Investigating hydrological and biogeochemical controls within Irish alkaline fen habitat for protection and sustainable use

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Project: Ecometrics

- Ecometrics - Research on ecological support metrics in GWDTE’s
- EU Habitats Directive requires action for protection/conservation of Alkaline and Cladium fens
- Aim of study:
  - define hydrological and hydrochemical metrics that to indicate fen ecological conditions
- Four fen research sites: varying intact to degraded ecological conditions
Fens in Ireland

- Fen habitat in Republic of Ireland: 20,000 ha
- Fen habitat conserved: 763 ha
- Loss of habitat: 79%
Preliminary conceptual model as described in: *Evaluating the Influence of Groundwater Pressures on Groundwater-Dependent Wetlands*
# Site specifics*

<table>
<thead>
<tr>
<th>Name</th>
<th>Pollardstown</th>
<th>Tory Hill</th>
<th>Scragh Bog (fen)</th>
<th>Ballymore</th>
</tr>
</thead>
<tbody>
<tr>
<td>County</td>
<td>Kildare</td>
<td>Limerick</td>
<td>Westmeath</td>
<td>Westmeath</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>266.1</td>
<td>76.9</td>
<td>23.9</td>
<td>43.1</td>
</tr>
<tr>
<td>Designation</td>
<td>SAC</td>
<td>SAC, NHA</td>
<td>SAC</td>
<td>SAC</td>
</tr>
<tr>
<td>Condition</td>
<td>Degraded</td>
<td>Degraded</td>
<td>Near intact</td>
<td>Intact</td>
</tr>
<tr>
<td>Damage, Threats and Pressures</td>
<td>Drainage</td>
<td>Drainage</td>
<td>Fertilisation</td>
<td>Diffuse Pollutio</td>
</tr>
<tr>
<td></td>
<td>Grazing</td>
<td>Infilling</td>
<td>Roads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dumping</td>
<td>Grazing</td>
<td>Diffuse Pollution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gravel quarry</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*as reported in Natura 2000 - standard data form*
Instrumentation

- Five research sites
  - Ballymore, Scragh, Pollardstown A+D, Tory Hill
- Nine piezometer transects in a range of different fen conditions
  - Groundwater level and chemical monitoring
  - Measurements taken from piezometers and phreatic tubes
- Well and borehole survey outside fen
  - Groundwater and chemical monitoring
- Rainwater sampling
Data Collection

- 12 data collections between July 2018 and February 2020

**Measurements**
- Water levels: Manually + Loggers
- Conductivity, oxygen, pH, temperature

**Water sampling**
- Nutrients: DRP, TP, NH$_3$, NO$_2$, TO$_x$N, TDN
- major ions: Alkalinity (HCO$_3$), SO$_4$, Cl, Ca, Na, Mg, K
- Metals: Fe$^{2+}$, Total Fe, Mn
Summary of Hydrochemistry
Data collected between July 2018 and December 2019

Dissolved reactive phosphorus (mg/l as P)  Total phosphorus (mg/l as P)


Total phosphorus (TP) is present in both phreatic tubes and groundwater piezometers in concentrations with means of 0.37 and 0.33 mg/L as P respectively. Scragh Bog (fen) stands out most for having the highest concentration of DRP in groundwater piezometers (0.26 mg/L as P), second is Tory Hill with 0.19 mg/L as P.
Both total dissolved nitrogen (TDN) and ammonia (NH$_3$) is found with higher concentrations in groundwater piezometers with means of 4.43 mg/L as N and 1.60 mg/L as N respectively. Again Scragh Bog (fen) stands out most displaying high concentration in samples taken from the groundwater piezometers for TDN and NH$_3$ with means of 6.88 mg/L as N and 2.98 mg/L as N respectively.
From the major ions, sulphate (SO$_4$) stood out most in samples collected from Tory Hill. Here concentrations with a mean of 89.0 mg/L SO$_4$ were found. This in contrast with the overall mean for the other fen sites combined (17.5 mg/L SO$_4$). This might be due to the oxidised conditions in Tory Hill caused by a high degree of artificial drainage.
Preliminary Results Ballymore

- Hydrology
  - Discharge and effective rainfall
  - Water balance
  - Hydraulic gradients

- Hydrochemistry
  - Linkages to fen habitat
No effective rainfall in summer; fen relies on groundwater recharge in winter to maintain stable surface water level. See surface water logs below:
Waterbalance

- Catchment area: 0.88 km$^2$
- Fen area: 0.23 km$^2$

- Water balance prepared on the assumption of no significant change on storage in fen between beginning and end of hydrological year
- Positive water balance in winter spring (net groundwater inputs) cf negative water balance in summer/autumn (net loss to groundwater?)
- However, hydrological changes made to fen could result in either flooding or drying out of the fen

<table>
<thead>
<tr>
<th>Hydrological year</th>
<th>Winter/Spring</th>
<th>Summer/Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>01-10-2018 to 30-09-2019</td>
<td>01-10-2018 to 01-04-2019</td>
<td>02-04-2019 to 30-09-2019</td>
</tr>
<tr>
<td><strong>Rainfall</strong></td>
<td><strong>Total (m$^3$)</strong></td>
<td><strong>Flux (mm/d)</strong></td>
</tr>
<tr>
<td>Rainfall</td>
<td>916119</td>
<td>2.84</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>591348</td>
<td>1.70</td>
</tr>
<tr>
<td>Runoff</td>
<td>319821</td>
<td>1.02</td>
</tr>
<tr>
<td>Storage</td>
<td>4949</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Lost from rainfall</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainfall</td>
<td>437856</td>
<td>2.73</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>129257</td>
<td>0.74</td>
</tr>
<tr>
<td>Runoff</td>
<td>194225</td>
<td>1.21</td>
</tr>
<tr>
<td>Storage</td>
<td>114374</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>Rainfall</strong></td>
<td><strong>Total (m$^3$)</strong></td>
<td><strong>Flux (mm/d)</strong></td>
</tr>
<tr>
<td>Rainfall</td>
<td>478263</td>
<td>2.96</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>462091</td>
<td>0.75</td>
</tr>
<tr>
<td>Runoff</td>
<td>125596</td>
<td>0.78</td>
</tr>
<tr>
<td>Storage</td>
<td>-109425</td>
<td>-0.68</td>
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Summer/winter hydraulic gradient and DRP comparison in transects

August 2020

Results: Hydrology
Summer/winter hydraulic gradient and DRP comparison

February 2020

Results: Hydrology
Summer/winter hydraulic gradient and DRP comparison

Results: Hydrology
Summer/winter hydraulic gradient and DRP comparison

Results: Hydrology
Habitat
Natura 2000 (Annex 1)  Irish habitats (Fossitt)

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<td>7230 Alkaline fens</td>
<td>PF1 Rich fen and flush</td>
</tr>
<tr>
<td>Menyanthes pool</td>
<td>7140 Transition mires</td>
<td>PF3 Transition mire and quaking bog</td>
</tr>
<tr>
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<tr>
<td>Molinia cutaway</td>
<td>7120 Degraded raised bog</td>
<td>PB4 Cutover bog</td>
</tr>
<tr>
<td>Filipendula-Holcus</td>
<td>GM1 Marsh</td>
<td></td>
</tr>
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<td>Ulex scrub</td>
<td>WS1 Scrub</td>
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Results: Hydrochemistry
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### Table: Irish Habitats (Fossitt)

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### Graphs:

1. **Sulphate, chloride and silica in fen habitats**
   - Phreatic tube average concentrations
   - Concentration (mg/l)
   - Habitats: Mosaic of Schoenus-Carex fen (7230, PF1) and Menyanthes pool (PF3), Mosaic of Carex-Menyanthes transition mire (PF3) and Filipendula-Holcus community (GM1), Mosaic of Ulex scrub (WS1) and Molinia cutaway (PB4)

2. **Sulphate, chloride and silica in fen habitats**
   - Piezometer average concentrations
   - Concentration (mg/l)
   - Habitats: Mosaic of Schoenus-Carex fen (7230, PF1) and Menyanthes pool (PF3), Mosaic of Carex-Menyanthes transition mire (PF3) and Filipendula-Holcus community (GM1), Mosaic of Ulex scrub (WS1) and Molinia cutaway (PB4)

**Results: Hydrochemistry**
Conclusions

- Main input of nutrients supplied to fen are largely driven by groundwater in Ballymore.
- Rainfall significant input to maintain surface water level in fen. Also acts as diluting agent in fen water.
- Fen surface water level is controlled by seasonal inputs.
- Fen vegetation appear to be resilient to climate fluctuations.

- Water balance and nutrient inputs are important to take into account with fen management.
Overview

- **Objective**
  - Indicate the relation between vegetation and water levels using satellite data
  - Use water level data to aid unsupervised habitat classification

- Classification of Scragh bog (fen) using habitat map produced in October 2019.
- Supervised classification --> Giving input from habitat map, defining training data; testing on the whole wetland.
- Unsupervised classification --> No input from habitat map; the clusters are formed on the basis of similar spectral patterns on the ground.
Methodology

- Satellite data used
  - Sentinel- 2 Multispectral Instrument - Level -2 - Ready to use data
  - 10 spectral bands
  - NDVI (normalised difference vegetation index)
  - NDWI (normalised difference water index)
1. WD4 - Conifer plantation
2. GS4 - Wet grassland
3. WN7 - Bog woodland
4. PF1 - Rich fen and flush
5. PF3 - Transition mire
6. FS2 - Tall herb swamp
7. FW2/WL2 - River/ tree line
8. FS1 - Reed and large sedge swamps
9. WN6 - Wet willows alder ash woodland
Ground Truth

Satellite Map - March 2019: SUPERVISED
Addition of hydrometer data

- Using the moisture information as obtained using NDWI (normalised difference water index) for the wetland, and using surface water level data of the sampling points on ground - predicting an approximate surface water level for the entire wetland.
Satellite Map - October 2019:
UNSUPERVISED

Unsupervised Map using satellite + Hydrometer data - October 2019
Conclusions

- If the method is supervised, good mapping accuracy to up to 83%.
- The unsupervised classification (clustering) brings out new/unknown patterns.
  - Something important while making the actual maps; maybe the field could be visited at those points to confirm.

- Addition of hydrometer information leads to formation of better boundaries of the vegetation communities such as Alkaline fen.
  - Need more surface water level collection points in order to make a more robust model.
Thank you for reading