Ecohydrology of an Embanked Lowland UK River Meadow and the Effects of Embankment Removal

H.M. Clilverd[1], J.R. Thompson[1], C.D. Sayer[1], C.M. Heppell[2], and J.C. Axmacher[1]

B23D-0473

[1]Department of Geography, University College London, Gower Street, London, WC1E 6BT, UK
[2]The School of Geography, Queen Mary University of London, Mile End Road, London, E1 4NS, UK

Introduction

- A wetland's hydrological regime determines the plant communities that are present. This is largely attributed to variations in water-table depth, and the magnitude-frequency characteristics of flood events, which in turn effect aeration stress in the root zone.
- Floodplain meadows are a resource of high nature conservation value in the UK. However river channelization and artificial embankments, soil drainage, and substantial increases in the application of inorganic fertilisers have altered the eco-hydrology of these habitats.
- Floodplain restoration, through embankment removal and the reconfiguration of river channels (Fig. 1), is now being increasingly employed to re-establish river-floodplain connection and assist the recovery of lost or declining species.

Research questions

1) **What is the relative importance of soil moisture and fertility on plant communities on a disconnected floodplain?**

2) **What is the relationship between aeration status and oxygen content in the root zone?**

3) **What is the likely long-term impact of floodplain restoration on plant biodiversity?**

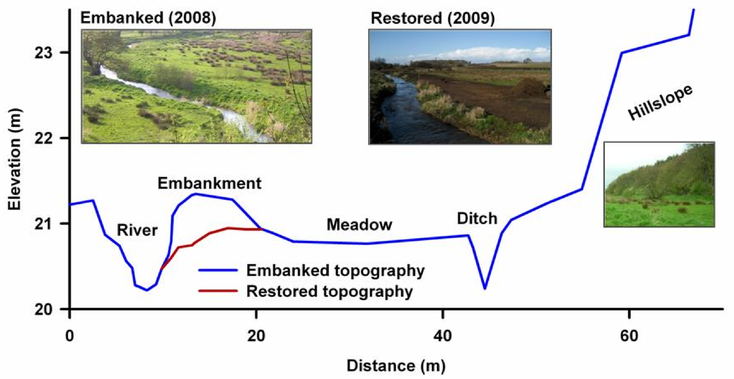
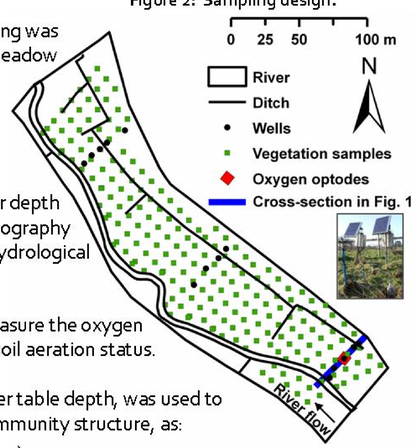


Figure 1: Cross-sections of the embanked and restored River Glaven floodplain.

Methods

Figure 2: Sampling design.



- Fine scale botanical and chemical sampling was conducted on an embanked grassland meadow on the River Glaven (Norfolk, England) to assess the spatial pattern of plant communities in relation to soil physicochemical conditions (Fig. 2).
- Continuous observations of groundwater depth and river stage, and dGPS surveys of topography were used to determine the long-term hydrological impacts of river restoration.
- Buried oxygen optodes were used to measure the oxygen status of the rooting zone and relate to soil aeration status.
- A cumulative stress index, based on water table depth, was used to estimate the aeration stress on plant community structure, as:

$$SEV_{as} = \int_1^N (D_{ref} - D_w)dt$$

where SEV_{as} is the sum exceedance value in metre weeks; N is the number of weeks from March - September; D_{ref} is the reference water-table depth (m) where air-filled porosity at the surface = 0.1; and D_w is the average depth to the water table (m) (Barber *et al.* 2004).

Results

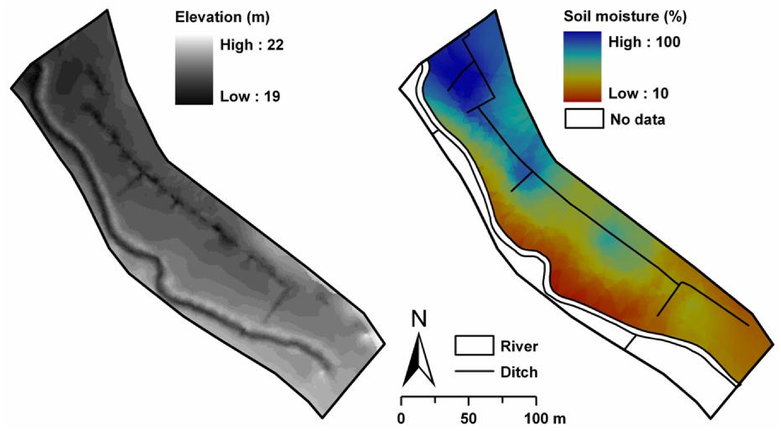


Figure 3: Topography and associated moisture gradient on the embanked floodplain.

- Soil water content and elevation were closely linked (decreasing in a north easterly direction) and exhibited a negative linear correlation ($r^2 = 0.52$, $p<0.05$; Fig. 3).
- Topsoil was fairly fertile (Fig. 4a), and river water was enriched in nitrate relative to groundwater (Fig. 4b).

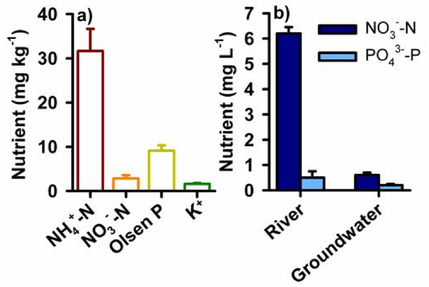


Figure 4: (a) Soil and (b) water chemistry.

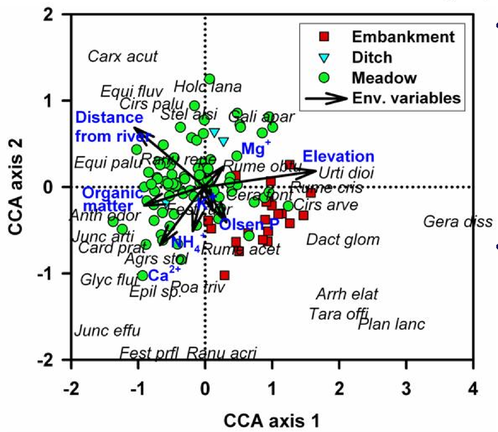


Figure 5: Canonical correspondence analysis (CCA) of vegetation data (67 species were analysed from 163 samples).

- Species richness was low (mean: 8 spp. per m²) and indices of alpha- diversity suggest low heterogeneity of the plant assemblages (mean Shannon's Diversity and 1/Simpson's Diversity = 1.4 and 3.4, respectively).
- Plant species associations chiefly occurred along a soil-moisture and elevation gradient on the meadow ($r = 0.79$; $p<0.05$) , and secondly according to soil fertility ($r = 0.63$; $p<0.05$) (Fig. 5).

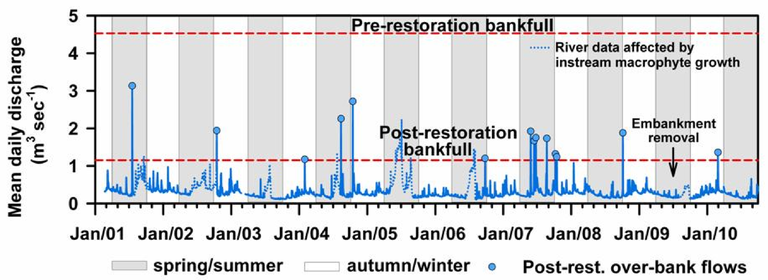


Figure 6: Mean daily river discharge from 2001 – 2010. Pre- and post-restoration bankfull capacity is shown, above which inundation of the floodplain would have occurred.

- Removal of the embankments has reduced bankfull capacity by 75% to 1.15 $m^3 s^{-1}$, a change which is sufficient to initiate over-bank inundation. Historical data suggest that future overbank flows will be of short duration (<1 day), separated by large time intervals (Fig. 6).
- Groundwater levels were typically close to the soil surface, but were lower after the restoration (Fig. 7). This could be associated with improved drainage after the embankment removal and/or the prevailing low rainfall during this period (Fig. 8).
- Sum exceedance values for aeration stress (SEVas) ranged on average from 1.9 – 3.8 metre weeks suggesting that plants experienced a high degree of aeration stress (Fig. 8).

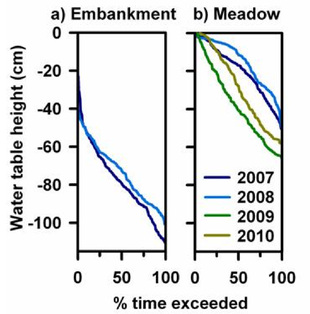


Figure 7: Water table duration curves before (2007/08) and after (2009/10) the restoration on (a) the embankment and (b) the meadow.

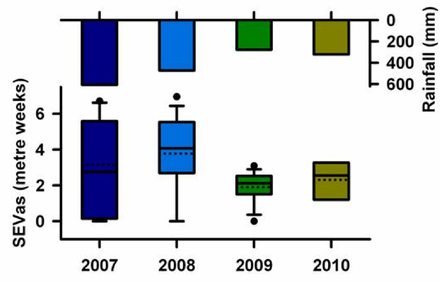


Figure 8: (top) Total rainfall (March - September) and (bottom) SEVas before (2007/08) and after (2009/10) the restoration.

- Oxygen status of surface soil pores was closely linked with water table height (Fig.9a).
- During waterlogged conditions, soil pores were filled with anoxic groundwater (mean DO = 0.85 ± 0.26 µM). During the 2010 growing season, vadose dissolved oxygen (DO) (295 ± 5 µM; 88 ± 2 % air saturation) was close to atmospheric levels (Figs. 9a & 9b).

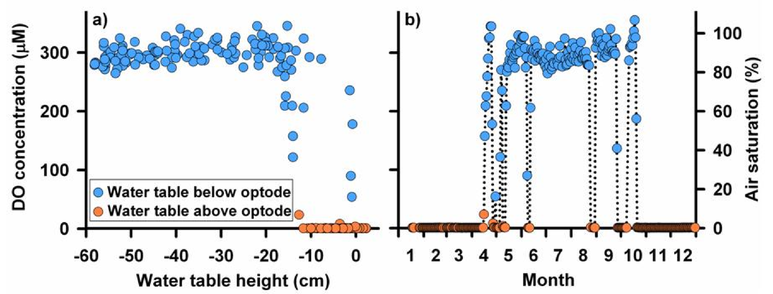


Figure 9: Relationship between mean daily dissolved oxygen (DO) concentration in soil and mean daily water table height (a), and time series of DO concentration (b). The DO optode was buried in soil 10 cm below the ground surface.

Conclusions

- Hydrology was the primary driver of plant community composition. However, soil fertility was also important. As is the case in many nutrient-rich habitats, Hunworth Meadow exhibited a high dominance of a few plant species.
- Oxygen optodes provided unique, direct measurements of vadose DO concentrations. High vadose DO concentrations were consistent with low aeration stress values during the same period, and support the use of water table depth as a proxy of oxygen status in soils.
- Inter-annual climate variability complicates direct comparisons of pre- and post-restoration hydrological conditions (Clilverd *et al.* in press). Therefore, hydrological/hydraulic modelling (Fig. 10) is being used to simulate the long-term effects of river restoration on floodplain hydrology and aeration stress in plants.

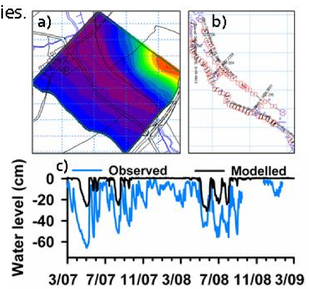


Figure 10: (a) MIKE SHE and (b) MIKE 11 models, and (c) pre-calibration groundwater results.

Contact h.clilverd@ucl.ac.uk for reference list.