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Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen.

Explanation of: Characterization of the Relationship between Hydrology and Vegetation in Catfield Fen

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Introduction

Catfield Fen is a pristine site which is representative of the wider Norfolk Broadlands system. It is separated from the river, but depends upon input from groundwater. While Catfield Fen is of high nature conservation interest, it has been suggested in recent decades that the quality of the fen system is declining as indicated by: reduced vigor of reeds; changes in frequency of certain rare fen species and; most notably, the large and increased area covered by *Sphagnum fallax* mosses. Management of Catfield has not changed in recent decades, but groundwater has been abstracted in the elevated area in the immediate vicinity. Locally within the fen vegetation of Catfield are *Sphagnum* islands e.g. with some rare fern species which are also of conservation value.

A conceptual model that hypothesizes the nature of the chemistry of unmodified fen ecosystems is that alkaline water dominates: the waters have high pH values and high concentration of ions like calcium and bicarbonate. These characteristics come about when groundwater flows through the buffered subsoil and discharges in the fen. In the case of Catfield, this water also passes through a discontinuous saline layer so that chloride and sodium concentrations will be high as well. These conditions would not be found if the predominant water source was rainwater, which has a lower pH value and low ionic content. The high level of groundwater that we expect to find in a rich fen is inhospitable to many plants; therefore many plants that we find in fens are rare. When acidic rainwater contributes a greater proportion of water into the system, other plants like grasses and *Sphagnum* mosses can outcompete the natural fen vegetation, which favors neutral conditions. The presence of the *Sphagnum* species, or small bogs that depend on rainwater inputs, conflicts with this general condition of fen vegetation.

With this study we want to determine the relationship between the water characteristics and vegetation at Catfield Fen, with the focus on the *Sphagnum* islands. Previous studies in Catfield Fen have aimed to characterize the hydrology and vegetation separately, yet no research has tried to determine the connections between the water chemistry and plant life at Catfield.

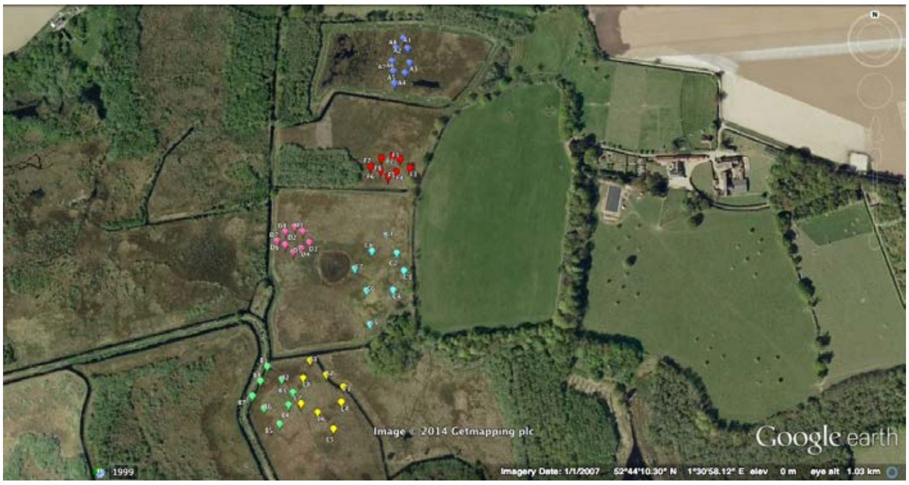

Figure 1: Map of Catfield Fen showing the six sampling locations, each using a different color.

Methodology

In the spring of 2014, we conducted research along six series of intersecting transects in Catfield Fen in order to get a three dimensional picture of chemistry, subsoil and vegetation (Fig. 1). The work especially sought to get a picture of the transition between a healthy rich fen and a *Sphagnum* island, and so the transects extend 20m away from the edge of an island on all sides.

The bulk of the study measures Electric Conductivity (EC) values across the fen, as an indicator for the hydrology conditions. EC is known to correlate with ionic composition, meaning that rainwater contains few ions and has low EC values and consequently high EC values indicate presence of groundwater rich in ions. We used a 2m long probe to measure the EC at 5m intervals on the surface and 20cm depth intervals into the subsoil. We also took samples to measure pH and bicarbonate at the surface at each point of each transect. Moreover, 40 water samples were collected at different layers and locations; these samples were brought to the laboratory to analyze the concentration of major ions. While EC values were being measured, the abundance of certain indicator plant species was recorded at each point. Finally, some drilling was conducted to determine the variation in subsoil and the chemistry of water deeper underground.

Results

Let us consider the example from Mill Marsh West-transect in the analysis with a *Sphagnum* island in the center (Fig. 2). The bottom portion of the figure represents the EC values in the peat, the middle the pH and bicarbonate values and, the top the vegetation. Note the lens of lower EC values found at the surface which extend to a depth of about 60-80 cm in the center of the figure. Furthermore, at the center we also see lower pH and bicarbonate values, indicating conditions where low EC and poor fen vegetation are found. This rainwater lens corresponds directly to the species found at the surface. *Sphagnum* and *Polytrichum* mosses are found in high abundance immediately over the deep lens of rainwater while species more indicative of a buffered fen, like *Cladium mariscus, Peucedanum palustre* and *Carex* species are found only at the edges of the transect where high EC values are found within 20cm of surface. This same phenomenon, in slightly different ways, is observed across other locations in the fen. Where *Sphagnum* is absent, pH, bicarbonate and EC are relatively higher at the surface.

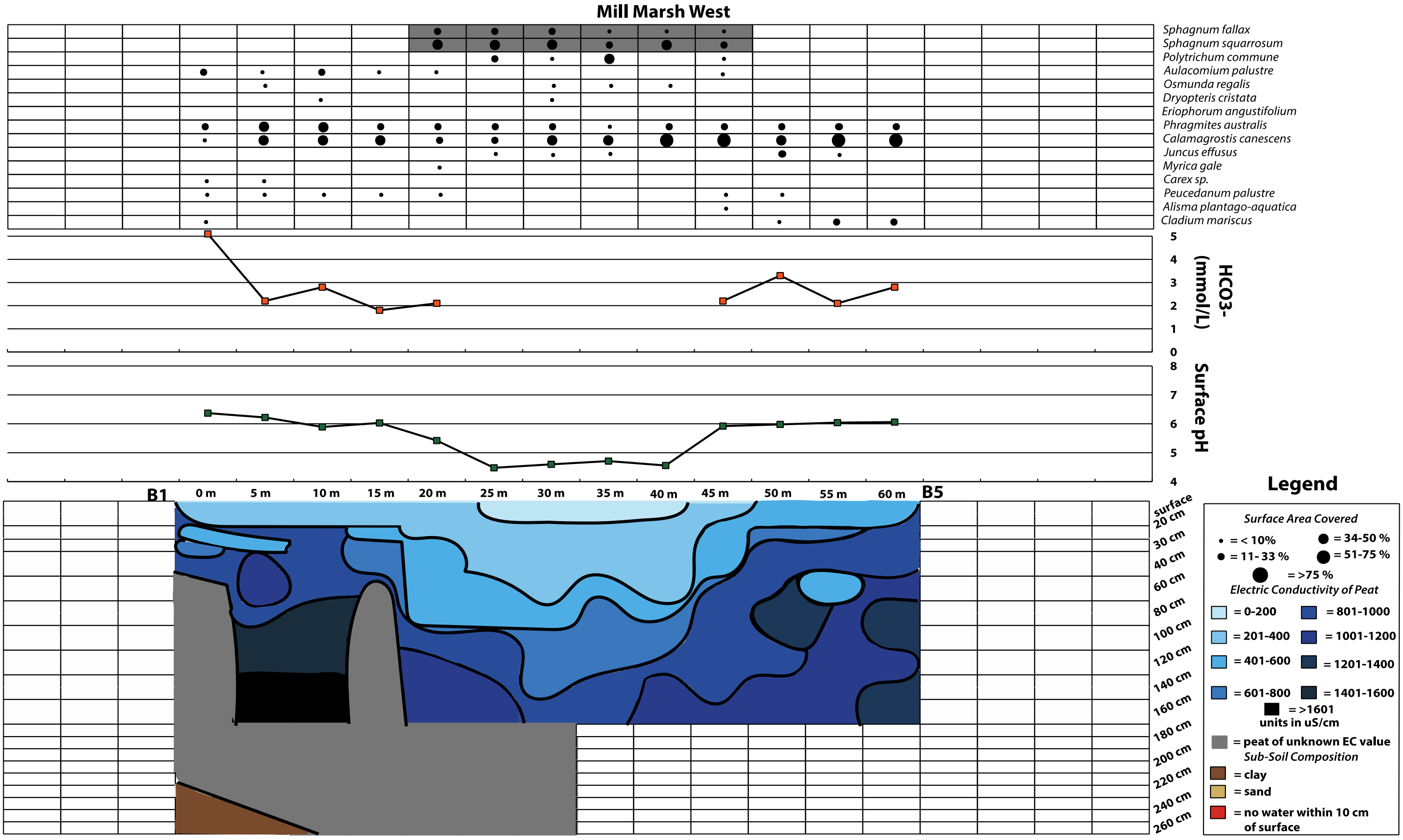

Figure 2: Transect of Mill Marsh West

Looking at general trends across the fen, we see a distinct correlation between the hydrochemistry and vegetation quality. To summarize the differences, we divided all of the 182 points into three vegetation categories to aid in analysis: Rich Fen, Transition Fen and Poor Fen as defined in Appendix 3 of the main report. In Table 1, we see that areas of poor fen correlate strongly with a reduction in groundwater flow.

Indicator	Rich Fen	Transition Fen	Poor Fen
EC at 20cm depth	648.94	381.79	257.93
pH	6.03	5.33	4.55
Calcium	33.11	21.41	2.52
Magnesium	10.70	7.42	2.12
Sodium	40.16	31.92	12.23
Chloride	75.48	58.77	26.78

Table 1: Average values for indicators across the fen divided by vegetation category.

Discussion

Observing average results of chemistry in the peat (Fig. 3 summarizes all EC measurements), the deeper layers in the peat have a higher EC from groundwater, which is also indicated by samples with higher calcium and chloride concentrations. At the surface are local *Sphagnum* islands with low EC values radiating out from the center of the island. The samples taken far from the island from depths of 0.5 and 2.5m are relatively similar in EC, pointing to the presence of groundwater. Moving toward the island we see sharp declines in ionic composition at surface. In fact, EC decreases by almost half from 20m away from the island to the island's edge with a noticeable decline in EC to the center. Moving to the center of the island the concentration phosphorous becomes higher (through chemical processes due to the low pH values).

The acidified islands spread due to the storage of rainwater and to the acidification by discharge of H^+ ions from the *Sphagnum* moss itself. It seems that the area and number of islands increased in recent years. But there is one remarkable aspect in the data: the islands seem to accumulate rainwater but the islands float on the groundwater. The islands are caused by hydrological process resulting in the accumulation of rainwater at the top, but at depth, the water source remains groundwater. Some islands are present for a long period; very local conditions (e.g. resistance in subsoil) might cause the hydrological conditions that groundwater cannot reach surface.

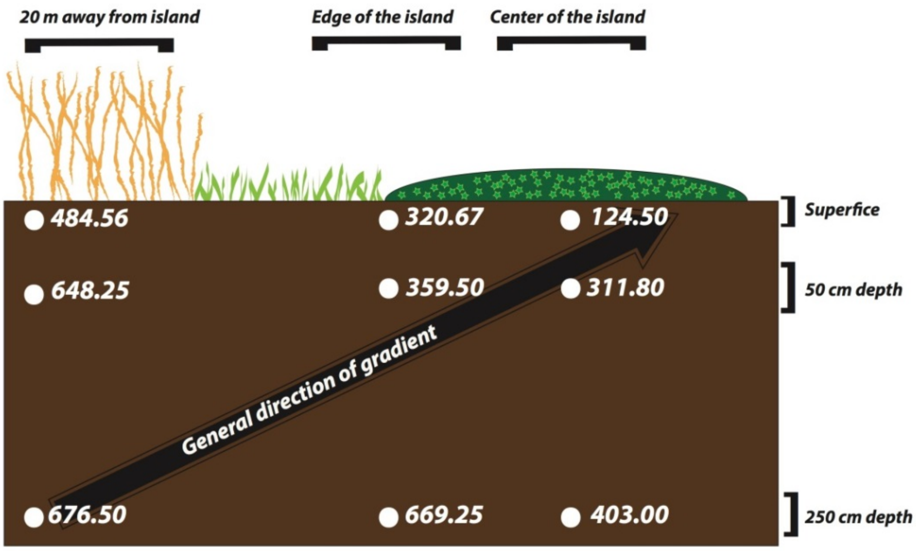

Figure 3: Scheme with mean EC values (µS/cm) at different depth and distance from an island.

The transition community with e.g. *Sphagnum fallax* appeared to be present in many locations in Catfield Fen. It is reported that this community has expanded recently. It is characterized by the accumulation of rainwater (Table 1), but this is only represented in the top layer (10-20 cm) and the groundwater input at surface is reduced. It seems that in recent years less buffered groundwater discharges at Catfield and as a consequence acid rainwater has accumulated on top of the soil, stimulating the presence of *Sphagnum fallax*. The balance in input with rainwater and groundwater changed at many locations in favor of acid rainwater and by this process it reduced the area providing the specific conditions suitable for rich fen vegetation, and also for *Cirsium dissectum* vegetation in Middle Marsh East.

In general, the number of locations where calcium-rich water is present at surface is very limited in spring 2014. The higher concentration in chloride and sodium at these locations prove the discharge of groundwater that has passed through saline layers. The absence of rich fen conditions, including vegetation, at many other locations is recent and can be explained by less groundwater input. Because the balance between rainwater and groundwater is dynamic in time, the overall effects of a change may only become visible after many years. Finally, on the most elevated and isolated locations, the *Sphagnum* islands may have been established a long time ago and probably they will maintain their conditions and vegetation, even when groundwater flow is prominent again.

Conclusion

Detailed research in groundwater chemistry in Catfield Fen indicates that many differences are present on a very local scale. Spatial variation in subsoil and in conditions caused by hydrology (vertical and lateral) is visible at a scale of 5-10m. The number of locations with rich fen vegetation and higher pH values, is restricted in 2014. The older *Sphagnum* islands are localities in the fen with 30-80 cm of rainwater chemistry in the soil, and deeper it is groundwater chemistry. The acid top layer with *Sphagnum fallax* is present at many locations but the acidification is only 10 cm deep. Detailed hydrological research is missing to link the variation in vegetation and groundwater chemistry with the hydrological flows. The general impression is that rain water is dominating the water balance in Catfield Fen and that the proportion of groundwater is reduced.

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