

Delimitation of the aerobic peat layer in a *Sphagnum* mire on the southern Alps

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Abstract. The hydrology of a *Sphagnum* mire in the southern Alps was studied during the 1991 growing season by measuring at regular intervals the depth to the water table in a number of water gauges. The thickness of the acrotelm was defined as the greatest depth to the water table measured during that season. The thickness of the aerobic layer was defined based on the change of colour of the water gauges which were withdrawn from the peat body five years later. The acrotelm consists of two layers : an upper aerobic layer and a lower anaerobic layer. The best indicators of the thickness of the aerobic layer are the smallest water-table depth at dry microsites and the greatest water-table depth at low microsites, while the median depth to the water table is the best indicator when comparisons are to be extended over a broad range of microsites. The thickness of the acrotelm and the thickness of the aerobic layer decrease from dry to wet sites, but the differences between them are not constant along the water-table gradient, being wider the higher are the microsites.

Key-words: acrotelm thickness; aerobic layer thickness; water-table fluctuations; poor mire; southern Alps.

Introduction

Soil layers in mires can be divided into two main horizons biophysically well separated: the acrotelm and the catotelm (Ingram 1978; Ivanov 1981). The acrotelm corresponds to the upper layers and is characterised by intensive exchanges of moisture and heat with the atmosphere. It contains the oscillating water table and this permits the periodic access of air promoting the humification processes. Hydraulic conductivity is high and declines with depth. The catotelm corresponds to the peat deposit between the acrotelm and the mineral subsoil. As water content is constant or nearly so, all biochemical and biophysical processes take place very slowly; compared to the acrotelm the hydraulic conductivity is very low.

The limit between the acrotelm and the catotelm is not well defined (van der Molen *et al.* 1994). Furthermore, the thickness of the acrotelm is not uniform over a mire but varies from site to site. According to Ivanov (1981), the thickness of the

acrotelm can be considered equal to "the distance from the mean level of the higher elements of the microrelief to the top of the mean minimum level of the water table in the summer".

Determination of the thickness of the acrotelm is interesting both to hydrological studies, as most of the water flow takes place in the acrotelm (Ivanov 1981; Ingram 1983; Damman 1986), and to biological studies, since biological activity is almost entirely restricted to this uppermost layer (Lähde 1967; Clymo 1978; Malmer 1988).

The aim of this study is to determine the thickness of the aerobic peat layer in a poor mire on the Southern Alps and to clarify the relationships among acrotelm thickness, aerobic layer thickness and water-table fluctuations.

Material and methods

Study area

The field work was performed at Stallner Loch, a 2 ha wide poor mire located on the Sarntaler Alpen (Monti Sarentini), province of Bozen (Bolzano) Italy, at 1,710 m above sea level.

Climate is temperate-continental with a mean annual temperature of 4.3 °C, a mean temperature of the coldest month (January) of -3.2 °C, a mean temperature of the warmest month (July) of 14 °C (Fliri 1975). The average total rainfall was 909 mm in 1991, with a peak in late spring-early summer.

Five main vegetation types were recognised in this mire (Gerdol *et al.* 1994):

1) A marginal forest of *Picea excelsa* (Lam.) Link developing over a shallow peat layer. Typical species are *Vaccinium myrtillus* L., *V. uliginosum* L., *V. vitis-idaea* L., *Avenella flexuosa* (L.) Parl., *Polytrichum commune* Hedw., *Sphagnum nemoreum* Scop. and *Dicranum scoparium* Hedw.

2) High hummocks of *Sphagnum nemoreum* Scop.; typical species are *Calluna vulgaris* (L.) Hull, *Eriophorum vaginatum* L., *Vaccinium vitis-idaea* L., *V. myrtillus* L. and *Polytrichum strictum* Menz. ex Brid.

3) Low hummocks of *Sphagnum magellanicum* Brid.; typical species are *Carex pauciflora* Lightf., *Sphagnum fallax* Klinggr., *S. russowii* Warnst. and *Calliergon stramineum* (Brid.) Kindb.

4) Carpets of *Sphagnum compactum* DC. occupying areas with shallow peat; typical species are *Carex rostrata* Stokes, *Trichophorum caespitosum* (L.) Hartm. and *Cladopodiella fluitans*

(Nees) Buch.

5) Hollows with *Drepanocladus fluitans* (Hedw.) Warnst., *Sphagnum subsecundum* Nees, *Carex limosa* L., *Carex rostrata* Stokes and *Scheuchzeria palustris* L.

Methods

At the beginning of the 1990 growing season, 180 plastic pipes were inserted into the peat along transects with the aims of studying the hydrochemical characters of the mire and to relate them to the vegetation types and to the plant species distribution (Bragazza 1993; Gerdol, Tomaselli and Bragazza 1994; Bragazza and Gerdol in press). The plastic pipes consist of plastic polyvinyl chloride (PVC) casings with an inside diameter of 14 mm and a wall thickness of 2 mm. The pipes were inserted with the apex at the level of the mire surface. Water enters the pipes through lateral openings.

The depth to the water table was measured from 21 May to 7 October 1991 at intervals of 10 ± 2 days. The following hydrological parameters were determined for every site: mean, median, maximum and minimum water-table depth. Water-table duration curves, indicating the percentage of time during which the water table is at or above a given level, were obtained by grouping the sites in intervals of 5 cm according to their mean water-table depth. Only for the interval -30 - -40 cm does the class span 10 cm.

At the beginning of the 1995 growing season, 60 pipes were extracted from the peat. The portion of

the pipes subjected to anaerobic conditions turned black while in the upper portion the original blue colour of PVC was retained. The length of the unaltered portion of the pipe was measured from the apex and this value was considered as the thickness of the aerobic peat layer. The greatest depth to the water table measured during the study period in every site was considered as the lower limit of the acrotelm, according to Ivanov (1981). The pipes lacking any sharp boundary between the black and the blue portion, as well as the pipes with a median water table higher than zero were omitted. Forty-eight pipes were available for the analyses.

Results

The relationships between the mean water-table depth and: 1) the thickness of the aerobic layer, and 2) the thickness of the acrotelm for every site are shown in Fig. 1. Both the thickness of the aerobic layer and the thickness of the acrotelm decrease linearly ($r = -0.92$, $P < 0.01$ for the first; $r = -0.98$, $P < 0.01$ for the second) from dry to wet sites. An aerobic layer is virtually absent in the wettest sites.

Both the median and the greatest water-table depth are greater than the thickness of the aerobic layer, so that the corresponding differences are negative. Both differences decrease from dry to wet sites but the range of variation is ca. 25 cm for the greatest water-table depth and less than 5 cm for the median.

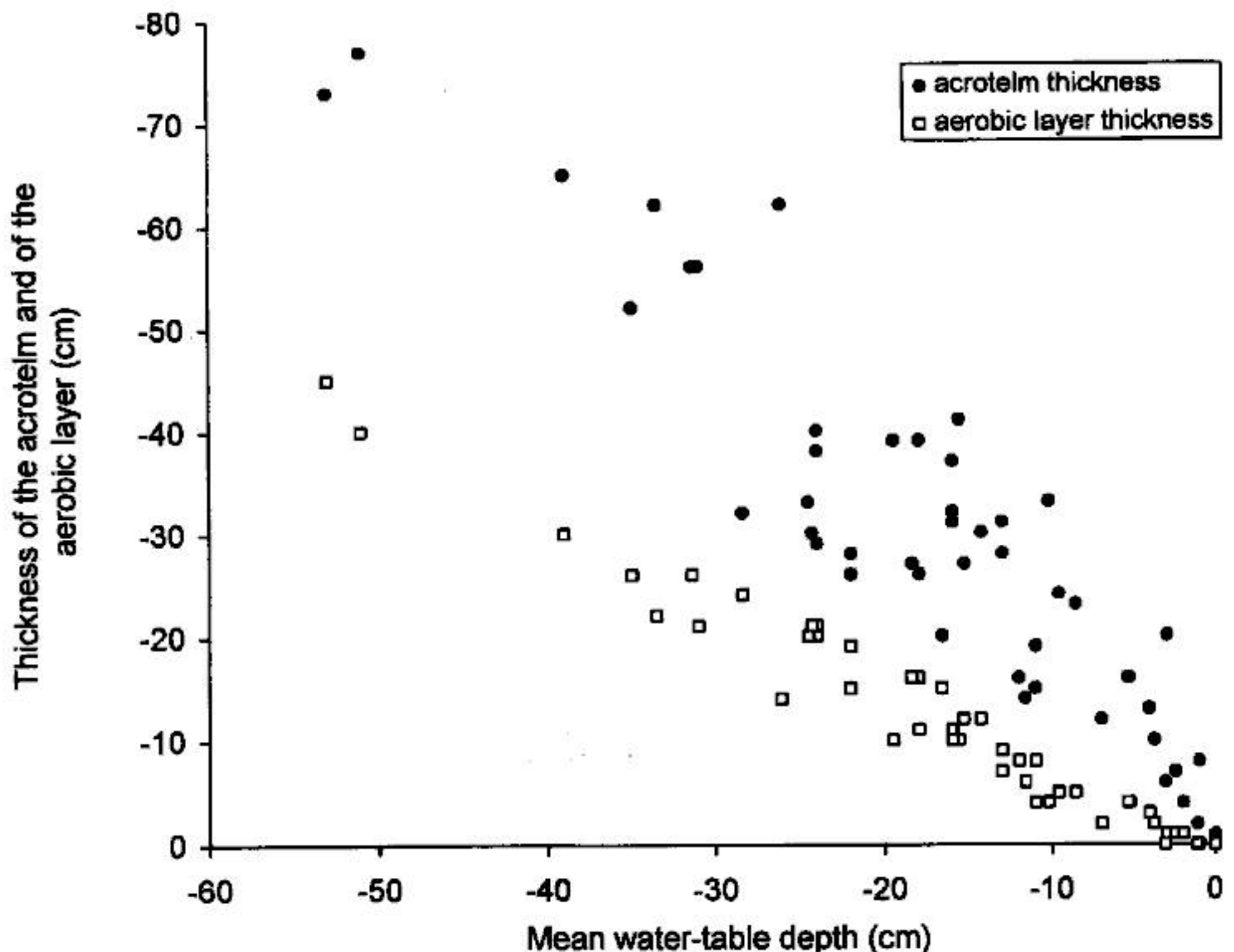


Fig. 1. Relationships between mean water-table depth and: 1) thickness of the acrotelm and, 2) thickness of the aerobic layer at each sampling site.

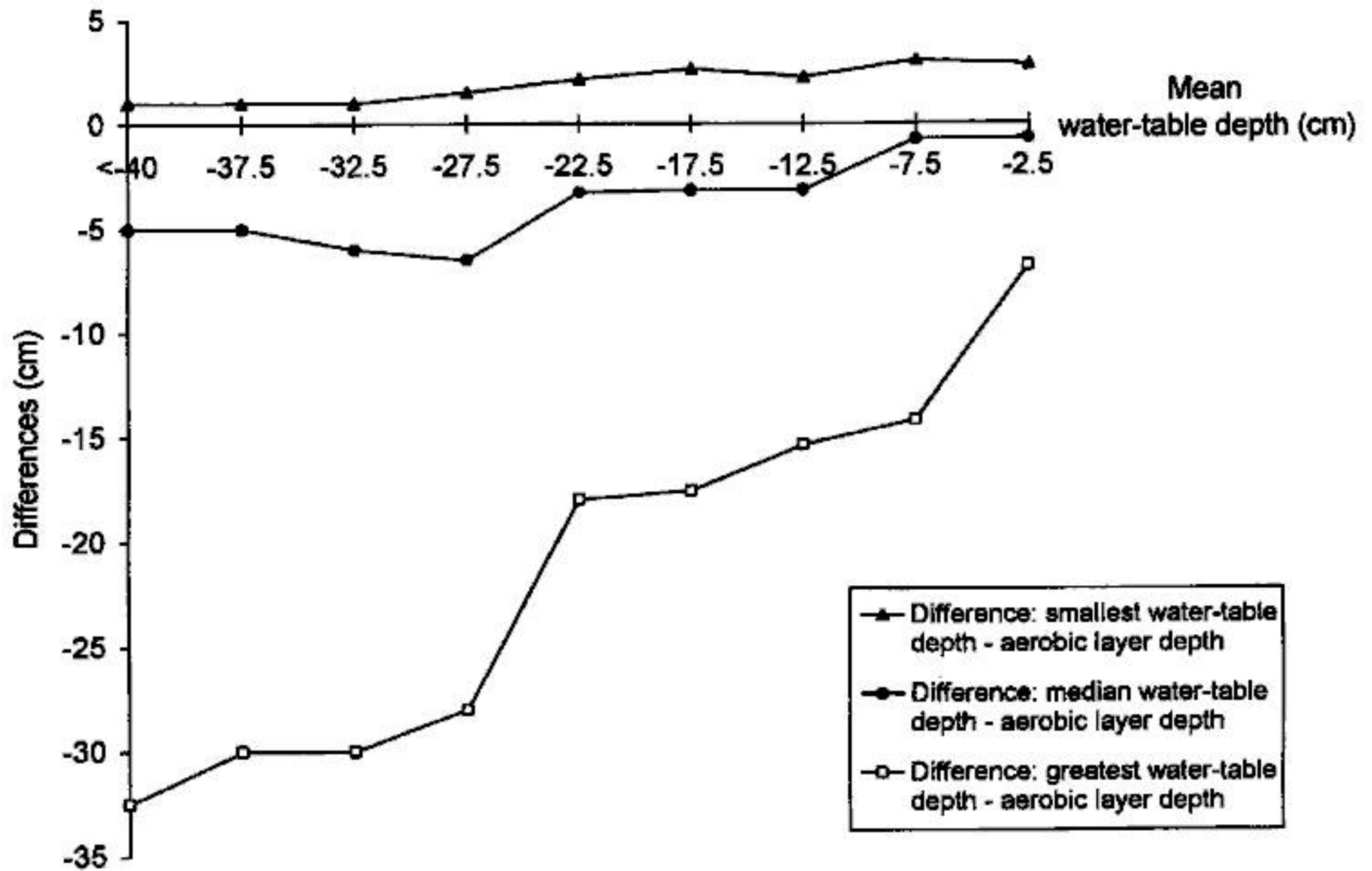


Fig. 2. Mean differences between 1) the smallest depth to the water table, 2) the median depth to the water table and 3) the greatest depth to the water table and the thickness of the aerobic layer. The sites were grouped in interval of 5 cm according to their mean water-table depth.

In contrast, the smallest water-table depth is smaller than the thickness of the aerobic layer, so that the corresponding differences are positive. These differences tend to increase slightly from dry to wet sites (Fig. 2).

On the whole, wet sites exhibit a narrower range of variation of water-table depth. The sites with a mean water table below -40 cm have a range of water-table fluctuation of ca. 45 cm, while the sites with a mean water table between 0 and -5 cm have a range of water-table fluctuation of ca. 11 cm. The water table lies above the limit of the aerobic layer for ca. 10% of the growing season in drier sites and of ca. 30% of the growing season in wetter sites (Fig. 3).

Discussion

Most authors define the acrotelm as the upper horizon of a peat deposit containing the oscillating water table (Ivanov 1981; Ingram 1978, 1983; Damman 1986). According to this definition the acrotelm can be delimited based on the greatest depth to the water table recorded during the growing season (Ivanov 1981).

The acrotelm is subjected to periodic aeration owing to the lowering of the water table. However, a major question is: does permanent anaerobiosis take place in a part of the acrotelm? My data show that anaerobic conditions occur in the peat layer being waterlogged for at least 70% of the time (Fig. 3). However the minor differences observed between the median depth to the water table and the thickness of the aerobic layer (Fig. 2) suggest that

the median depth to the water table, which is usually determined in current studies of mire hydrology, can be regarded as a reliable estimate of the limit below which peat is presently anaerobic.

Anyway, the acrotelm can be divided into two main layers: an upper aerobic layer (occasionally inundated) and a lower anaerobic layer (occasionally aerated). The thickness of the acrotelm and the thickness of the corresponding aerobic layer decrease from hummocks to hollows, but the difference between them is not constant along the water-table gradient. This may be explained considering the capillary action of peat mosses. Particularly, the *Sphagnum* species living at increasing heights above the water table have a strong capacity to conduct water by capillary action and this may determine the wide differences between the greatest water-table depth and the thickness of the aerobic layer in drier sites (Clymo and Hayward 1982; Ingram 1983; Lindholm and Markkula 1984). It should be considered, however, that the possibility of rising the water by capillarity is closely related to the extent of the capillary space, i.e. to the bulk density. Accordingly, water rising is hampered both in poorly decomposed peat layers, where pores are too large (Päivänen 1973), and in the highly decomposed peat of the hollows where living and dead *Sphagna* exhibit, in addition, a less pronounced capillary action (Clymo 1973; Johnson, Damman and Malmer 1990). Overall, the role of peat-forming *Sphagnum* residuals, with a particular regard to species composition, is of great importance in controlling water retention in peat (Päivänen 1973).

Malmer and Holm (1984) distinguished three different layers in the upper horizon of peat bodies: 1) the uppermost layer characterised by living mosses, 2) the "litter peat layer" where plant litter is weakly

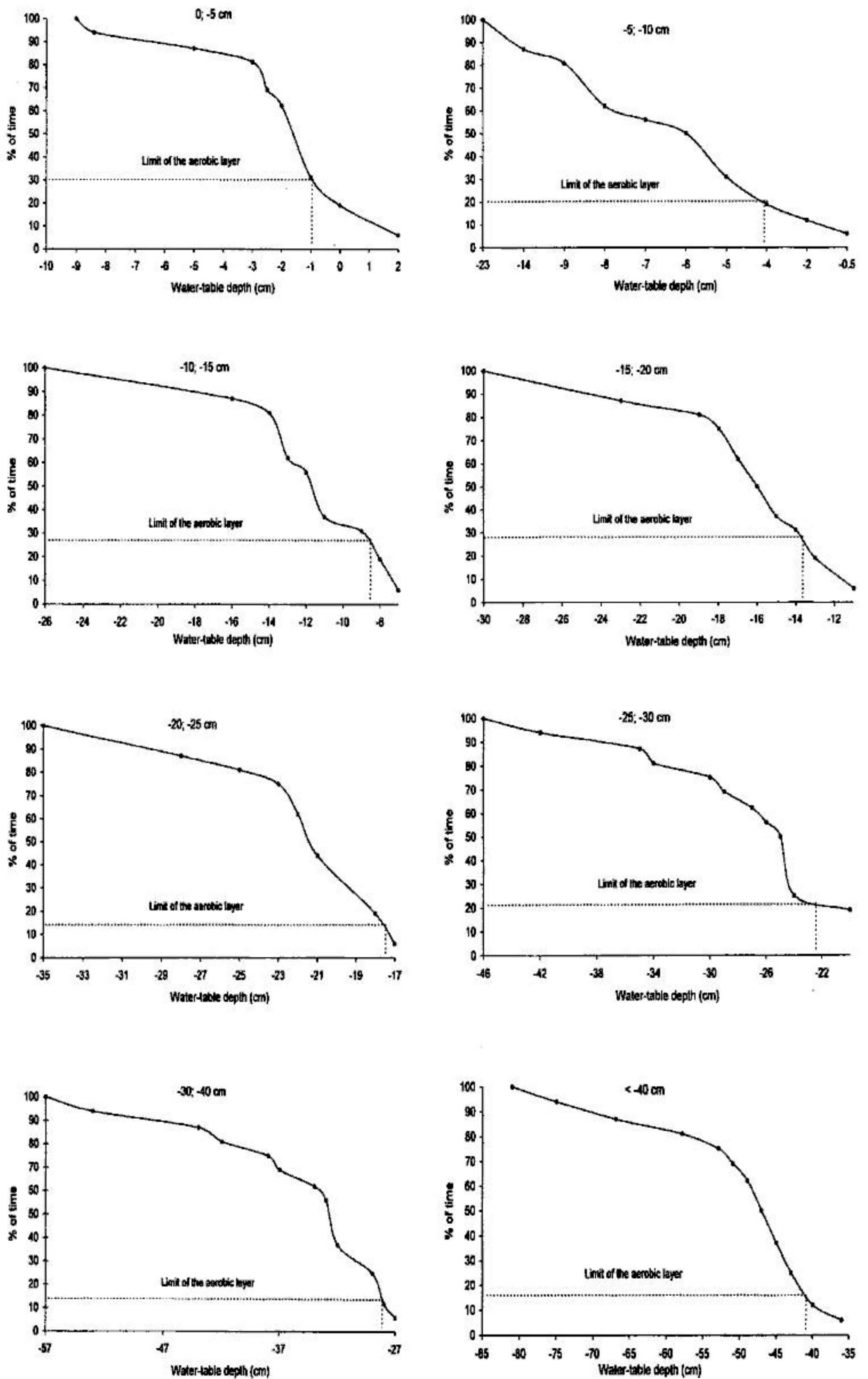


Fig. 3. Water level duration curves at sites grouped in intervals of 5 cm (10 cm for the interval -30 - -40 cm) according to their mean water-table depth.

decomposed and humified, 3) the "peat layer" where peat is much more compact, decomposed and humified. These authors suggest that the three layers "may together correspond to the acrotelm layer in Ingram (1978) and they may be well above the water table most of the year". Such different degrees of humification are clearly associated with the mean water content of peat which is, in its turn, related to the water-table fluctuations (Heikurainen, Päivänen and Sarasto 1964). Anyway, only the uppermost layer of living *Sphagnum* and the litter peat layer may be above the water table for most of the year, because of the capillary action which reduces the thickness of the aerobic layer, also when the water table is low.

The presence in the acrotelm of layers with different degree of aeration brings about a relocation of mineral nutrients. The distribution of some elements undergoing variations in the redox state as a consequence of water-table fluctuations, such as Pb, Al, Fe and Zn (Damman 1978), may be good indicators of the limit between the aerobic and the anaerobic layers in the acrotelm.

From a hydrological point of view, the greater water-table fluctuations in hummocks may be due both to the greater thickness of the acrotelm within which the water table fluctuates, and to the steeper hydraulic conductivity gradient of hummock peat which causes an increasing lateral runoff when the water level rises (Ivanov 1981). The range of fluctuations is less wide in hollows owing both to the small thickness of the acrotelm, and to the fact that any rise in water table will result in rapid drainage over the surface (Damman and Dowhan 1981). The occurrence of the water table close to the mire surface in hollows for most of the time may be due to the fact that during dry periods evapotranspiration rates in hummocks are greater than in hollows, thus causing a more pronounced lowering of the water table in the former (van der Molen, Schalkoort and Smit 1994; Streefkerk and Casparie 1989). It should be also considered that hollows behave as recharge zones from higher sites (Streefkerk and Casparie 1989).

In terms of data obtained by measuring depth to the water table, the best indicator of the thickness of the aerobic layer seems to be the highest position of the water table for hummocks and the lowest position of the water table for hollows. The median value of depth to the water table seems to be the best indicator when comparison are extended over a broader range of microsites.

The use of steel-rod oxidation as a hydrologic indicator of reducing conditions gives reliable values if the site is not subjected to rapid fluctuating hydrology for the inability of previously formed rust to dissolve after reflooding (Bridgham, Faulkner and Richardson 1991). Water-table fluctuations are particularly important to mire ecology and present differing ranges in different microsites. The use of plastic polyvinyl chloride (PVC) pipes can help in solving these problems, considering the necessity to leave the pipes in situ for a long time in order to obtain mean values of the thickness of the aerobic layer. Although this method is reliable for measuring the depth of the aerobic layer, and at the same time the water-table fluctuations, further laboratory re-

search is need to clarify the time required for determining color change in the pipes.

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