# Carbon in the Broads fens

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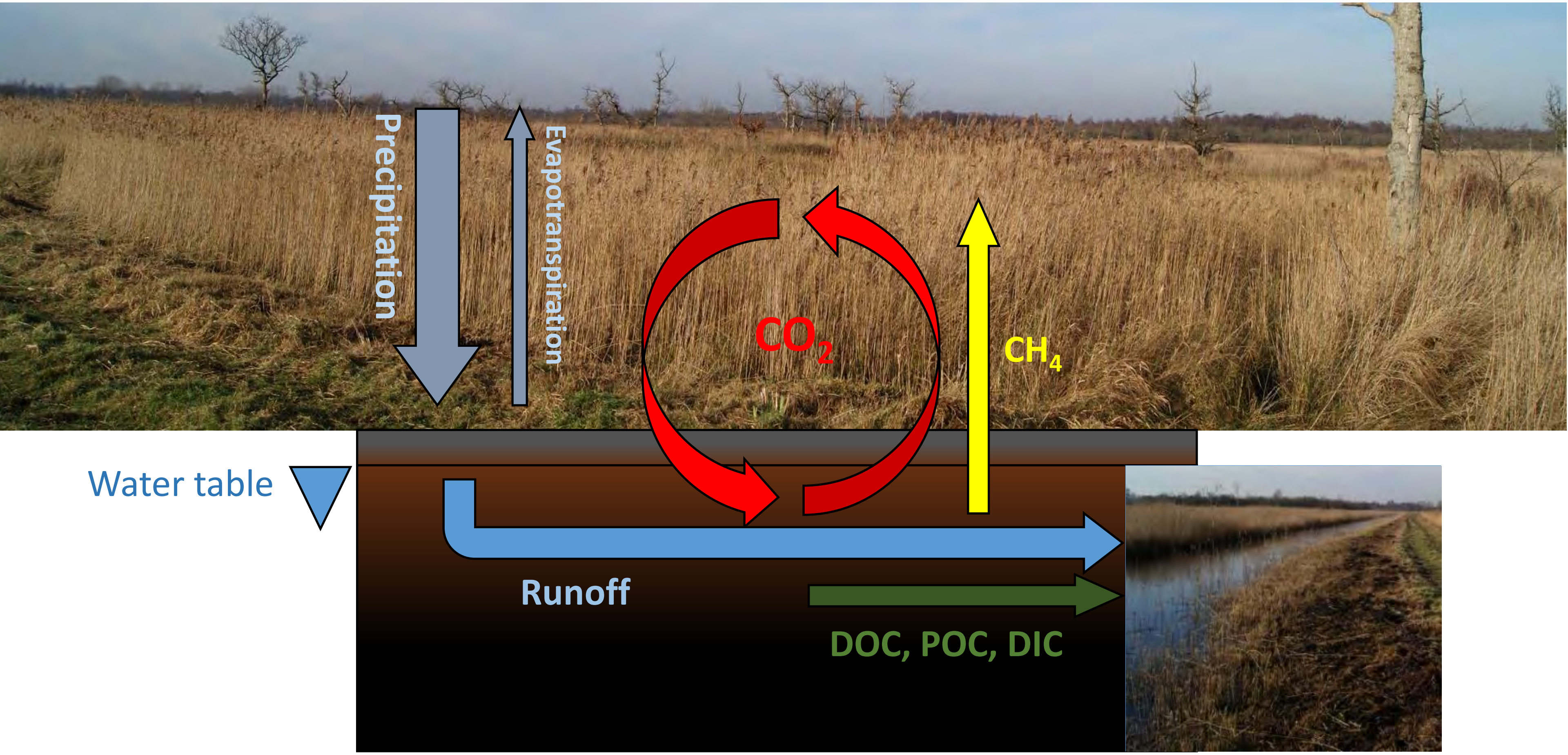
**Kieran Stanley (NERC / Defra funded PhD student)**

The impacts of nutrient loading on greenhouse gas exchange in floodplain fens.

**Eleanor Webster (NERC CASE funded PhD student)**

How will projected sea-level rise affect carbon storage in floodplain fens?

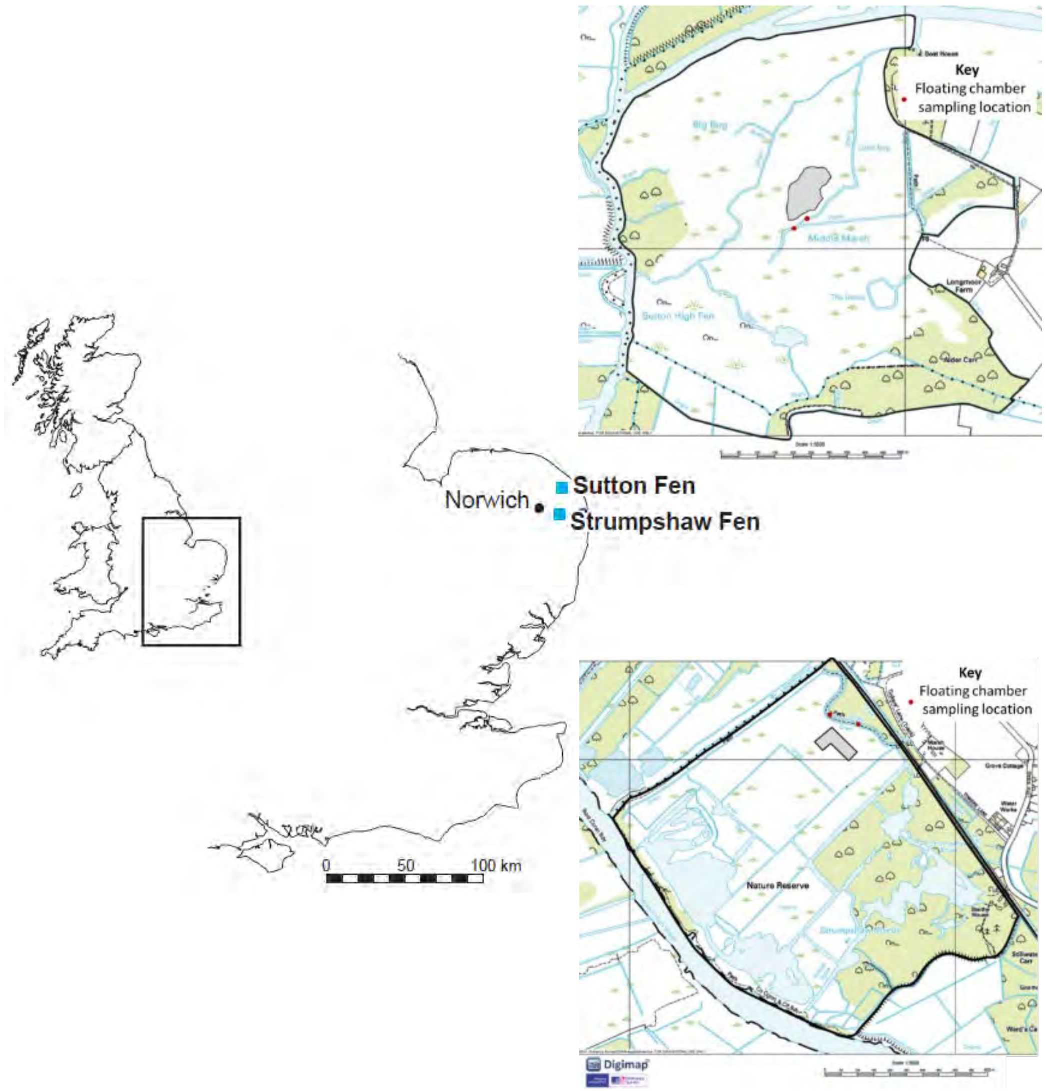
# Carbon storage in fens as an ecosystem service




- Carbon storage achieved by photosynthesis of plants and subsequent storage of plant biomass in peat
- Balanced against release of $CH_4$ and $CO_2$ to the atmosphere (via plants, diffusion and ebullition)

# Sutton Fen and Strumpshaw Fen

## Are these fens a net source or sink of carbon on an annual basis?




<u>Similarities:</u>

Vegetation cut in 2009

> 3 m peat (sig. carbon storage)

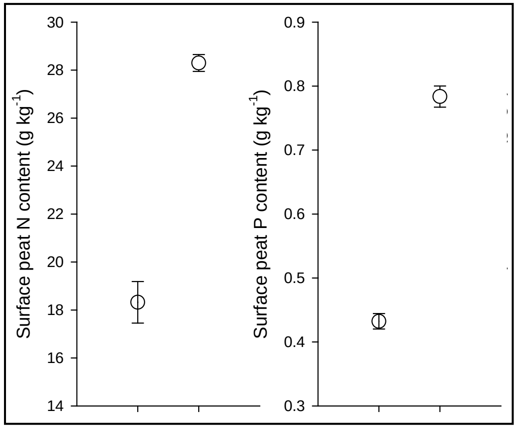
Conservation management

<u>Differences:</u>

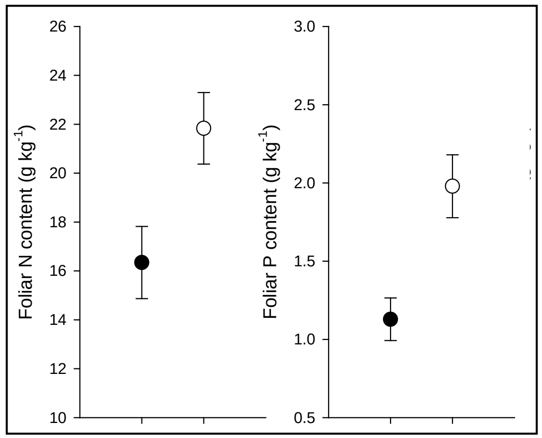
Nutrient status

National Vegetation Classification

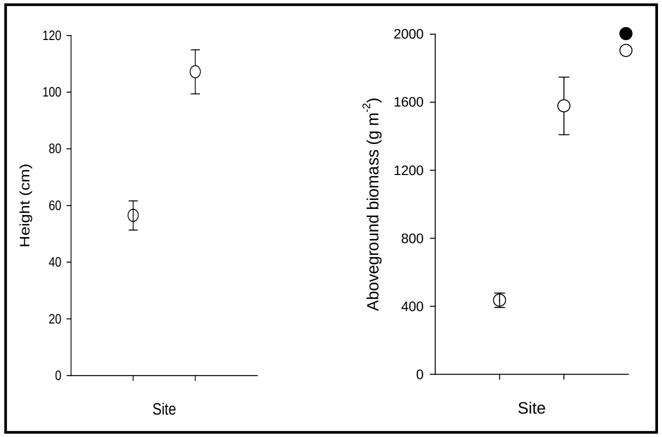
# Sites of contrasting nutrient status




Peat N and P content
sig. higher at Strumpshaw



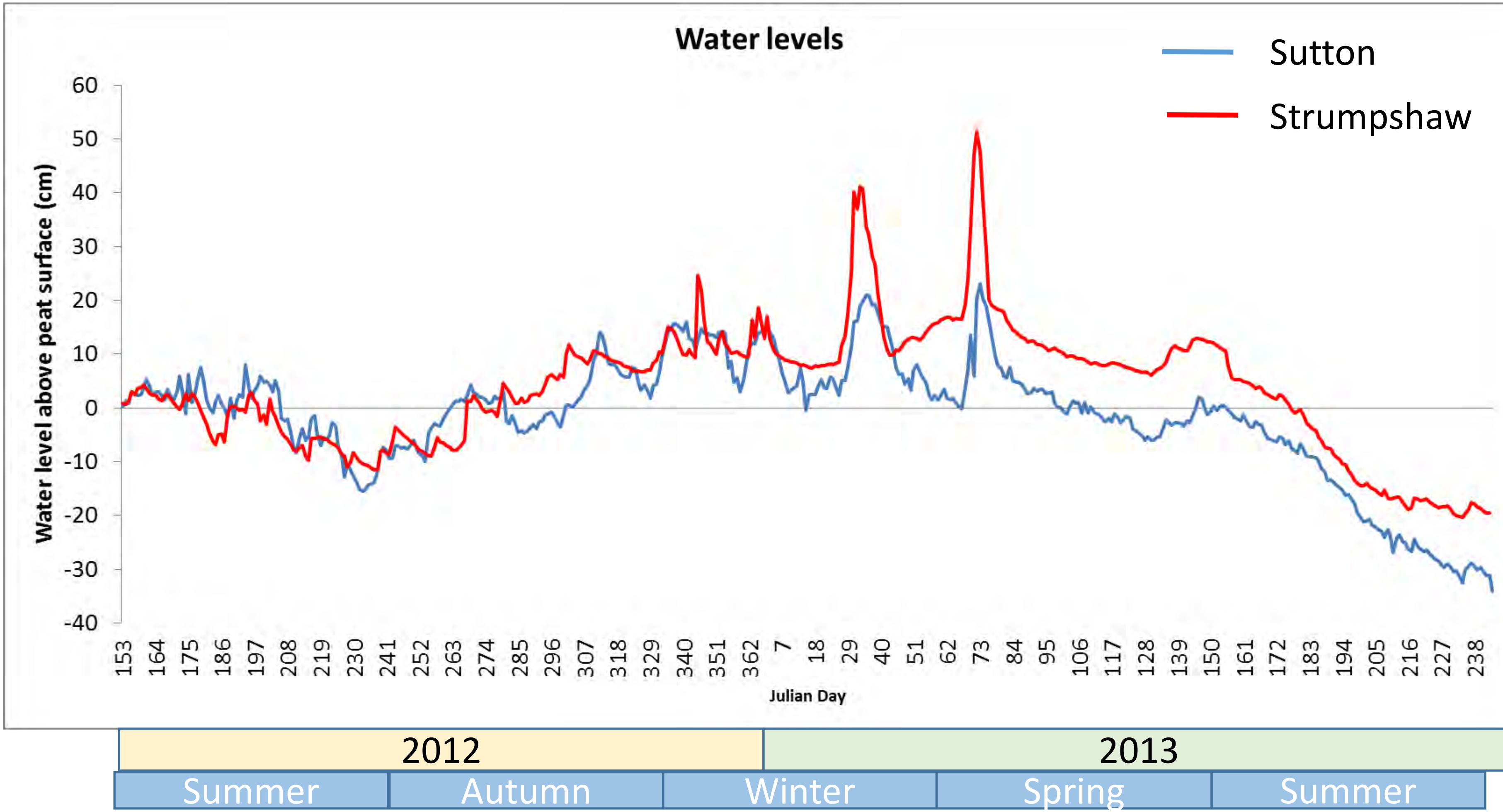

Foliar N and P content
sig. higher at Strumpshaw



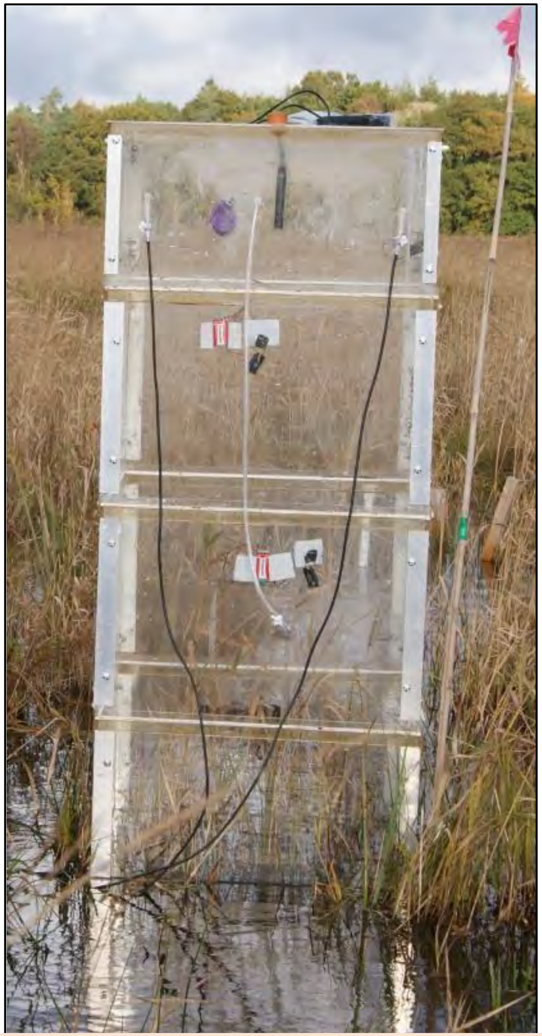

Vegt'n height and biomass
sig. higher at Strumpshaw

| Site | No. Species | NVC |
|---|---|---|
| Sutton | 34 | S24 *Phragmites-Peucedanum* |
| Strumpshaw | 31 | S25 *Phragmites-Eupatorium* |

# Mean water levels during study



# Measurements of carbon fluxes

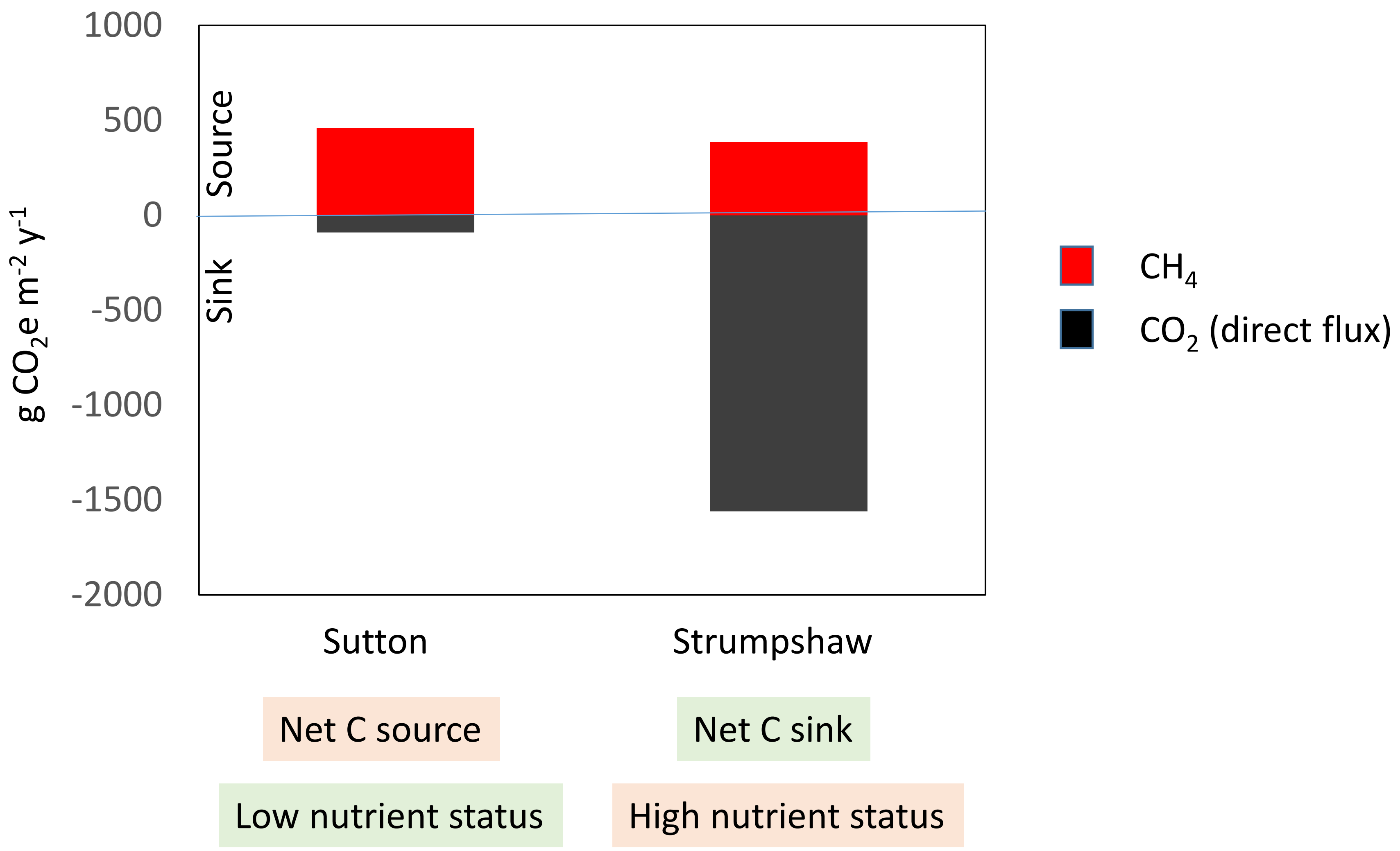


Static chambers to capture diffusive and plant-mediated C fluxes (n=6 at each site)

Funnels to capture ebullition (bubbling) of methane from peat (n=12 at each site)

Floating chambers to capture diffusive C fluxes from water (n=2 at each site)

# Global Warming Potential: 100-yr period



# Quantifying GHG fluxes from managed UK peatlands: Defra Lowland Peat Project

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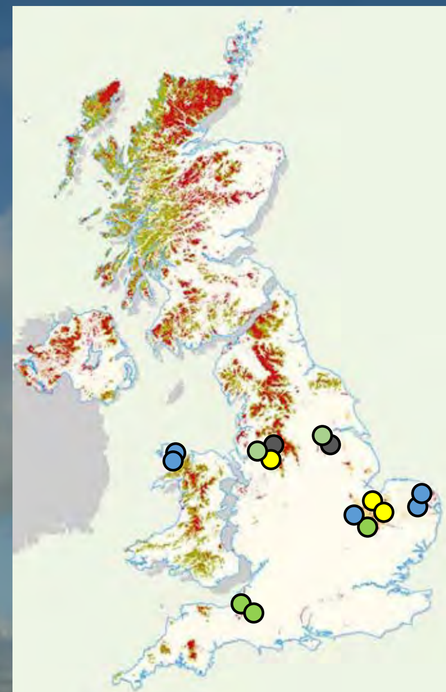
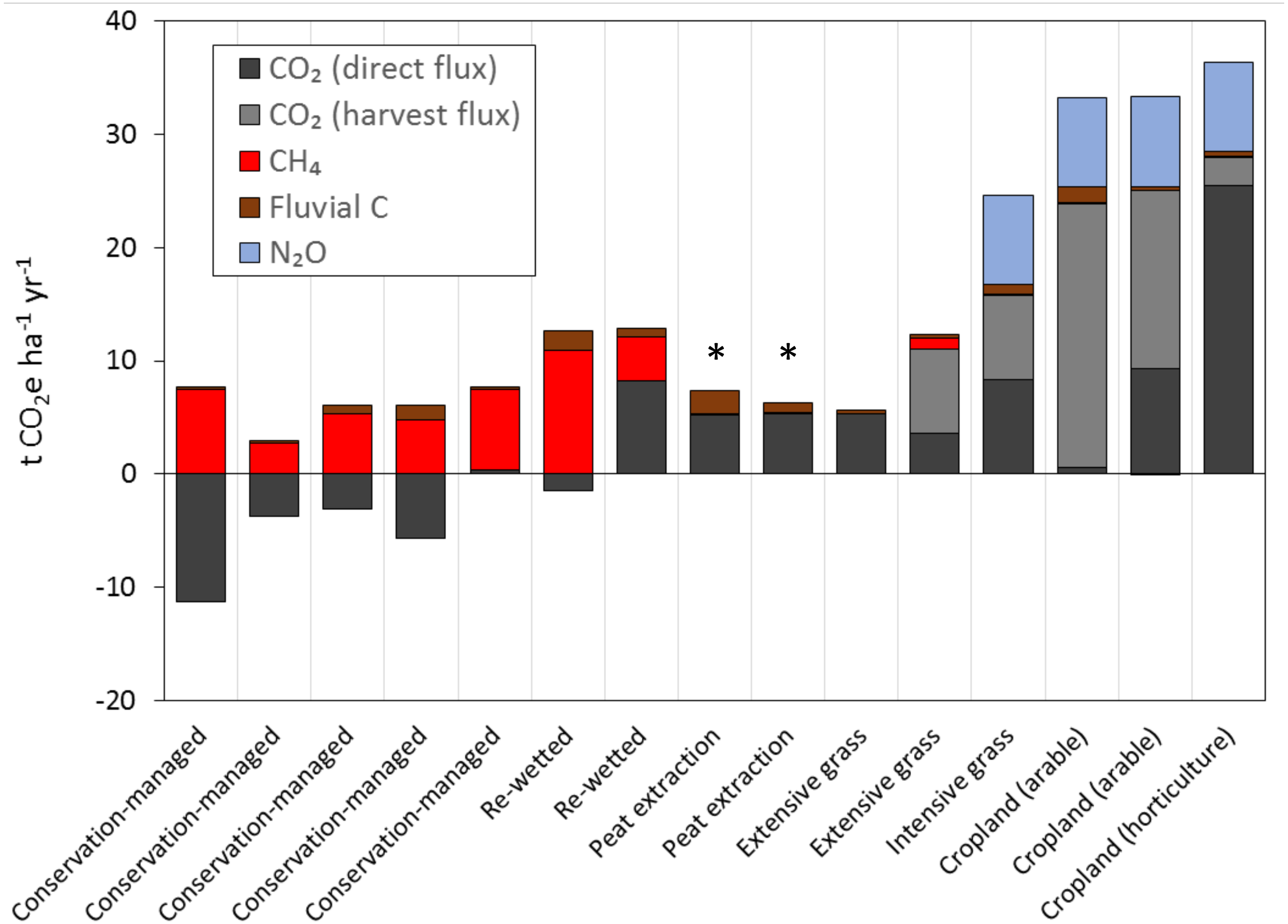


*Chris Evans, Ross Morrison, Annette Burden, Jenny Williamson, Andrew Baird, Emma Brown, Nathan Callaghan, Pippa Chapman, Alex Cumming, Hannah Dean, Simon Dixon, Gemma Dooling, Jonathan Evans, Vincent Gauci, Richard Grayson, Neal Haddaway, Yufeng He, Kate Heppell, Joseph Holden, Steve Hughes, Jörg Kaduk, Davey Jones, Rachel Matthews, Nina Menichino, Tom Misselbrook, Sue Page, Gong Pan, Mike Peacock, Mark Rayment, Luke Ridley, Inma Robinson, Matthew Scowen, Fred Worrall*

# Full GHG balance, all lowland peatland sites




Conservation-managed sites have lowest C emissions to atmosphere (as $CO_2e$)
$CH_4$ plays an important contribution to overall GHG fluxes

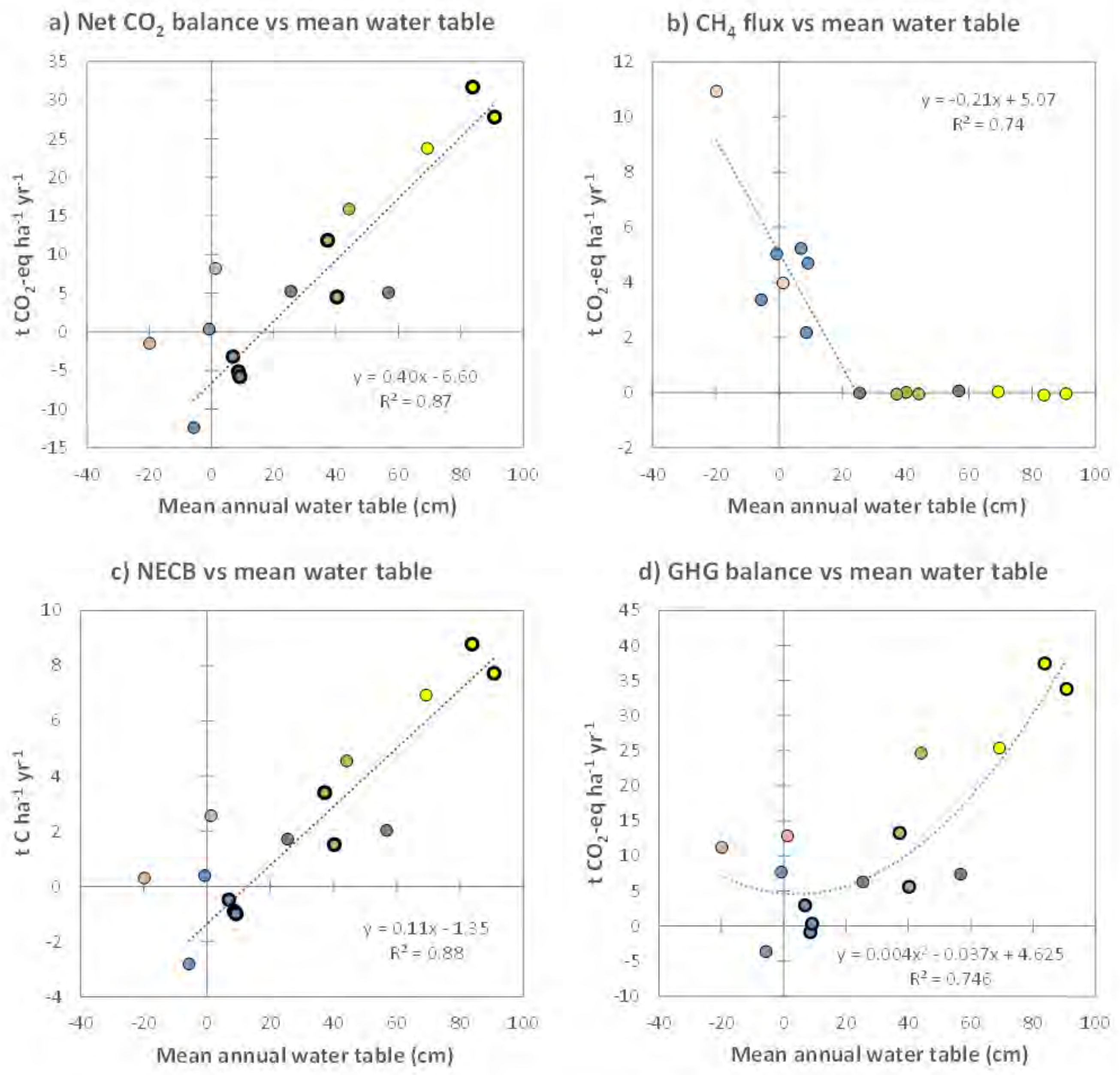
*Evans et al., Report to Defra (2017)*

* Inactive extraction sites, so emissions from harvested peat not included

# Water level is an important control on C fluxes

- Near-natural fen
- Re-wetted bog
- Extraction
- Grassland
- Cropland

*(Re-wetted former peat extraction sites appear to be outliers)*



Findings:

- Methane fluxes from fens are high compared to other lowland peatland types due predominantly to higher water levels, so idea of fens as net carbon sinks may be an over-simplification
- Role of fen as a net C sink or source may be dependent on nutrient status (which influences productivity) however, this is in conflict with desire for high plant biodiversity
- The management of nutrients and water level is critical to ecosystem services with respect to carbon in fens

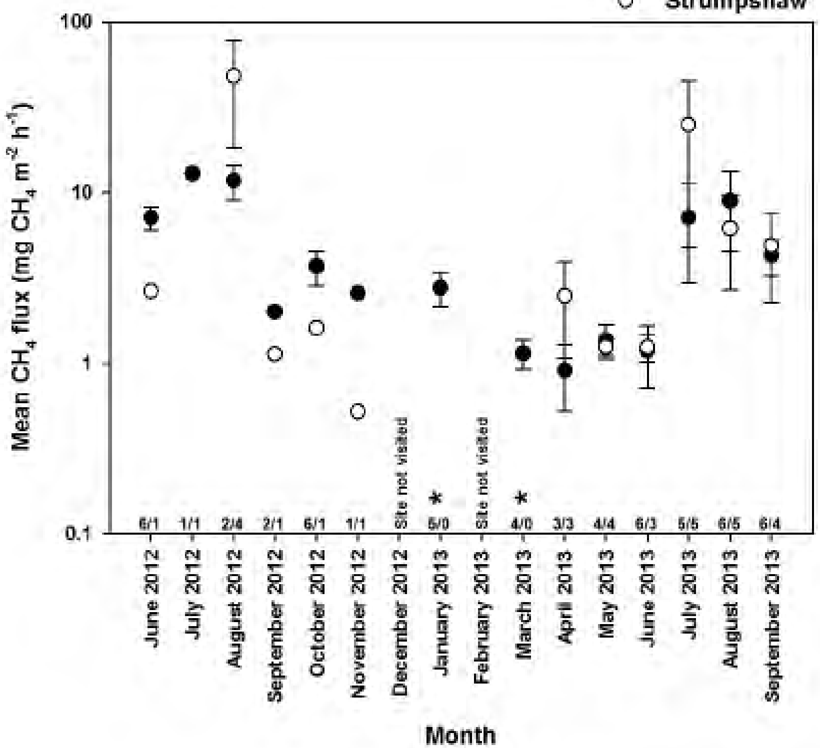
Limitations:

- Only measured for one cutting regime (2-yrs after cutting) at two sites so productivity may not be typical (cf. measures of above ground biomass for other sites?)
- Only NVC S24 and S25 - other vegetation classifications? Phragmites is an active $CH_4$ transporter bypassing $CH_4$ oxidisers in peat
- Role of reed harvest/mowing is not yet accounted for: depends on balance of above-ground and below-ground biomass and fate of material (e.g. burning)

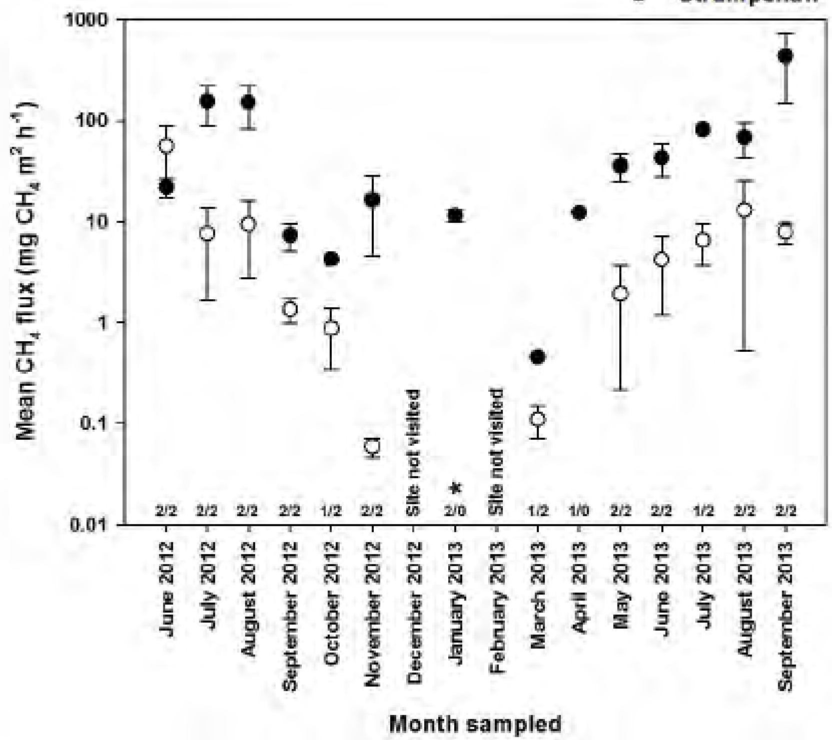
- Does not include contribution of open waters (ditches, dykes and turf ponds)
- Assumes 'business as usual' over 100-year time period but storm surges increasing so potential changes in salinity and water level which may influence C cycling

# $CH_4$ fluxes to the atmosphere from open water

Vegetated peat

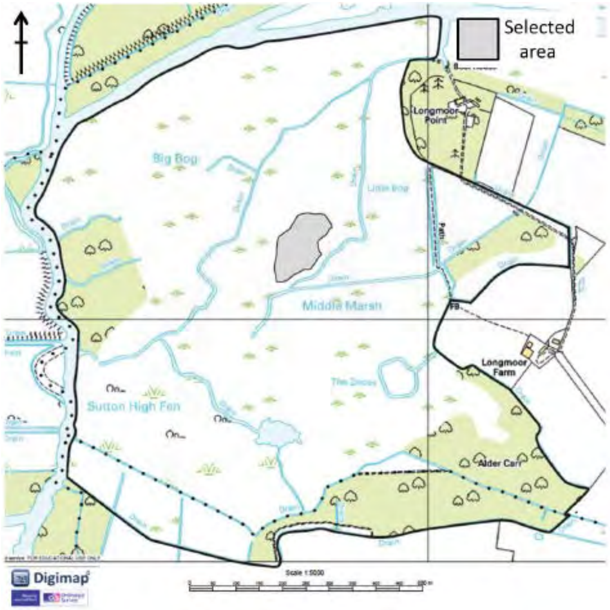


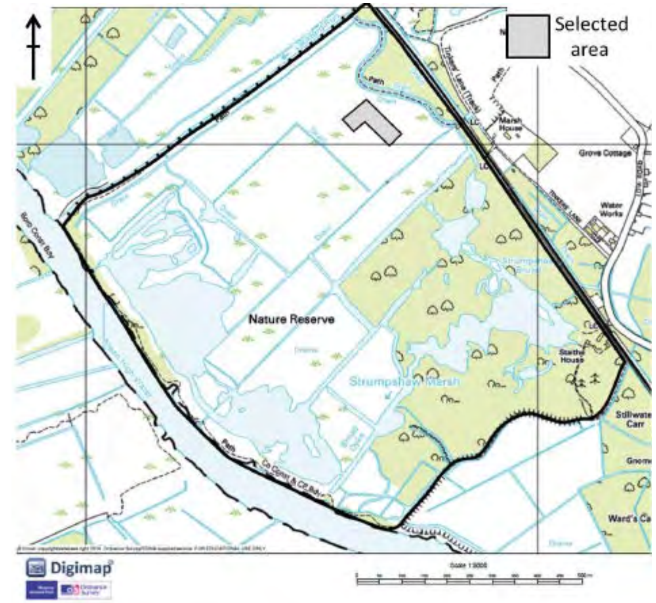

Ditches (n=2 at each site)




Methane was transported from reeds and ditches to the atmosphere throughout the study

Methane fluxes (on unit area basis) from ditches often exceed fluxes from reeds




| Site | % cover | | Methane from site (Mg $CH_4$ $y^{-1}$) | |
|---|---|---|---|---|
| | Open water | Reed | Open water | Reed |
| Sutton | 4 | 96 | 22.54 | 29.64 |
| Strumpshaw | 21 | 48[a] | 13.00 | 39.10 |

[a]fen carr = 31% (not evaluated); [b]calculated on basis of annual mean flux by unit area

Overall methane loss from open water is significant
Few replicates (n=2 per site x 16 separate occasions) so further evaluation necessary

# Carbon storage in the Broads

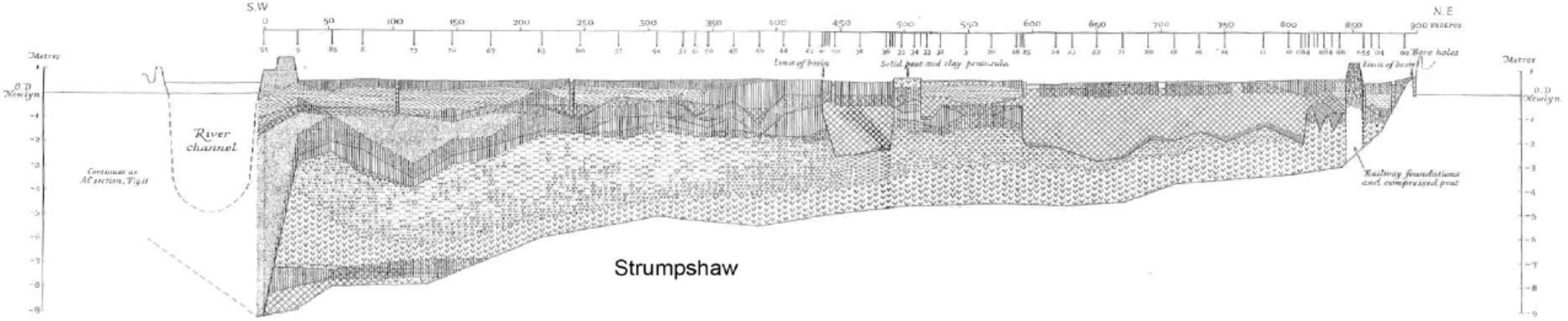
Area-specific C stock = C density × peat depth

Total C stock = C density × peat depth × surface area


Fen surface area from aerial photography (Google Earth).

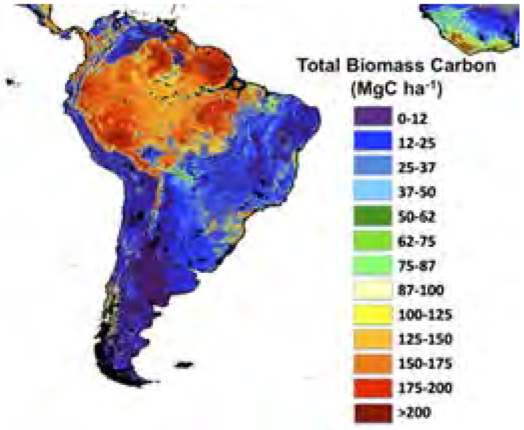
Peat depths from Joyce Lambert's stratigraphic transects.

C density from field sampling & lab measurements: dry bulk density × C content



# Carbon storage in the Broads

| Site | C density (Mg C ha$^{-1}$) | Scaled peat depth (m) | Fen surface area (ha) | Area-specific C stock (Mg C ha$^{-1}$) | Total C stock (Gg C) |
|---|---|---|---|---|---|
| Wheatfen | **22.2** | 4.3 | 45 | **946** | 43 |
| Strumpshaw | **31.9** | 5.6 | 74 | **1780** | 132 |



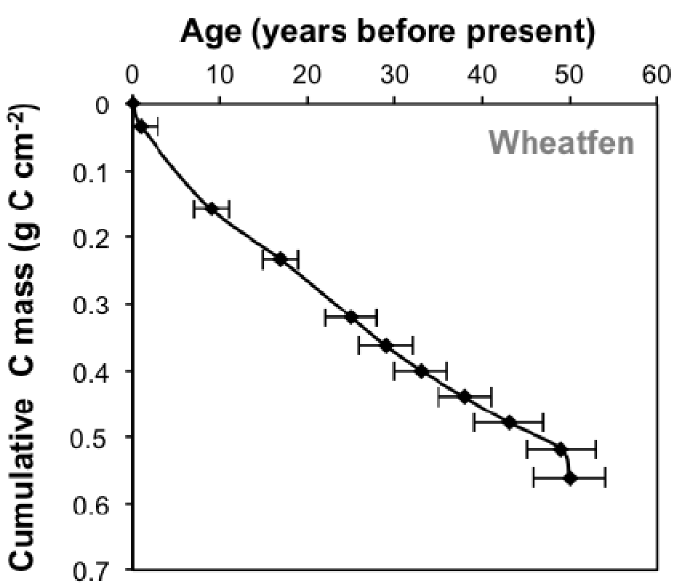
Source: Saatchi et al. (2011)

C density, bulk density & C content were lower than global averages for peat (C density 58 Mg C ha$^{-1}$; Loisel et al., 2014).

Peat depth has a strong influence on the amount of C stored, but is variable and is generally poorly estimated (Lambert's heroic effort excepted!) .

***On a per area basis, the Broads store about 10 times the amount of C in tropical forest biomass.***

# Recent rates of C sequestration and vertical accretion

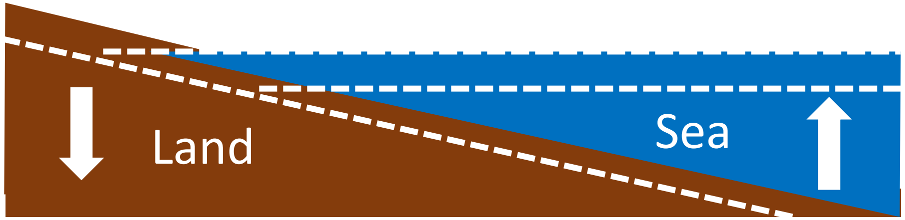

| Site | Accretion (mm $y^{-1}$) | C sequestration (t C $ha^{-1}$ $yr^{-1}$) |
|---|---|---|
| Wheatfen | 2.7 | 1.1 |
| Woodbastwick | 2.6 | 1.2 |
| Strumpshaw | 2.8 | 1.1 |

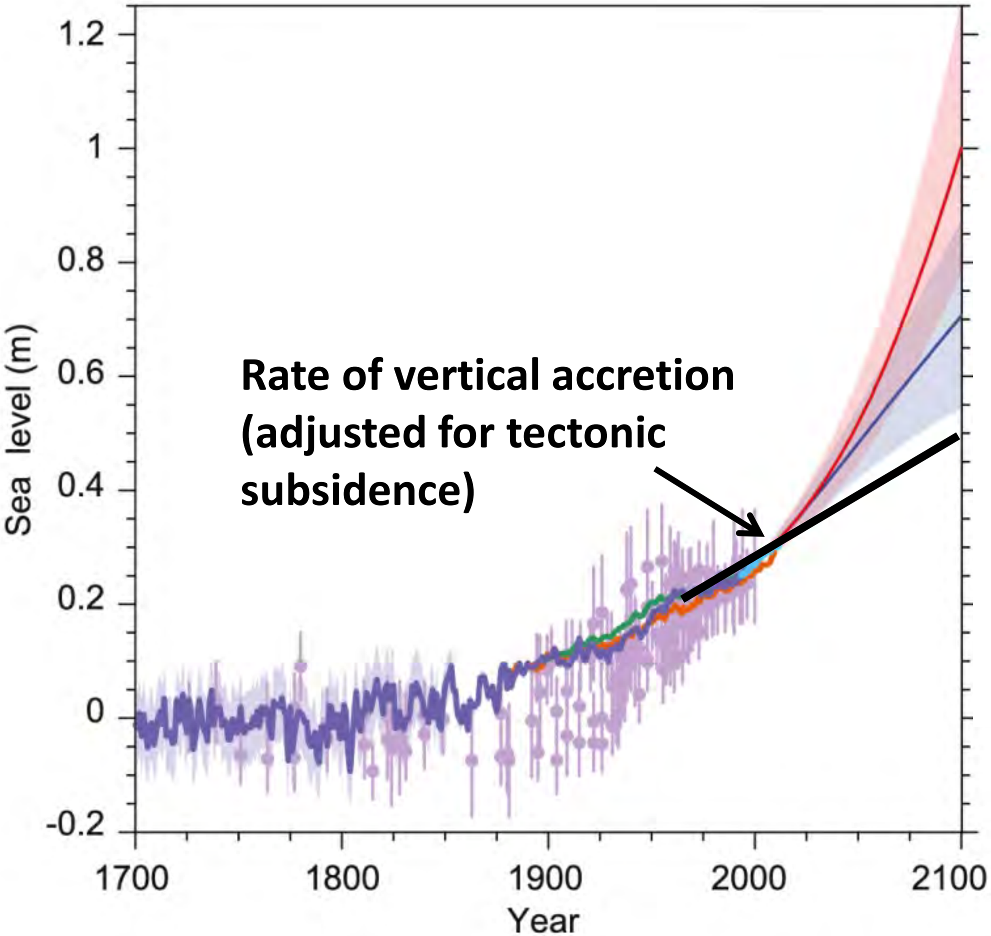
Values fairly typical for similar wetlands around the globe.

How does rate of vertical accretion compare with rate of sea-level rise?

# Projected sea-level rise

SLR in UK from 1901 to 2010: ~1.4 mm $y^{-1}$
Land subsidence in Broads: ~0.5 mm $y^{-1}$
Relative SLR: 1.4 + 0.5 = ~**1.9 mm $y^{-1}$**




Global sea level is rising due to added water + thermal expansion.

The pace of SLR is increasing.

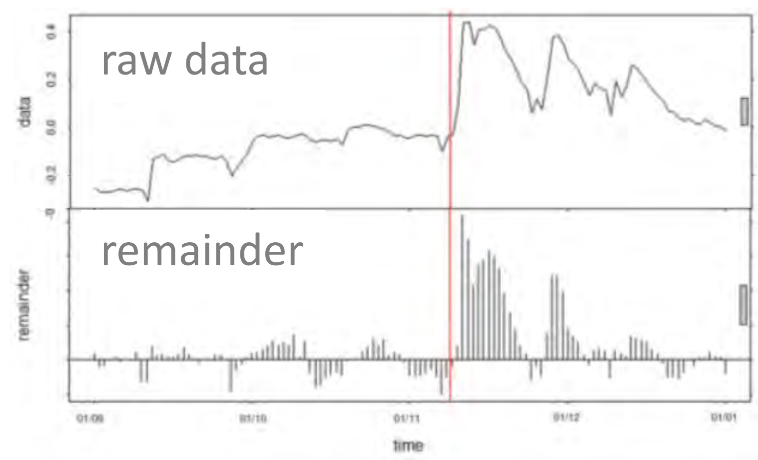
***Vertical accretion of Broads fens cannot keep pace with projected relative SLR.***

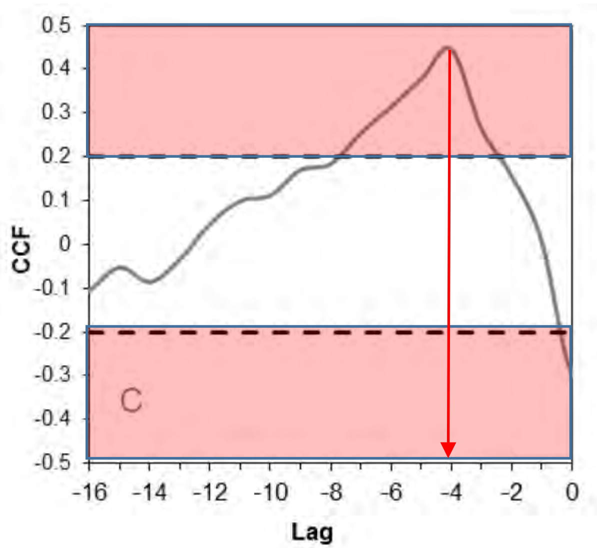
*IPCC AR5, 2013*

# Tidal storm surge, 9th November 2007

Tide gauge


Strumpshaw water level

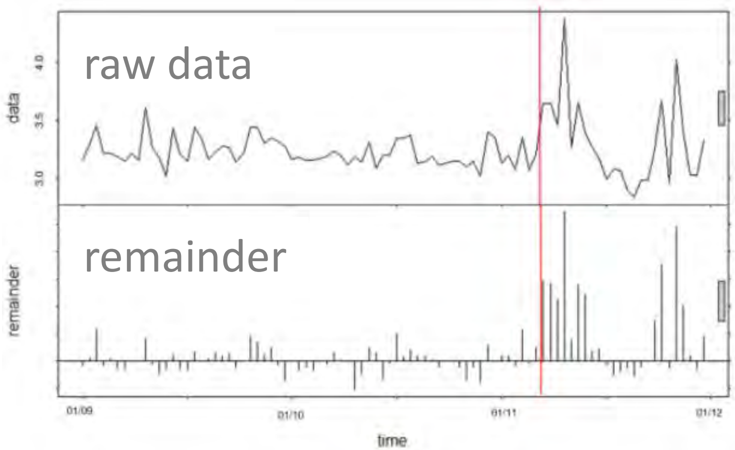


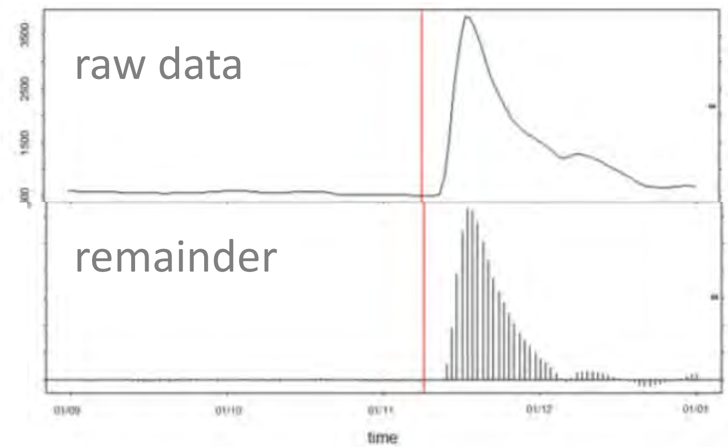

Strumpshaw water level responded to tidal storm surge, with a lag of about 4 days.

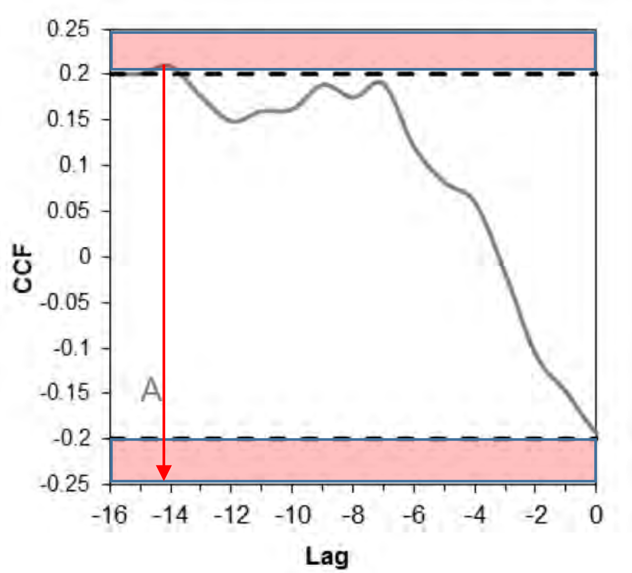
# Tidal storm surge, 9th November 2007

Tide gauge




Catfield electrical conductivity

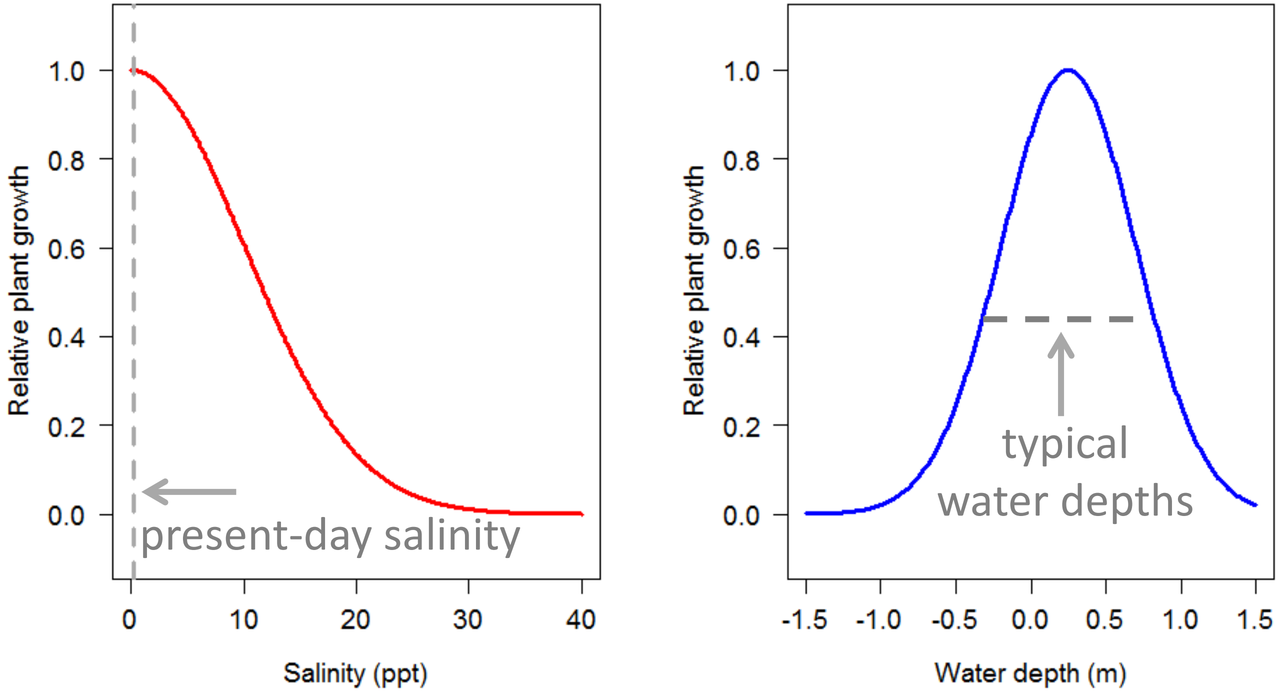



Catfield EC responded to tidal storm surge, with a lag of about 14 days.

# Environmental drivers of vertical accretion and C sequestration

## Response of *Phragmites* growth to salinity and water depth




Plant growth has a strong influence on rate of C sequestration.

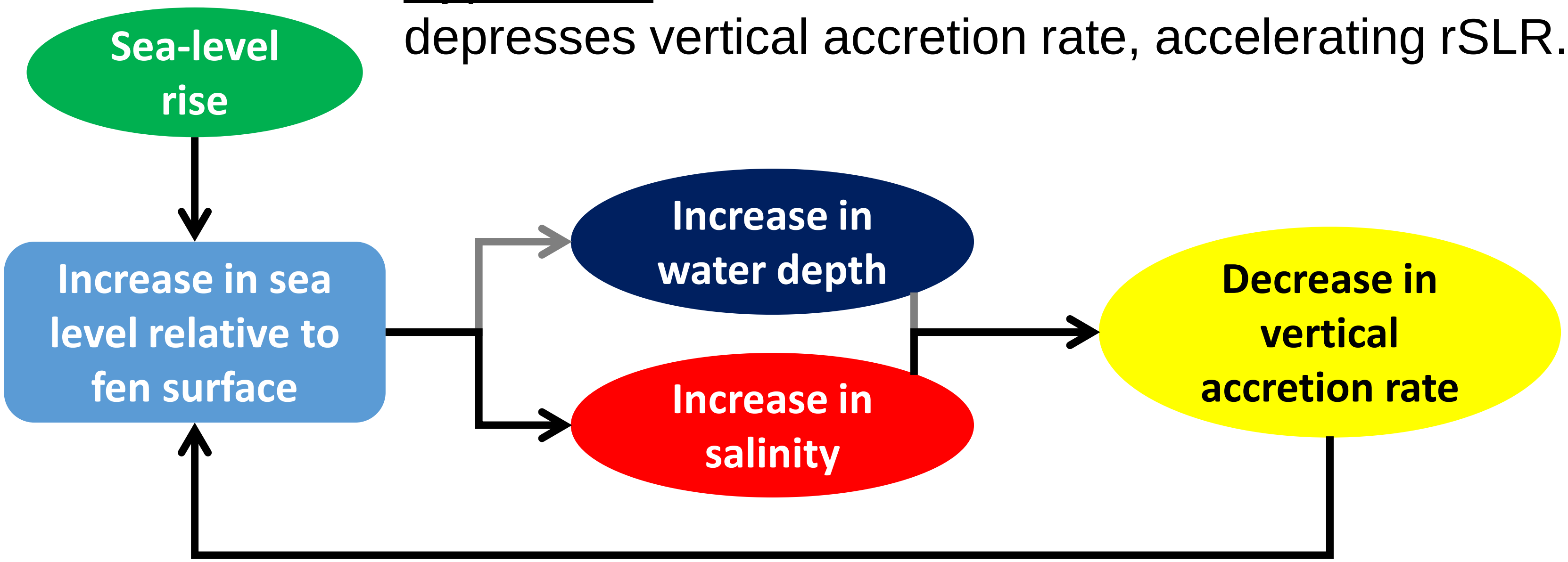
Sharp decline in growth of *Phragmites australis* when salinity exceeds ~ 10 ppt.

Nutrient availability, cutting regime, competition with other species, …?

Response curves based on Qi et al. (2016)

# Feedback between relative SLR and vertical accretion?

<u>Hypothesis</u>: rise in sea level relative to the fen surface depresses vertical accretion rate, accelerating rSLR.




- Management strategies to maximise vertical accretion rate of fens (e.g., cutting, grazing, nutrient management)?
- Managed succession to other habitat types with higher accretion rates?
- Engineered structures?

# Carbon in the Broads fens

**Key finding 1**: On a per unit area basis Broads fens store more carbon than tropical forest biomass, so they represent a dense carbon stock.
Research need: To improve quantification of the total stock of carbon in the Broads by including more data points (peat type and carbon density).

**Key finding 2**: The role of the Broads fens as net C sinks or source may depend on nutrient status (which influences productivity of Phragmites sp.)
Research need: To understand whether fens with different vegetation classifications act as net C sinks or sources.

**Key finding 3**: Current vertical rate of accretion in the Broads fens may not keep pace with future predictions of an increased rate of sea level rise
Research need: Accretion rates only determined for Phragmites-dominated fen so further measurements required in different habitat types, and to consider management initiatives designed to increase accretion rates.

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