Catfield Hall Estate fens (Ant Broads, Norwich)

Visit June 5th 2013

Middle Marsh

North Marsh north

Utrecht, June 20th 2013

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Introduction

This report describes my observations during a field trip to the Catfield Fens in the Ant Broads on June 5th 2013. Mr and Mrs Harris invited me to come and see the condition of the fens belonging to their Estate and to compare them to other European fens where I performed research.
In the following text there will be a description of my observations, followed by an explanation of the general European processes in fens, and an interpretation of the conditions in a final section with discussion / conclusion.

Field observations

During several hours I observed most of the Catfield fens, in sequence it were: Middle Marsh, Mill Marshes, South Marsh, Long Marsh, Rose Fen and North Marsh. The observations were for plant and moss species, vegetation structure, and some measurements of pH and conductivity of the water. Moreover, four samples of water were brought to the laboratory at GeoSciences at Utrecht University within 20 hours, to analyse (with ICP analysis) some basic elements; these results will be introduced in the text later.
The general impression on the 5th of June was that there had been rain in recent days; water tables were high in many locations (also on the roads/tracks). The dykes (= ditches) in between the fens showed not any current, the impression was that there is not any difference in surface water levels between the different marshes.

Middle Marsh
A field with *Phragmites australis* (low, ca. 1.4 m), *Eriophorum angustifolium* and *Calamagrostis* with at many locations the mosses *Sphagnum cf fimbriatum* and *Aulacomnium palustre*. These mosses grow there recently; there was no layer of dead mosses beneath. First groundwater had pH of 4.85 and an Electric Conductivity (EC) of 130 µS/m. In the middle of the marsh is a "pond" where the water has pH = 5.56 and EC = 95 (sample 1). Around this pond is a wet zone with some forbs e.g. with *Iris pseudacoris* and *Menyanthes trifoliata*. Here the water at surface had pH = 5.0 and EC = 225 (sample 2). In some ditches the species *Stratiotes aloides* is present; the distribution of this species in the Netherlands of mostly linked to nutrient-rich conditions. The ditch at the boathouse close to the elevated area was the location where *Hottonia palustris* was growing (indication of seepage of groundwater); digging the ditch created an opening in clay layer? Here the water in the ditch was pH = 7.5 and EC = 700 (sample 3).

Mill marshes + South Marsh
These fens show variation in the vegetation. Most of them are *Phragmites* dominated (sparse, 1.5 m high), with locally many *Cladium mariscus* plants. In the middle of a field of *Cladium mariscus* in Mill marsh west the pH = 5.3 and EC = 530. But many locations had lower pH and EC values. Locally *Myrica gale* dominates. Also locally many indications for acidification are present. *Aulacomnium palustre, Sphagnum cf fimbriatum* and *Sphagnum squarrosum* are present in many places; *Drosera rotundifolia* is represented too. At some locations the Sphagna are present for a longer period with accumulation of dead

mosses below the living ones. Here the acidification can continue and the building of a moss layer makes that the mosses create some elevation; it is there that *Polytrichum commune* grows on top (very dry conditions). Very remarkable was that in these spots the *Betula* (birch) is germinating many times. Other locations in these marshes have higher water table and just here *Alnus glutinosa* is germinating.

Long Marsh and Rose Fen
The impression is that the water table in these marshes is higher, but the pH and EC remain on lower levels, comparable with former fens. The vegetation is mostly a mix with *Phragmites* and *Cladium*; the moss *Calliergonella cuspidata* was frequent. Striking was that at many locations the grass *Calamagrostis canescens* and *Juncus effuses* were co-dominant (indicators of higher nutrient levels or fluctuations in water table). The ditches and the trenches did not show eutrophication; some of them have fine vegetation with *Chara* species or *Fontinalis antipyretica*. At one spot in a *Cladium* field the moss *Drepanocladus* species was present (indicator for higher pH values).

North Marsh north
This marsh differs totally from the other ones. The reed marsh harbours many other species; *Phragmites australis* is frequent but is mixed with e.g. *Peucedanum palustre, Alisma plantago-aquatica* and *Carex pseudocyperus*. Indicators for higher pH values and seepage of groundwater were present: *Ranunculus lingua, Equisetum fluviatile* and *Juncus subnodulosus* for the plant species, and the moss species *Calliergon cordifolium* and *Mnium rugicum*. There are spots in this marsh were the seepage can be observed with/by the film of iron-bacteria on the top layer. Here the water had a pH = 6.9 and EC = 850 (sample 4).

Water chemistry
The four water samples have been analysed for some basic ions in the laboratory (ICO-OES analysis). The first two samples represent the lower pH and EC values; the third and fourth samples indicate the water higher in pH and EC.

Sample Name	pH	EC	Ca	Mg	Cl	K	Na
1	4.85	130	1.430	1.600	21.470	1.050	11.100
2	5.56	95	9.146	2.810	36.300	4.980	14.770
3	7.5	700	57.950	14.090	86.780	5.900	50.320
4	6.9	850	68.060	19.170	104.260	11.380	55.840

There appeared to be a huge contrast in chemistry. The concentrations for Ca and Mg (in mg/l) in the high pH-range appeared to be 10 times higher than that in the low pH-range. The buffer complex (also including the not-measured HCO_3) is well developed in samples 3 and 4, whereas it is almost absent in samples 1 and 2. The observed differences in pH and EC are also present in chemistry.

The fen-ecosystem and its processes

General conditions for fen-ecosystems are high water tables and buffered conditions. Fens should accumulate organic matter to create a peat layer and this is only possible with constantly a high water table. The characteristic species from this ecosystem survive the stress from water logging and the an-aerobic conditions prevent other species to invade. In case of periods with lower water tables, the organic soil gets oxidized and the result will be mineralization of the peat layer and the nutrients from the organic matter (the carbon disappears as CO_2) will become available. Thus, desiccation will result in eutrophication. As a consequence other species will be stimulated to grow and a succession is observed. In the Netherlands we call this "accelerated succession"; where during decades a defined type of vegetation was present, within a few years a next phase in the succession can be present.

But at the same time the other aspect of the process is that first cm's (or more) of the soil will be drained. The consequence of this change is that the (constant during seasons) input with rainwater will infiltrate the top layer. Because rainwater is acid, the conditions in the soil change from buffered to acidified. The second characteristic condition in fens is that the pH should be neutral. When the pH in the top layer in fens gets acidified, conditions for bogs will dominate; this bog-vegetation only needs an input from rainwater. Absence of input with calcium and accumulation of atmospheric deposition will result in the process of acidification. When *Sphagnum* species can establish in this vegetation, the *Sphagnum* layer stimulates the acidification by expulsion of H^+ ions. A positive feed back loop is started to stimulate the acidification of an originally buffered environment; accelerated succession will be the result.

Finally, also the availability of phosphorus is linked to the buffer-capacity of the soil. When there is enough calcium and (reduced, from groundwater) iron in the soil, phosphorus will precipitated with these ions and cause that the ecosystem remains in the mesotrophic or even in oligotrophic condition, fine for many endangered plant species. Absence of the buffer-capacity will not bind the free phosphorus in the system. Acidification will result in the opposite process: at pH = 5 most phosphorus gets free available.

The buffered conditions in fen ecosystems are closely linked to hydrology. The origin of the calcium input can be or from groundwater that is buffered, or from flooding with buffered surface water. These general relations between vegetation and hydrology are e.g. described from the Netherlands (Wassen et al. 1990a, Wassen & Barendregt 1992), Germany (Succow & Joosten, 2000), Poland (Wassen et al. 1990b) and Siberia (Grootjans et al. 2006).

In general, the fen vegetation is bordered by an elevated area where rainwater (EC values between 50 and 100) infiltrates and results in a higher potential energy between the hill ridge and the low laying marsh land. Rainwater accumulates in the soil of the ridge and stays there for a longer period. Chemistry of the rainwater changes in the interaction with this soil and gets rich in calcium / bicarbonate and reduced iron (pH values 6-7 and EC values between 500-800). This groundwater from the ridge exfiltrates at the edge with the valley, so that there is seepage with water rich in calcium that creates buffered conditions in the soil of the fen area. Moreover, the soil is always filled with water due to the permanent seepage of groundwater; desiccation is not possible. The other possibility is that river water (a mix of groundwater and rainwater) floods the fenlands, causing buffered conditions. Both hydrological processes result in the condition that the fen areas are supplied with water rich in calcium, and for that reason buffered and not acidified; at least the fens remain always wet.

These processes can be interrupted by changes in hydrology. One possibility is the drainage (ditches, pumps) for agriculture, but this is not valid in the Catfield Fen. The other way is the abstraction for groundwater (for reasons of drinking water, industry or agriculture) that will cause the water tables in the hill ridge (= the potential energy) will fall down and that the flow of groundwater into the fen area will be blocked. Especially in the Netherlands with high pressure from the society these effects are reported (e.g. Barendregt et al. 1995, Van Belle et al. 2006). The consequences are that the fen ecosystems get dryer and not buffered anymore; acidification and accelerated succession are the final results, causing decrease in characteristic diversity. In many cases the internal production of nutrients from mineralisation will also result in a process of eutrophication.

Discussion and conclusion

The observations indicate that the buffered conditions with high groundwater table are not met in most fen areas at Catfield. Especially in the Middle marsh and the Mill marshes are many indications that acidification and desiccation are problems for the vegetation. Another indication is that the stems of *Phragmites australis* remain short. Not only the presence/absence of plant and moss species indicate this change, but also the measurements in the field with low pH values and low conductivity of the water support this hypothesis.

In the Rose fen and the Long Marsh the presence of *Calamagrostis canescens* and *Juncus effuses* (plus *Alnus glutinosa*) indicate desiccation or nutrient-availability. However, the water tables were high at the moment of the observation in June 2013. The possible explanation is that the effects of accumulation of rainwater might dominate. When there is no seepage of groundwater and still addition with rainwater, the water tables can be correct, but the pH and EC values will be too low. Periods with mineralisation of peat soil during dry periods will be combined with periods with addition of rainwater. That is probably what is observed.

As a reference how a correct fen marsh maintains its conditions, the North marsh north can be applied. At this marsh the diversity and structure in the vegetation seems correct. The measured values in pH and EC support this observation.

The impact of other processes that might result in the change in vegetation was also incorporated in this evaluation. First, the effects of acid rain could have dominated the vegetation. However, in most locations the growth of *Sphagnum* species is definitely recent (last decade), and the acid rain was most severe in a period longer ago. Second, direct eutrophication in the fen systems might explain the increased succession. However, there were no indicators for increased input of nutrients from the river (moreover: isolated marshes). Plant and moss species that could directly indicate this cause were absent. Third, a change in management could explain the succession. However, what I observed is that the reed marshes are cut on a yearly base (or in 2 / 3 years) in a proper way; minimal mowing facilitates diversity but this minimal activity is enough to prevent germination of trees. Also this argument seems not valid. (I have the impression that the management remained the same for a long period). Fourth, I could not observe a change in the management of surface water; the fens are isolated from the river system.

Giller & Wheeler (1988) described poor fen locations, scarce and locally in the region but they do not answer the question whether there is a process to explain the presence of ombrotrofic fens in the mesotrophic fen areas. They suggest succession. In the Netherlands the acid and ombrotrofic fen types of vegetation are e.g. rich in liver mosses and the *Sphagnum* species are different. The vegetation type with *Sphagnum fimbriatum* and *Sphagnum squarrosum* indicate in the Netherlands desiccation and acidification, caused by shortage in groundwater supply or by reduced flooding with river water. I could not fully compare with the conditions 20-30 years ago in Catfield fen, but the general conditions seem to be not perfect in present times. If Giller & Wheeler (1988) describe the spots where I observed the excessive growth of *Polytrichum commune*, the present system will be too dry to be maintained as a real fen area.

Restoration of the fen systems that suffered from desiccation / acidification appeared to be difficult. Beltman et al. (2001) offer examples how that might be performed, but the final conclusion is that most activities cannot sustain for a longer period. Dekker et al. (2005) modelled the hydrology of fen systems; the conclusion was that the resistance in peat (organic soil) is too high to stimulate the lateral flow of surface water or groundwater, so that acidified soils cannot be supported with surface water. The only process that can support sustainable restoration is that the groundwater seeps up into the peat layer constantly and directly adds buffer capacity to the soil.

The real explanation of the changes (acidification and succession) might originate from the changed hydrology in the area, comparable with the observed relations in the Netherlands. The publication from Gilvear et al. (1997) offers good information, but it is outdated in data (1988/1989) because the change in vegetation / chemistry is probably from recent periods. What is needed now (in my opinion) is a new research in the flows in groundwater from the elevated areas into the fens; this should be on a local scale. Piezometers installed in some transects from the top of the elevated areas into the real fen areas could assist with this hydrological research. The results can be compared with older data. When the difference in potential energy between the elevated area and the fens is minimal and does not result in a prominent groundwater flow, it explains the observed problems in vegetation and chemistry.

The final conclusion will be that many fens in Catfield Fens are not in optimal conditions in June 2013. When the Catfield Fens are so special that they became a SSSI, some indications (in vegetation and chemistry) point to the fact that characteristic fen-biodiversity is at least affected in a negative way.

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