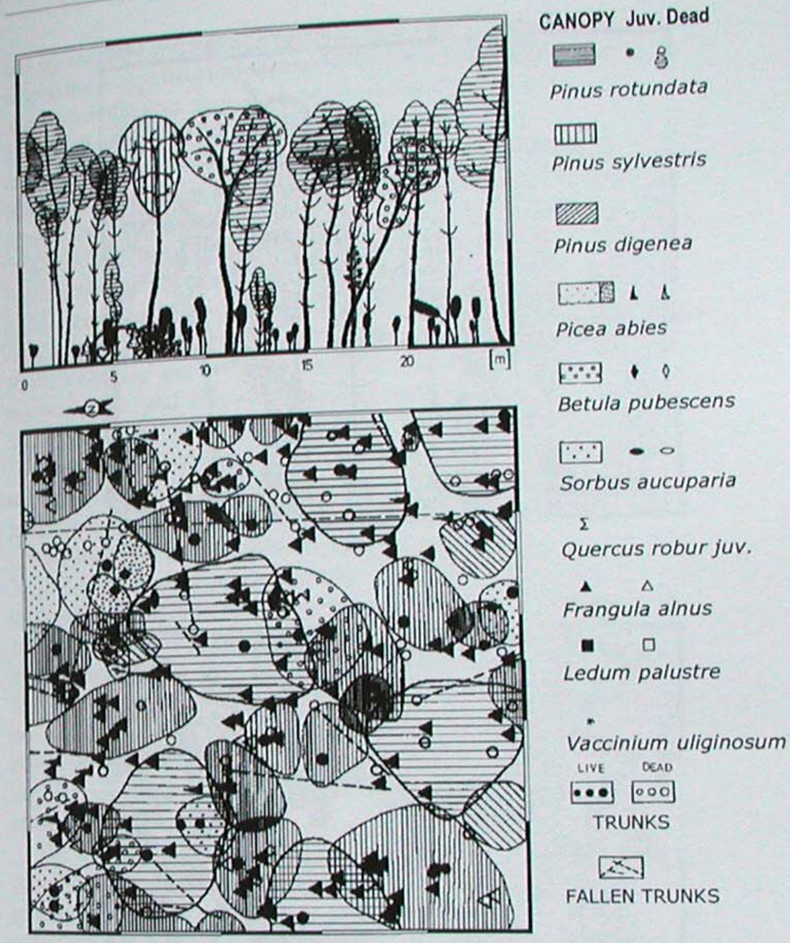

Figure 36.3 Horizontal and vertical structure in sample plot P-3 representing vigorous stands of *Pino rotundatae-Sphagnetum* in the transition zone between birch-rich woodland in Libořezy Bog

Figure 36.4 Horizontal and vertical structure in sample plot P-6 representing tall spruce-rich forest in the lagg zone of Libořezy Bog. For symbols see Figure 36.3

and was highest among the examined plots, but basal area per tree was lowest among the examined plots (Table 36.1). Average height of the canopy was 8 m and no trees higher than 12 m were noted. Crowns of the dominant species developed freely and did not contact neighbouring trees. The trunks occurred in clusters and showed sabre-like curving at the base – a response to instability in peaty ground; crowns spread irregularly. Saplings of bog pine were present around the clustered trees. Both standing dead and fallen trees were common.

The lower water level in the bog pine woodland changed the growth performance of the trees (P-2). Though the increase in crown cover and total basal area is negligible (44.3% and 0.0022 $m^2 m^{-2}$, respectively), the index of dominance decreased remarkably as less vigorous individuals of Scots pine, *Pinus* x *digenea* and birch were included (Table 36.1). Mean canopy height reached 12 m, and only exceptionally were trees higher than 15 m present. Suppressed trees with sabre-like trunk bases and standing dead trees were common in the lower tree layer. Numerous seedlings and saplings indicated rich regeneration of both bog pine and birch and black dogwood was concentrated in small openings.

The driest bog pine woodland on the thickest peat deposit (Figure 36.3, Table 36.1: P-3) had a high canopy cover (72.8%) with a highly undulating upper surface due to different heights of the crowns. While bog pine and birch attained 15.5 m, Scots pine reached 23 m. Suppression of the bog pine and birch by vigorously growing Scots pines was obvious. Norway spruce participated in the understorey, attaining 6 to 7 m in height. Total basal area was lowest among the examined plots (Table 36.1), however, basal area per tree was highest in *Pinus rotundata* and *P. sylvestris*. All tree species regenerated, and even seedlings of *Quercus robur* appeared. Index of dominance was lowest among the examined plots.

The transitional stand of bog pine to birch woodland (P-4) has a continuous upper tree canopy created by bog pine and conspicuous emergent trees of Scots pine and *Pinus* x *digenea*. Most of the Norway spruce and birch occur in the lower canopy. With similar total cover of the tree layer as found in P-4, this plot shows much higher basal area (1.67 m^2). Many standing dead trees of bog pine and fewer fallen trees suggest recent changes in the ecosystem.

Mixed birch–spruce forest on the bog (Table 36.1: P-5) was highly diversified. The upper storey at 10 m was formed by a closed canopy of Norway spruce, bog pine, Scots pine and birch, only emergent trees of the two latter species reached 20 m. Prevailing total basal area belonged to Scots pine although its basal area per tree was low and comparable with that in wet bog pine woodland (0.051 m^2). The main canopy consisted of a lower storey at 5 m composed of Norway spruce (with the highest density) and a few individuals of birch. In depressions with pools, trees were absent and dead fallen trees were frequent. Juvenile beech and oak appeared in the shrub layer.

Coniferous lagg forest (Figure 36.4: P-6) had the highest closed canopy at 18 m, with the tallest emergents of Scots pine and spruce reaching 27 m. Dead

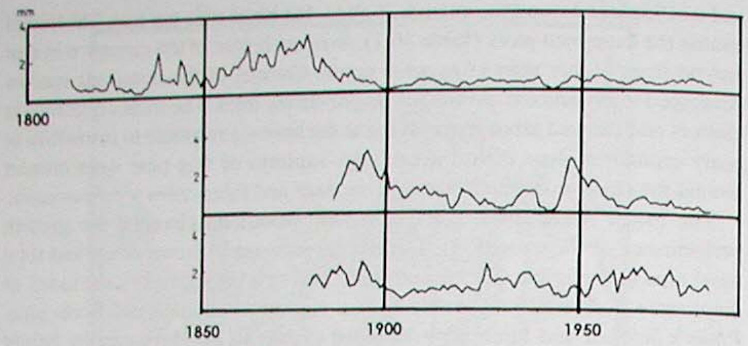

Figure 36.5 Radial increment in three selected sample trees of bog pine (*Pinus rotundata*) growing in Libořezy Bog

trees were mainly birch, suggesting its suppression by coniferous components. Total cover of crowns (88.5%) and total basal area (20.2 m^2) were highest. Basal area of Norway spruce was slightly higher than that of Scots pine (Table 36.1), while the basal area of birch was maximal among the examined plots. The basal area per tree for all species showed best growth performance. Species in the tree layer usually appeared in clusters, and shrubs and young trees were mostly found in small gaps.

Radial increment of representative sample trees

Variation in radial increment in bog pine suggests the impact of both the internal development of individual specimens (possible effect of competition and ageing) and external factors related to climate and hydrology of the peat deposits. The oldest tree of *Pinus rotundata* (171 years) was found on the wettest plot of the *Pino rotundatae-Sphagnetum*. Its dbh and height were 23.4 cm and 10.5 m, respectively. After an initial 20 years of suppressed development, the annual increments between 1835 and 1880 were comparable with those of Scots pine on favourable sites (with a maximum in 1878). After 65 years of intensive growth, the trees stagnated and, possibly, reflected only macroclimate fluctuations.

Comparative analysis of several *Pinus rotundata* trees from various plots indicated two factors decisive for the development of bog pine stands (Figure 36.5). Three sample trees reflected a growth depression in 1918, another depression in the first half of the 1940s, and a smaller increment in the 1960s. Two sample trees reflected the minimum in 1948/1949. Fluctuation of the minimum and maximum growth increments were greater in Scots pine that seems more sensitive to actual habitat changes in the area of the mire. Depressions in increments observed between 1898 and 1901 and between 1940

and 1946 were obviously related to severe winters with hard frosts. This factor controlled development of trees in waterlogged stands with low canopy cover. On the inclined margins of the peat bog, the depressions in growth increments were related to periods of drought (between 1929 and 1931, after 1947 and 1976). In *Pinus sylvestris*, the periods of drought were often followed by intensive growth (plot P-3, P-4). In the lagg zone, the minima in increments were similar to *Pinus rotundata*. Minima in *Picea abies* in the lagg zone were observed in 1917, 1929, 1942 to 1944, 1964, and 1976, reflecting both drought and frost periods.

DISCUSSION AND CONCLUSIONS

The structural study of the woody Libořezy Bog on the margin of Třeboň Basin suggests its affinity to oligotrophic mire complexes widespread at lower altitude of temperate Central and Eastern Europe. Such bogs have been mainly controlled by resources of groundwater (telluric water) and are adapted to modest supply of meteoric water and higher degree of climatic (sub)continentality (Kulczynski, 1939/1940). Evolution of the Libořezy Bog followed environmental changes: it commenced with paludification on ill-drained depressions and/or by terrestrialization of a shallow pool/lake behind a natural elevation (possibly levées of a stream), and continued by gradual upwelling of the peat deposits to about 4 m in height. Graminoid macro-remainders in the bottom layers and several transitions from woody to mossy sediments suggest gradual change from minerotrophic to oligotrophic conditions, but fluctuations in other factors varied in favour of either treeless or forested succession stages. Appearance of the bog pine, whose timing remains unresolved, might have been an essential factor in the enhanced discharge of water through tree transpiration.

Four basic vegetation zones could be distinguished in Libořezy Bog (Figure 36.1). Outwards from the bog core, along the gradient of surface waterlogging and decreasing depth of peat, the following zonation has been reconstructed:

(a) A treeless zone of the *Eriophoro vaginati-Sphagnetum recurvi* association,

(b) Bog pine woodland of the *Pino rotundatae-Sphagnetum* association (Figure 36.2 and 36.3),

(c) Birch-rich woodland of the *Betulion pubescentis* alliance (Figure 36.4), and

(d) Spruce lagg zone with lofty stands of the *Vaccinio-Piceetea* class.

Phytosociological units in terms of the current phytosociology (Rybníček *et al.*, 1984; Moravec *et al.*, 1995) do not allow any detailed syntaxonomical differentiation along a short gradient.

Occurrence of tree species dominants in experimental plots was closely related to the depth of water in the peat bog transect and less expressively to the thickness of peat deposits (Table 36.1). Density and basal area of *Pinus rotundata* increased with rising waterlogging while the same characteristics of *Pinus sylvestris*, *Picea abies* and *Betula pubescens* decreased. Distribution of total density of trees along the water gradient showed two peaks: the maximum value was found in the wettest stand with dominant *Pinus rotundata* and high density was also found in the spruce lagg forest. In both cases, the high values correspond with sites where the dominant species is in unfavourable marginal conditions and where competitive species, which could displace the present dominant species, are absent.

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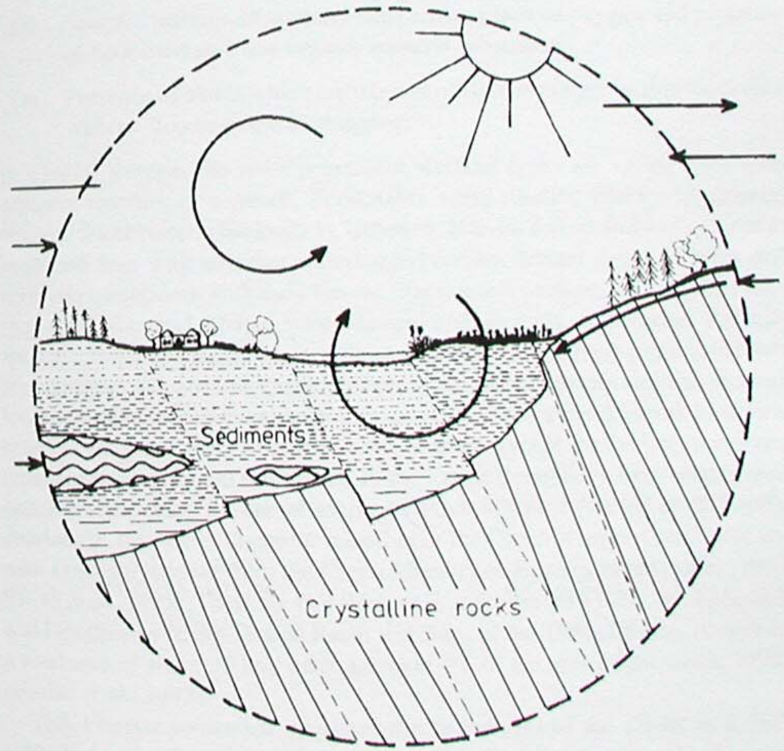
Section 5

FUTURE PROSPECTS FOR WETLANDS



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A case study of Třeboň Basin Biosphere Reserve, Czech Republic

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CONTENTS

PREFACE

UNESCO's Man and the Biosphere Programme

Improving scientific understanding of the natural and social processes relating to human interactions with the environment; providing information useful to decision-making on resource use; promoting the conservation of genetic diversity as an integral part of land management; enjoining the efforts of scientists, policy-makers, and local people in problem-solving ventures; mobilizing resources for field activities; strengthening of regional cooperative frameworks – these are some of the generic characteristics of UNESCO's Man and the Biosphere (MAB) Programme.

The MAB Programme was launched in the early 1970s. It is a nationally based, international programme of research, training, demonstration, and information diffusion. The overall aim is to contribute to efforts for providing the scientific basis and trained personnel needed to deal with problems of rational utilization and conservation of resources and resource systems and problems of human settlements. MAB emphasizes research for solving problems. It thus involves research by interdisciplinary teams on the interactions among ecological and social systems, field training, and application of a systems approach to understanding the relationships among the natural and human components of development and environmental management.

MAB is a decentralized programme with field projects and training activities in all regions of the world. These are carried out by scientists and technicians from universities, academies of sciences, national research laboratories, and other research and development institutions under the auspices of more than one hundred MAB National Committees. Activities are undertaken in cooperation with a range of international governmental and non-governmental organizations.

Man and the Biosphere Book Series

The Man and the Biosphere Book Series was launched to communicate some of the results generated by the MAB Programme and is aimed primarily at