Assessing the impacts of climate change on phosphorus transfers in a headwater agricultural catchment

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Justification

• More than 70% of UK surface waters still fail to achieve WFD ‘good’ status
• Nutrient pollution from agriculture is one of the main contributors in rural catchments

And in the future:
UK Climate Projections for most of the UK suggest:
• Warmer wetter winters, hotter drier summers
• More intense events (more intense rainfall, longer droughts...)

Objectives

• To use high temporal resolution data to investigate present day phosphorus dynamics
• To use a nutrient transfer model to estimate phosphorus loads in the future, including uncertainty/inter-annual variability
Study catchments

• 2 sub-catchments of River Eden
  – Newby Beck (12.5 km²)
    90% grassland, BFI 0.39
  – Pow Beck (10.5 km²)
    58% grassland, BFI 0.38

• Data collected by Eden Demonstration Test Catchment Project

• Rainfall, discharge, turbidity (15 min resolution)

• Total P, Total reactive P (Bank-side analysis at 30 min resolution)
Analysis

Present day dynamics
• Event classification with method of Haygarth et al., 2004 (HESS, 8, 88-97)

Present day and future phosphorus loads
• Modelling with Soil and Water Assessment Tool (SWAT) (process-based, semi-distributed model)
  o Calibration with observed data
  o Run with time series of weather variables from UKCP09 Weather Generator (present day and future)
Time series data from Pow outlet
**Results: Event classification**

### Pow Beck outlet  (April 2012 – March 2013)

<table>
<thead>
<tr>
<th>Total</th>
<th>$Q_{05} = 0.72, C_{p05} = 0.55$</th>
<th>56 events</th>
<th>75% of TP load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>$Q \geq 0.72, C_{p} &lt; 0.55$</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>Type 2</td>
<td>$Q \geq 0.72, C_{p} \geq 0.55$</td>
<td>26</td>
<td>69%</td>
</tr>
<tr>
<td>Type 3</td>
<td>$Q &lt; 0.72, C_{p} \geq 0.55$</td>
<td>26</td>
<td>2%</td>
</tr>
</tbody>
</table>

### Newby Beck outlet  (Sept 2011 – Jan 2013)

<table>
<thead>
<tr>
<th>Total</th>
<th>$Q_{05} = 0.82, C_{p05} = 0.22$</th>
<th>72 events</th>
<th>78% of TP load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>$Q \geq 0.82, C_{p} &lt; 0.22$</td>
<td>9</td>
<td>1%</td>
</tr>
<tr>
<td>Type 2</td>
<td>$Q \geq 0.82, C_{p} \geq 0.22$</td>
<td>49</td>
<td>76%</td>
</tr>
<tr>
<td>Type 3</td>
<td>$Q &lt; 0.82, C_{p} \geq 0.22$</td>
<td>14</td>
<td>1%</td>
</tr>
</tbody>
</table>

The bulk of the load is transported in Type 2 (high discharge, high concentration) events.
Non-linearity between the peak discharge and peak TP concentration,
but better agreement between event rainfall total and event TP load.
Rainfall following dry periods can result in high P concentrations in spite of little runoff.
### Predicted rainfall from UK Climate Projections (UKCP09): 2050s medium emissions

Mean rainfall (and standard deviation) in mm

#### Pow Beck

<table>
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<tr>
<th></th>
<th>Baseline</th>
<th>2050s</th>
<th>% change in mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual rainfall</strong></td>
<td>831 (96)</td>
<td>850 (110)</td>
<td>+ 2%</td>
</tr>
<tr>
<td><strong>Winter rainfall DJF</strong></td>
<td>217 (50)</td>
<td>250 (63)</td>
<td>+ 15%</td>
</tr>
<tr>
<td><strong>Summer rainfall JJA</strong></td>
<td>203 (45)</td>
<td>171 (51)</td>
<td>- 16%</td>
</tr>
</tbody>
</table>

#### Newby Beck

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<th>% change in mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual rainfall</strong></td>
<td>1056 (134)</td>
<td>1083 (158)</td>
<td>+ 3%</td>
</tr>
<tr>
<td><strong>Winter rainfall DJF</strong></td>
<td>334 (83)</td>
<td>372 (101)</td>
<td>+ 11%</td>
</tr>
<tr>
<td><strong>Summer rainfall JJA</strong></td>
<td>202 (46)</td>
<td>170 (53)</td>
<td>- 16%</td>
</tr>
</tbody>
</table>
Results: SWAT model calibration for daily TP load at Newby Beck

Calibration for 2011-2012 and 2012-2013 hydrological years

Nash Sutcliffe efficiency = 0.5
SWAT model results, monthly TP loads
baseline and 2050s medium emissions

Median annual TP load increased by approx. +16%, but more in winter months
Large inter-annual variability indicated by 5th and 95th percentiles

Median annual TP load
2050s 1810 kg
Baseline 1560 kg
For comparison, observed loads:
1730 kg in 2012
1640 kg in 2013

Month
Monthly TP load (kg)
baseline median
5th and 95th percentiles
2050s median
5th and 95th percentiles
Conclusions

• More than 70% of the total phosphorus load from both catchments was transferred in 5% of the time, mostly during Type 2 events \((Q > Q_{05}, C_P > C_{P05})\). These events may become more frequent in future and could stress stream ecology by frequent scouring

• There was good correlation between event rainfall total (mm) and event total phosphorus load (kg), with some outliers explained by high stream concentrations following dry periods

• SWAT model indicated that median annual TP at Newby Beck outlet may increase by approximately 16%, with most of the change during winter months
Thank you

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For further information, please visit our website: http://nutcat2050.org.uk/