,J

The Marshy Heathland of 's Gravendel (Belgium): Trophic Gradients in Relation to the Vegetation, with Special Reference to Littorellion Communities

D. Boeye, D. Paelinckx & R. F. Verheyen

Department of Biology, University of Antwerp, UIA, Universiteitsplein 1, B-2610 Wilrijk, Belgium

ABSTRACT

's Gravendel is a marshy heathland of high botanical interest. Its amphiphytic communities of the Eleocharitetum multicaulis association (Littorelletea) contain almost all typical taxa, nowadays a rare situation. In this paper the hydrology of the nature reserve is studied. The combined effect of the complex microtopography and historical flooding results in some interesting trophic gradients which provide the basis for the species richness of the reserve. Intensive agriculture in the immediate surroundings of the reserve has as yet apparently had no negative effects. Problems may, however, occur in the future.

INTRODUCTION

Infertile wetlands of low productivity are known to support species-rich vegetation and/or a large number of rare species. This is explained by the absence of competitors, leaving possibilities for co-existence (Grime, 1979; Wisheu & Keddy, 1989). In these systems subtle gradients in abiotic conditions may be reflected in the vegetation. For this reason infertile wetlands deserve a high conservation priority (Moore *et al.*, 1989). However, due to reclamation, acidification and eutrophication, many have been destroyed or endangered throughout Europe and North America. Soft-water systems with low availability of nutrients are particularly vulnerable

Biol. Conserv. 0006-3207/91/$03·50

to these threats (Arts, 1990). In Western Europe they are often situated in shallow pools on sandy soils within (former) heathlands. Their typical vegetation is one of small, evergreen, plants (isoetids) such as *Littor ella uniflora* and *Lobelia dortmanna.* In Belgium this vegetation type used to occur very frequently in the Campine region but has undergone a dramatic decline in the past decades (De Blust, 1977). Similar reports have been made from neighbouring countries (Schoof-van Pelt, 1973; Dierssen, 1981; Wittig, 1982; Arts, 1990). As a consequence the remaining well-developed sites have international significance for nature conservation. In this paper we discuss the results of an investigation of trophic gradients and vegetation in a marshy heathland.

MATERIALS AND METHODS

Description of the study area

'sGravende!(5° 02' 20" E, 51° 14'30" N) is located in the Campine region in the northern part of Belgium (Fig. 1). The subsoil in this region is predominantly sandy with low agricultural potential. The natu ra! vegetation is *Quercus* forest, with *Alnus* woods in wet areas. Exhaustive cultivation during the last two thousand yea rs destroyed the forest, and vast

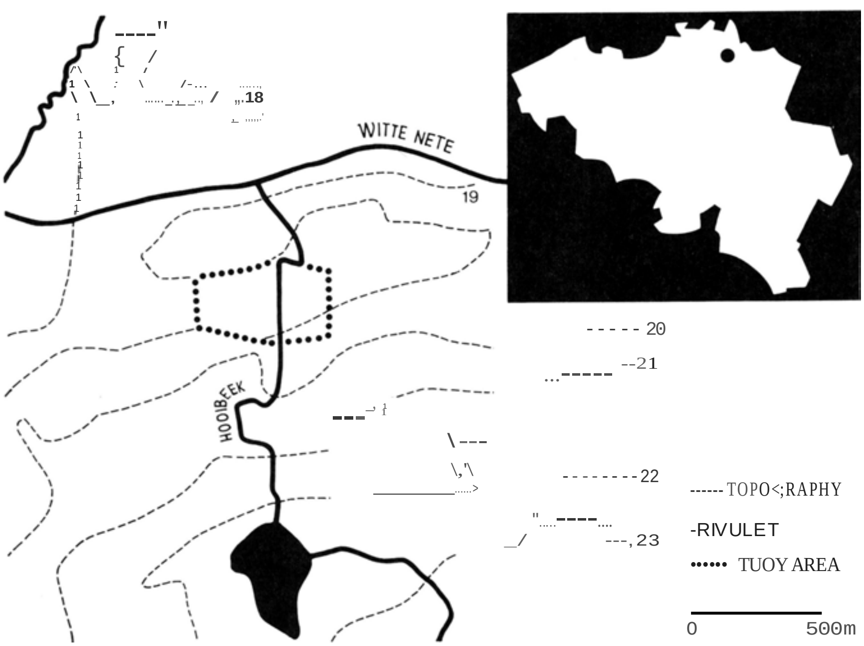

Fig. **1.** Map of 'sGravende! and its surroundings.

"

areas of heathland with scattered infertile wetlands developed. This situation persisted in many places until the beginning of this century. The introduction of chemica! fertilizers made it possible to reclaim heathlands for agriculture, and most were transformed into pasture. The development of bioindustrial activities during recent decades has put the region under even greater environmental pressure; nevertheless, the Campine region still supports much natura! vegetation (De Baere *et al"* 1986) and soft-water systems are almost restricted to this region of Belgium.

'
's Gravende!, a marshy heath of 11ha surrounded by agricultural land, is situated in the valley of the Witte Nete (Fig. 1), forming a depression in the gentle valley slope. The attitude (18-19m above sea level) is comparable to the alluvial land near the river, from which the area is separated by a ridge (19-20 m). As a consequence the natura! drainage of the area is poor. However, it is increased by an artificial ditch ('Hooibeek') which cuts through the higher ridge. The geological substrate consists of Kasterliaan, a moderately fine, glauconite-containing sand overlain by Quaternary cover sands. The sediments are permeable to a great depth. The nature reserve consists mainly of a series of pools with Littorellion communities and drier areas with *Erica* and *Myrica* heath. Some parts are affected by eutrophication and are covered with Magnocaricion vegetation and *Salix* bushes. A detailed description of the vegetation can be found in Paelinckx and Soetens (1983).

Water table measurements

1n and around the study area a network of piezometers of different lengths, but with filters in the lowest 15cm, was installed and levelled with a Pentax PAL-5C theodolite (Asahi Precision Co"Tokyo). Water table measurements were made on 24 April 1984 and 4 February 1985.

Chemica! analysis

Ground and surface water was sampled on 4 February 1985. Water samples were stored in bottles without air. pH and conductivity were measured immediately on arrival in the laboratory. Al, Ca, Fe, K, Mg, Na and Si were analysed using an Atomcomp Model 750 plasma-emission spectroscope (Jarrell Ash, Massachusetts). NH;was analysed by the Harwood and Kuhn method (McGlynn, 1974), HC03 by titration with O·OlN HCI to pH 4·2 (Taras *et al"* 1971), N03 by hydrazine reduction to N02 (McGlynn, 1974) and N02 by diazotization (Taras *et al.*, 1971). Orthophosphate, c1- and SO- were determined with an auto-analyser (Skalar, Breda, The Netherlands).

Data processing

A hierarchical cluster analysis (using Ward's error sum of squares, Jongman *et al.*, 1987) was used to classify the samples in different 'water types'. In order to relate them to the measured variables, a principal components analysis was applied. The results are presented in a plot of the first two principal components. The samples are labelled by their cluster number. Although the main clusters form distinct ordination groups, some smaller ones are scattered over the diagram (see Fig. 6). If samples from these clusters are situated within or very near to the main ordination groups they were included, and their original cluster number was indicated between parentheses. The ordination groups (OG) will be used for further analysis. All calculations were made using the DPP-package (van Espen, 1984). A visual representation of some variables is provided by means of maucha-diagrams. The relative concentrations of six major ions are represented in a pie plot, visualizing the dominant ions and water type. Each piece represents an ion, and the length of its axis is proportional to the relative concentration.

RESULTS

Water level measurements

Figure 2 gives the water table measurements on both dates, together with the equipotential lines derived from them. The water table shows a downward slope in a northerly direction. This is in agreement with the regional groundwater table, which one can assume to follow the regional topography, starting at the interftuve in the south and ftowing towards the Witte Nete just north of the reserve. In addition to this genera! trend, some local features are revealed by the water tabJe measurements. The strongJy draining inftuence of the ditch is striking. Since it was only deepened around 1950 (Paelinckx & Soetens, 1983), we may expect that this inftuence did not previousJy exist. However, the most important feature in our view is the difference shown by the water table in the western compared to the eastern part of the reserve, taking the Hooibeek as the boundary. In the western part the water table shows a sharp fall to the south but is almost level in the northern half. In the eastern part it decreases gradually over the whole range. This difference is caused by the topography (Fig. 3). Since January 1985 was a wet month and April 1984 dry, this a]so expJains why these features were more marked in 1985 than in 1984.

From these results we may conclude that groundwater ftows in from the south into the whole reserve. Because of the sudden fall in topography in the

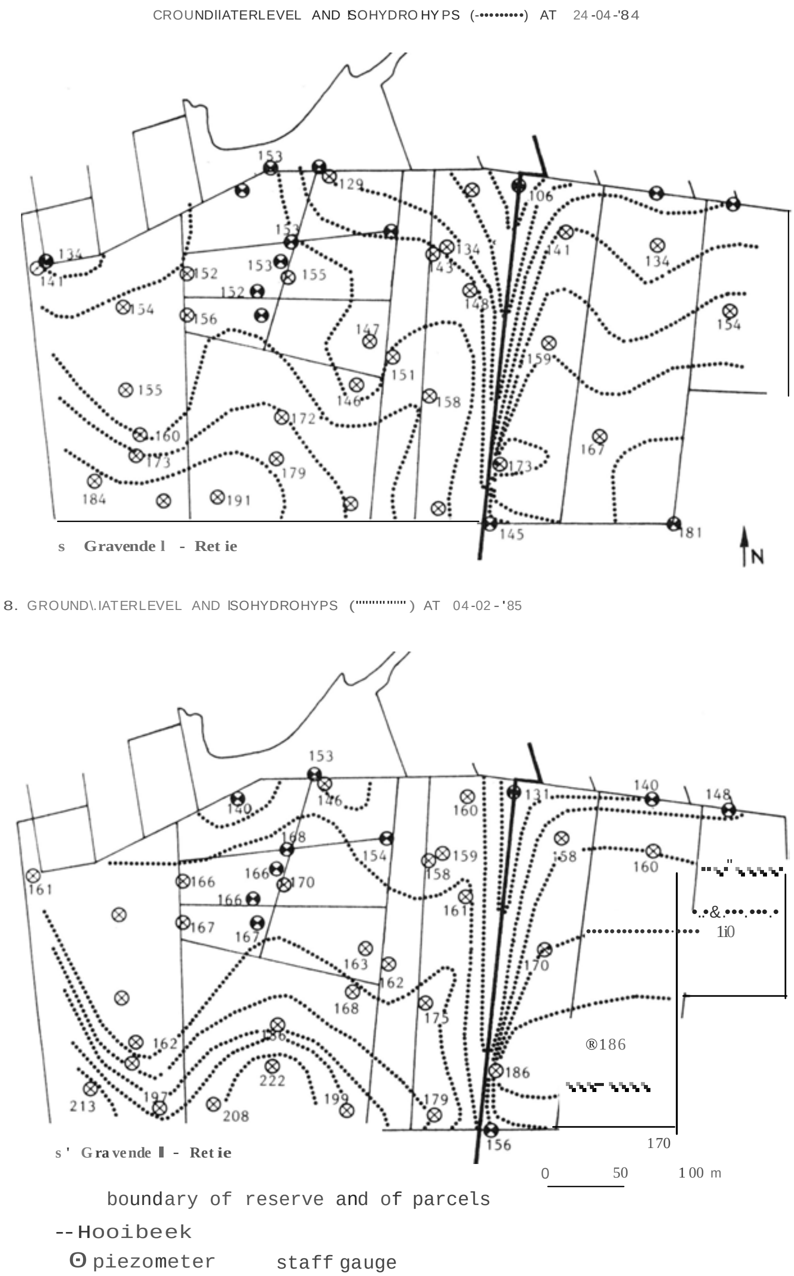

Fig. 2. Equipotential lines (A, 24 April 1984; B, 4 February 1985).

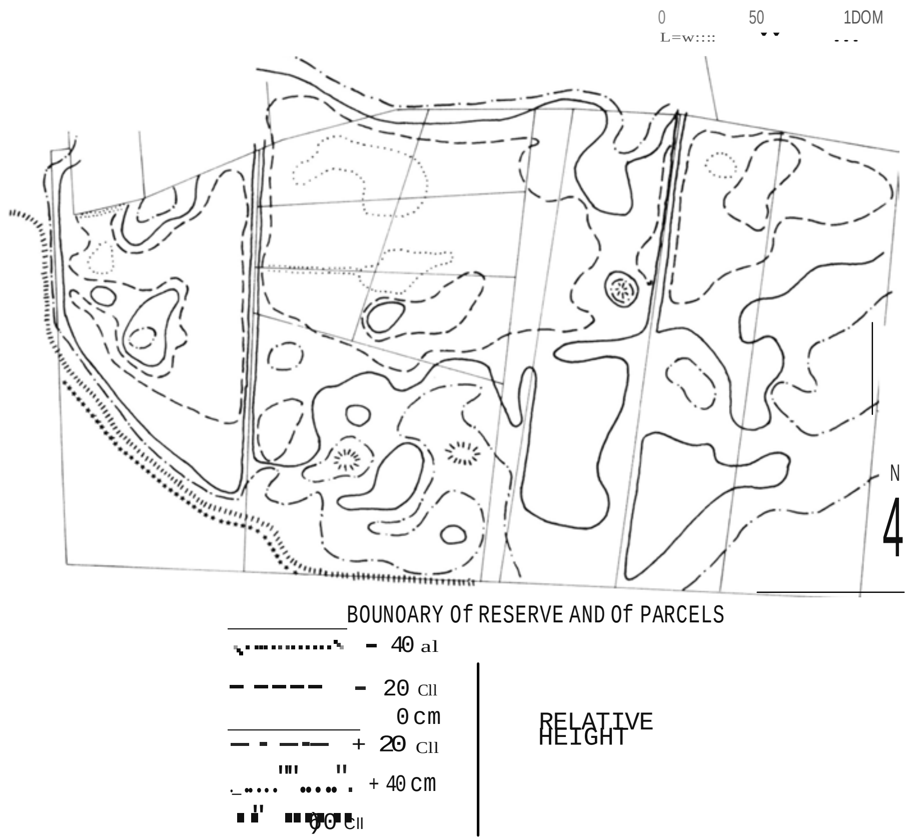

Fig. 3. Topographical contour lines (Paelinckx & Soetens, 1983).

west, the water table reaches the land surface, giving rise to pools fed by ground water discharge (i.e. the movement of water out of the soil). This can be illustrated from our measurements, since the water in the piezometers is above the water level in the pools (Fig. 4). These are drained through a badly maintained system of ditches and banks (Fig. 5). At the northern border of the reserve, the water level in the piezometers is lower than in the pools, indicating percolation from the reserve in the northerly higher ridge. In the eastern part the water table remains near to, but generally below, the surface.

Water chemistry

The results of the cluster and principal components analysis are combined in Fig. 6, showing the ordination diagram. The two largest ordination groups form two parts, 4a/b and 8a/b, smaller clusters (2, 5 and 6) being scattered over the diagram. The correlation between the first two axes and the variables is shown on the right side of Fig. 6. PC I is associated with electric

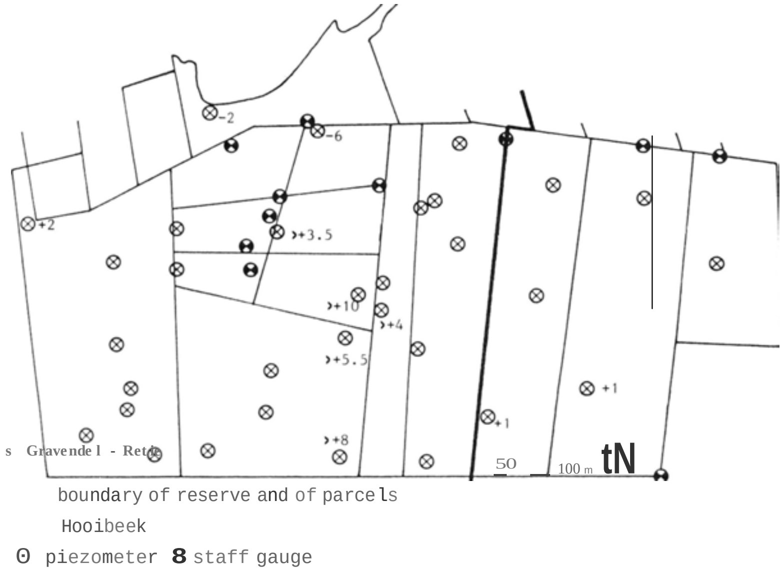

Fig. 4. Difference between water levels in and outside piezometers (cm): +, groundwater discharge (movement of water out of the soil); –, infiltration (movement of water through the soil surface into the soil); no speciation, level is lower than the surface or higher than the top of the piczometer.

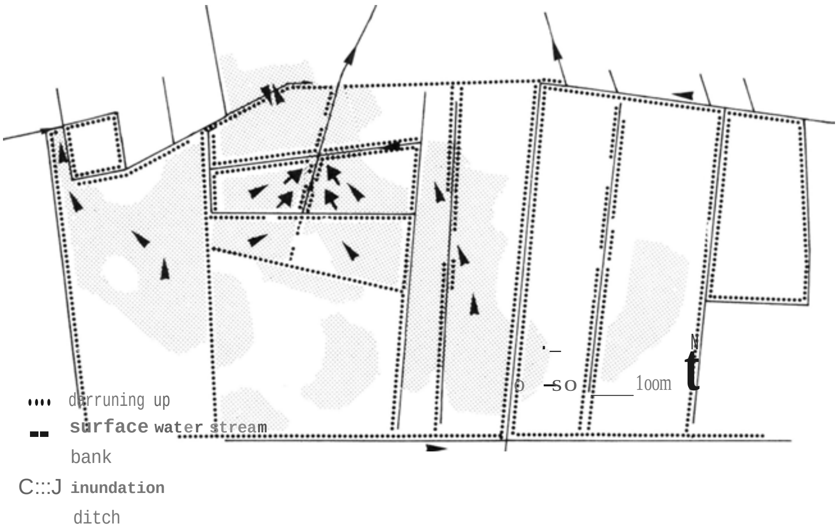

Fig. 5. Surface water flow pattern.

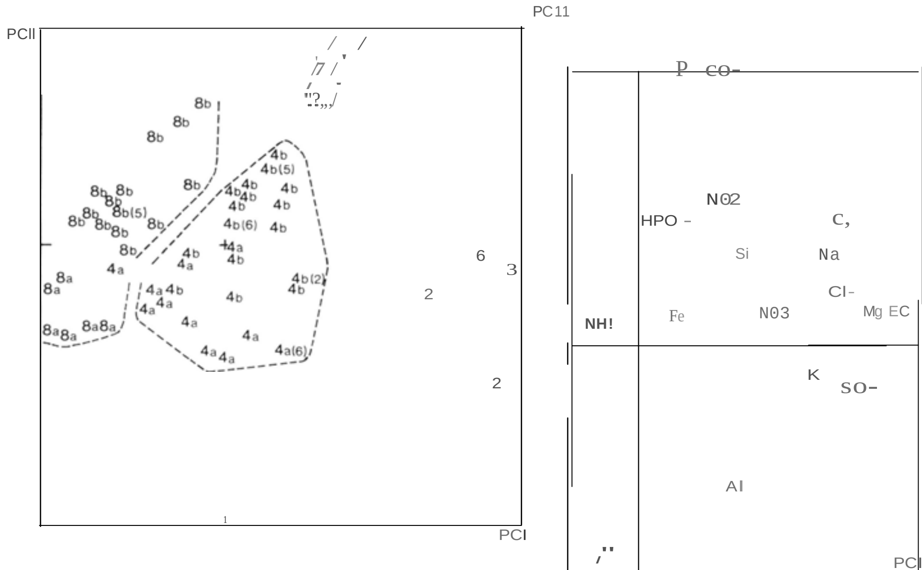

Fig. 6. Principal component analysis (PC T and IT in relation to ordination groups and correlation between PC 1 and 11 and variables).

conductivity and most individual ions, and PC II with acidity. Figure 7 provides a visual representation of some variables by means of maucha-diagrams.

OG 1 contains samples with a strongly acid reaction (pH c. 4) and a high conductivity. Dominant ions are calcium and sulphate, but the high aluminium content is also striking. OG 2, 3 and 6 are all moderately acid (pH c. 5) with high conductivity. They are therefore situated together on the right side of the ordination diagram. Figure 7 shows that OG 3 is clearly different from OG 2 and 6, resembling OG 1 but less acid. Its high nitrate and potassium concentrations are also different. OG 2 also differs from OG 6 with respect to nitrate. OG 7 shows a slightly acid reaction (pH c. 6), being a calcium carbonate-dominated water with moderate conductivity. The predominant water type in 's Gravendel is characterized by low electrical conductivity, pointing to a small amount of solutes and a moderate to strongly acid reaction (pH 4-5·5). Examples of this type are OG 4 and 8. From the ordination diagram it can be seen that OG 4 has a higher conductivity than OG 8, and OG 4a and 8a are more acid than OG 4b and 8b, respectively.

Vegetation

Figure 8 shows a simplified vegetation map of 's Gravendel. Essentially, it is a wet heathland area dominated by Ericetum tetralicis Schwick 1933. In

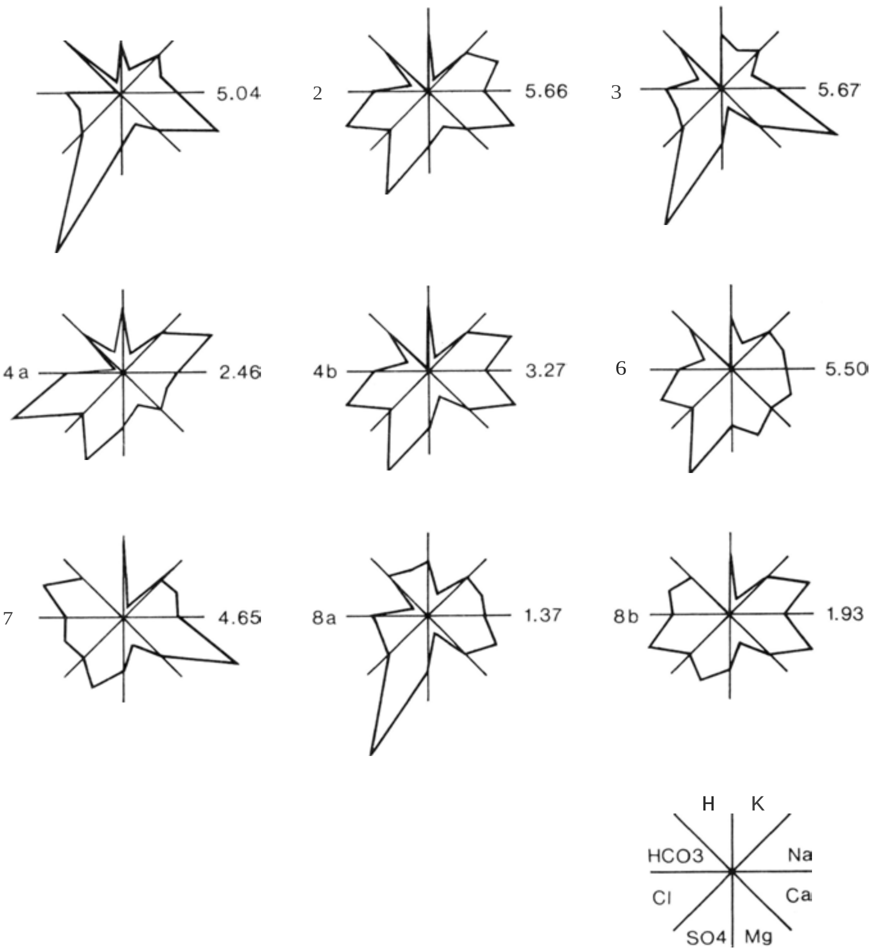

Fig. 7. Maucha-diagrams and total ion content (meq/litre) of ordination groups.

many places this is replaced by Myricetum gale (Gadecau 1909) Jonas 1935, a species-poor vegetation with predominantly *Molinia caerulea* and *Myrica gale*. In the eastern part of the reserve this vegetation type forms homogeneous stands. In accordance with the topographical gradients, the western part is more complex. In the south-east corner a Sphagno-Rhynchosporetum albae (Steffen 1931) Barkm. 1968 vegetation is associated with the steeply sloping ground. Further north-east a number of pools exist in which appears an Eleocharitetum multicaulis sphagnetosum Dierssen 1972 vegetation and a variant rich in *Molinia caerulea*. In the south of the reserve, near to the Hooibeek, a 'productive' vegetation type has developed due to the farmer flooding of the Hooibeek. Elements of Phragmitetea vegetation are present; large tussocks of *Carex elata* determine the aspect.

Fig. 8. Simplified vegetation map of 's Gravende! (Paelinckx & Soetens, 1983): ES, Sphagno-Rhynchosporetum albae; ET, Ericetum tetralicis, oligotrophic Myricetum gale and related vegetation; LM, Eleocharitetum multicaulis sphagnetosum and variant rich in *Molinia caerulea;* Lh, Eleocharitetum multicaulis hypericetosum elodes; LR, Ranunculo-Juncetum bulbosi; My, eutrophicated Myricetum gale vegetation; Pin, pine and birch wood; Ph, eutrophic spot with Phragmitetca clements; SA, woods of *Salix* sp. and/or *Alnus glutinosa.*

On the left bank of the Hooibeek the influence of flooding spreads out in a north-westerly direction, giving rise to dense stands of *Myrica* and *Sa!ix* bushes. On the border between this productive vegetation and unproductive wet heath, two very interesting vegetation types occur: Eleocharitetum multicaulis hypericetosum elodes Dierssen 1972 and Ranunculo-Juncetum bulbosi Oberd. 1957. Many rare species growing in 's Gravendel are present in these vegetation types: *Utricularia minor, U. intermedia, Hypericum elodes, Carex lasiocarpa, Littorella uniflora, Deschampsia setacea, Ranuncu/us ololeucos, Eleocharis multicaulis, Scirpus fluitans, Potamogeton polygonifolius* and *Pilularia globulifera* (in the Ranunculo-Juncetum bulbosi).

DISCUSSION

Spatial relations between vegetation and hydrology

Figure 9 shows the distribution of different water types in 's Gravende!. It is evident that the difference in complexity between the eastern and western parts of the reserve is also reflected in the water quality pattern. In the

boundary of reserve and of parcels

Hooibeek

piezometer staff gauge * sample place

Fig. 9. Distribution of water types according to ordination groups (see text for explanation): A, surface water; B, ground water.

eastern part, the groundwater and the surface water in small ditches (not in the Hooibeek) belong almost exclusively to OG 4b. All the rest of the surface water samples belong to OG 8a, indicating a strong precipitation influence. There is poor drainage of precipitation water in this area. Deep infiltration is, however, impossible because of the upward flow of groundwater. The result is little modified precipitation water (OG 8a) over relatively ion-rich groundwater (OG 4b). This explains the presence of a homogeneous oligotrophic wet-heath vegetation.

Groundwater discharge occurring in the western part gives rise to poor fen vegetation. In the south-west corner the Sphagno-Rhynchosporetum is related to a strong, local groundwater flow. Further north-east the groundwater discharge pools support different variants of Eleocharitetum multicaulis vegetation. The Eleocharitetum multicaulis sphagnetosum and a variant rich in *Molinia caerulea* are associated with OG 4a, OG 8b supports the E. m. hypericetosum, but also a productive *Salix* vegetation located in the south near the Hooibeek and spreading in a north-easterly direction (Fig. 8). Although OG 8b has a low ionic content (and is in this respect similar to OG 8a), its relative ionic composition is clearly different. It is a $Ca\text{-}HCO_3$ water, which might point to an influence of somewhat deeper groundwater (van Wirdum, 1981) or to disturbance due to eutrophication in the productive vegetation. Additional sampling will be necessary to solve this problem. It is not surprising that on the verges of the productive vegetation (and on the border between OG 8b and other water types) a species-rich vegetation has developed. It has been shown for many other vegetation types that stabie contact zones between different water quality types support high species densities with many rare species (van Wirdum, *1979a,b*, 1981, 1982; Kemmers & Janssen, 1980; Grootjans, 1985).

Future developments

Many workers have reported the decline of oligotrophic wetland vegetation due to eutrophication. The question arises how the poor fen vegetation types in 's Gravende! are able to persist in an area surrounded by intensive agriculture. A water sample from the agricultural area taken 100 m south of the western part of the reserve shows a clear agricultural influence. Since the groundwater flow is directed towards the reserve problems may be expected. OG 3, which is composed of only one sample (from a 3-m deep piezometer at the southern border of the reserve, Fig. 9), shows some influence. The concentration of nitrate and potassium is high in comparison with other samples from the reserve. However, the concentration of phosphate is clearly much lower than in the agricultural area, in agreement with the fact that phosphate is less mobile than nitrate or potassium.

Although it may be only a question of time before 's Gravende! will eutrophicate, this does not seem very likely. The intensive agriculture started about 35 years before the samples were taken, and the sandy subsoil in this region has a high permeability. So we might expect that this would have already resulted in eutrophication, or at least a rise in nitrate concentrations. Another possibility is that the regional hydrology is such that most of the water draining from the agricultural area is going under 's Gravende!, without reaching the root zone. More detailed hydrological research is necessary to solve this problem.

Conservation impacts

's Gravende! is an interesting nature reserve from a conservation point of view. It is very well suited for more fundamental research on Littorellion communities, as it contains almost all typical species of the Eleocharitetum multicaulis, a situation which is nowadays very rare in the Campine region of Antwerp (De Blust, 1977) but also in other countries (Schoof-van Pelt, 1973; Pietsch, 1977; Arts, 1990). Much vegetation of this type in Western Europe has shown a steep decline in species richness due to eutrophication and acidification (Leuven, 1988; Arts, 1990). For this reason 's Gravende! deserves a high priority for conservation (Moore *et al.*, 1989). It is in private ownership and has been managed in recent years for hunting, providing breeding areas and shelter for wildfowl and small mammals. Although this management is the prime reason for its present state, it is not optima! for nature conservation. Since the most interesting vegetation communities are located on both sides of the productive vegetation (Fig. 8), care should be taken not to alter the existing trophic gradients, and expansion of the *Salix* bushes should be stopped. However, to attract waterfowl, eutrophicated water of the Hooibeek is used to irrigate pools where there is Littorellion vegetation and has had an adverse effect in some places. For this reason it seems opportune that a public authority should buy the area and that it should be managed according to nature conservation objectives. It may also be useful to create a buffer zone around the reserve, with constraints on agricultural practice. For the moment, however, we have no clear evidence that agriculture forms a major threat, and there are no indications that any of these actions will be undertaken in the near future.

ACKNOWLEDGEMENTS

Thanks are due to Prof. Dr O. Vanderborght (UIA-SCK), in whose laboratories many of the water analyses have been carried out, and to Mr S. Van Puymbroek (SCK) and Mr G. Vanderkinderen (UIA) for technica! assistance and advice concerning analytica! problems.

REFERENCES

Arts, G. (1990). Deterioration of atlantic soft-water systems and their flora, a historica! account. PhD thesis, Catholic University Nijmegen.

De Baere, D., De Blust, G. & Verheyen, R. F. (1986). Een globale beschrijving van natuur in Vlaanderen voor de ruimtelijke planning. *Landschap*, 3, 140-8.

De Blust, G. (1977). Littorelletea-vegetaties in de Antwerpse Noorderkempen. *Bio/. lb. Dodonaea*, 45, 62-83.

Dierssen, K. (1981). *Littoreletea-comm*unities and problems of their conservation in Western Germany. *Coli. Phytosociol.*, X *(Lille)*, 319-32.

Grime, J. P. (1979). *Plant Strategies and Vegetation Processes*. John Wiley, Chichester.

Grootjans, A. P. (1985). Changes of groundwater regime in wet meadows. PhD thesis, University of Groningen.

Jongman, R. H. G., Ter Braak, C. J. F. & Van Tongeren, 0. F. R. (1987). *Data Analysis in Community and Landscape Ecology*. Pudoc, Wageningen.

Kemmers, R. H. & Jansen, P. C. (1980). De invloed van chemische faktoren in grondwater en bodem op enkele vegetatietypen in het CRM-reservaat 'Groot Zandbrink'. ICW-nota, 1181.

Leuven, R. S. E. W. (1988). Impact of acidification on aquatic ecosystems in The Netherlands with emphasis on structural and functional changes. PhD thesis, Catholic University of Nijmegen.

McGlynn, J. A. (1974). Examination of waters: evaluation of methods for selected characteristics. *Austral. Water Resour. Counc. Tech. Pap.*, No. 8. Australian Government Publishing Service, Canberra.

Moore, D. R. J., Keddy, P. A., Gaudet, C. L. & Wisheu, I. C. (1989). Conservation of wetlands: do infertile wetlands deserve a higher priority? *Bio/. Conserv.*, 47, 203-17.

Paelinckx, D. & Soetens, R. (1983). Het natuurgebied 's Gravendel (Retie, België), T. Fytosociologische beschrijving in relatie tot vochtigheid en bodem. *Bull. Soc. Roy. Bot. Belg.*, **116**, 74-92.

Pietsch, W. (1977). Beitrag zur Soziologie und Ökologie der europäischen Littorelletea- und Utricularietea-Gesellschaften. *Fedd. Repertor.*, 88-3, 141-245.

Schoof-van Pelt, M. M. (1973). Littorelletea, a study of the vegetation of some amphiphytic communities of Western Europe. Nijmegen, Stichting Studentenpers.

Taras, M. J. *et al.* (1971). *Standard Methods for the Examination of Water and Wastewater*, 13th edn. American Public Health Association, Washington.

van Espen, P. (1984). DPP, a program for the processing of analytica! data. University of Antwerp, UIA, Department of Chemistry, Wilrijk.

van Wirdum, G. (1979a). Dynamic aspects of trophic gradients in a mire complex. *Comm. Hydro/. Res., TNO, Proc. & lnf*, 25, 66-82.

van Wirdum, G. (1979b). Veen, venen en moerassen. In *Levensgemeenschappen*. Pudoc, Wageningen, pp. 99-138.

van Wirdum, G. (1981). Linking up the natec subsystem in models for the water management. *Comm. Hydro/. Res., TNO, Proc. & lnf*, 27, 108-28.

van Wirdum, G. (1982). The ecohydrological approach to nature protection. *Ann. Rep. Res. lnst. Nat. Manage.*, 60-74.

Wisheu, I. C. & Keddy, P. A. (1989). Species richness-standing crop relationships along four lakeshore gradients: constraints on the general model. *Can. J. Bot.*, **67**, 1609-17.

Wittig, R. (1982). The effectiveness of the protection of endangered oligotrophic-water vascular plants in nature conservation areas of North rhine-Westphalia (Federal Republic of Germany). In *Studies on Aquatic Vascular Plants*, ed. J. J. Symoens, S. S. Hooper & P. Compère. Royal Botanical Society, Brussels, pp. 418-24.