Diffuse pollution in groundwater-dominated agricultural catchments

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Water quality responses to environmental change
BHS, University of Birmingham

Outline

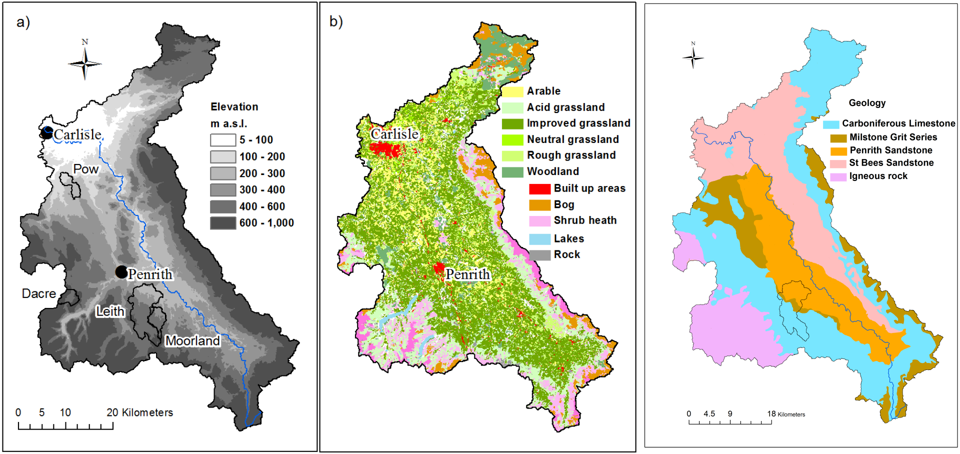
The River Eden and the River Leith catchments

High-frequency vs. low-frequency monitoring

High temporal resolution nutrient dynamics

Implications for water quality monitoring

The River Eden and the River Leith catchments



Surface and groundwater TRP and NO_3-N concentrations

The Environment Agency routine water quality monitoring

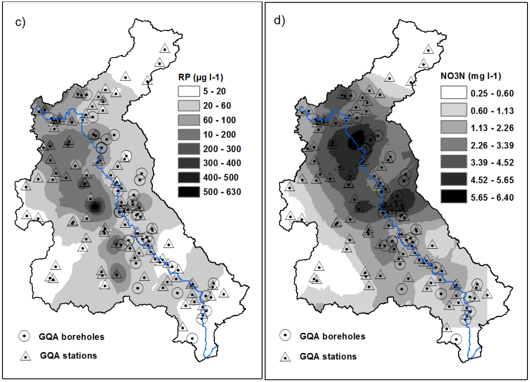


Table : Mean TRP and NO_3-N concentrations (mgl^{-1}) for the EA sampling

	TRP	NO_3-N	N
Surface waters	0.07	2.20	103
Improved grassland	0.05	2.25	31
Arable	0.12	2.42	19
Woodland	0.06	2.54	18
Rough grassland	0.18	3.53	11
Built-up areas	0.04	1.46	8
Other grassland	0.07	4.04	5
Other	0.08	1.52	11
Groundwaters	0.70	5.70	39
Sherwood Sandstone	0.87	13.14	2
St Bees Sandstone	0.79	7.96	11
Carboniferous Limestone	0.37	2.01	9
Penrith Sandstone	0.82	5.51	16
0-10 m	0.59	4.52	9
11-40 m	0.64	10.63	3
41-80 m	0.76	6.58	20
$\geq$ 81 m	0.70	2.73	7

The River Leith at Cliburn

- Narrow floodplain (< 100 m)
- Riffle-pool sequences
- GW-SW interactions - a gaining reach, potential importance of the hyporheic processes on in-stream biogeochemistry
- Hourly *in situ* monitoring since 2009 (TRP, NO_3-N, WQ)
- Environment Agency gauging station

High-frequency vs. low-frequency monitoring

The Environment Agency routine water quality monitoring

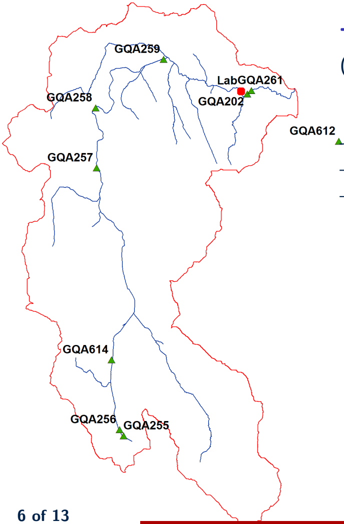
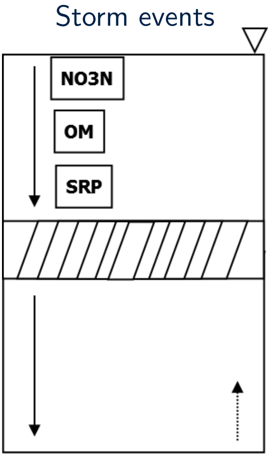


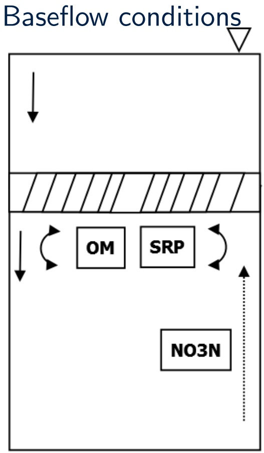
Table : Mean TRP and NO_3-N concentrations (mgl^{-1}) for the EA and *in situ* sampling

	Start	End	N	TRP	NO_3-N
GQA612	1990	2013	244	0.031	2.10
In situ	2009	2012	16521	**0.037**	**2.57**
GQA202	1990	2013	527	0.062	3.00
GQA261	2002	2013	59	0.060	3.20
GQA259	2002	2003	20	0.102	3.70
GQA258	2002	2009	20	0.120	3.70
GQA257	2002	2009	18	0.114	3.80
GQA614	1992	2013	214	0.455	3.20
GQA256	2002	2003	19	1.383	5.90
GQA255	2002	2003	19	0.201	2.50

Hyporheic exchange of nutrients

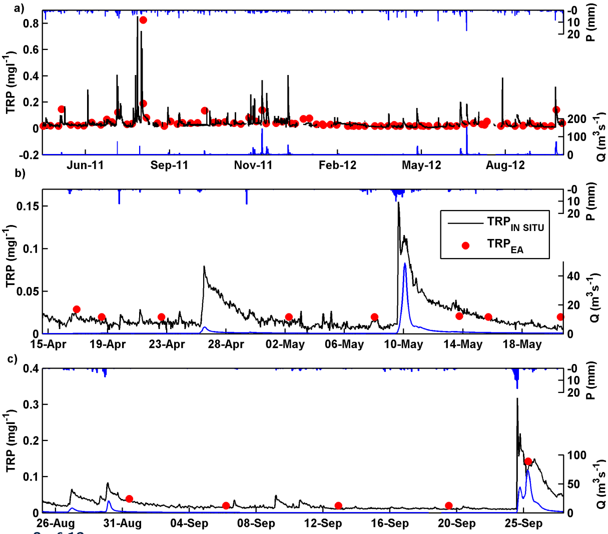
A conceptual model





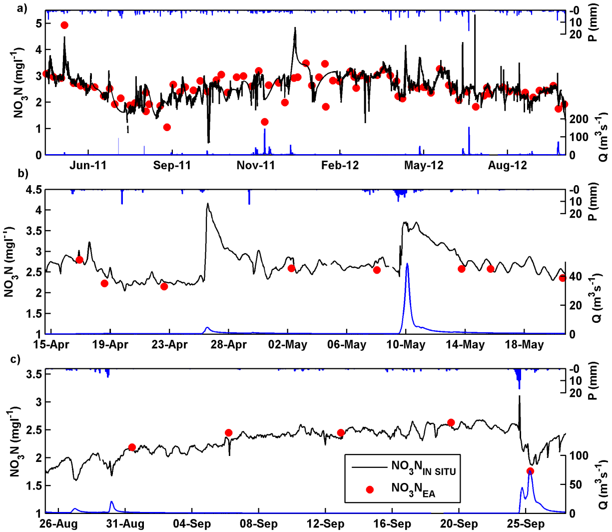
Kaser et al (2009), Byrne et al (2012), Krause et al (2013)

Total Reactive Phosphorus



- Diffuse P inputs
- Episodic behaviour
- Surface and subsurface delivery pathways
- Chemical status can change from high ($\leq$ 0.12 mgl^{-1}) to poor ($\geq$1.0 mgl^{-1})
- Coarse sampling underestimates true concentrations

Nitrate-nitrogen



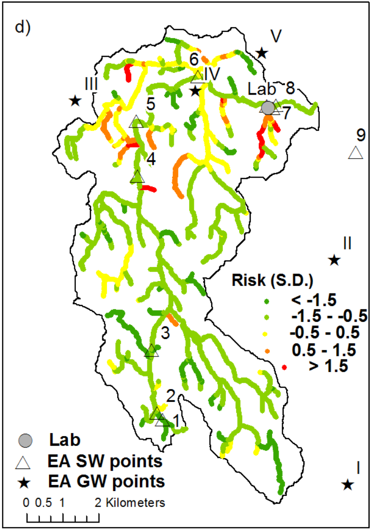
- Chemostatic behaviour
- Groundwater delivery
- Dilution and concentration effects
- Narrow range of concentrations (1-5 mgl^{-1})
- Coarse sampling under- and overestimates true concentrations

Load estimation

Table : TRP and NO_3-N load estimation for the *in situ* and EA routine monitoring time series and artificially resampled *in situ* time series to coarser resolution

	Dataset	TRP ($kgPyr^{-1}$)	NO_3-N ($kgNyr^{-1}$)	TRP (%)	NO_3-N (%)
May 2011-Sep 2012	*In situ*	5790	143200	-	-
	EA	6200	101400	7.1	-29.2
	GRAB	4760	100100	-17.8	-30.1
15 Apr-19 May 2012	*In situ*	260	13100	-	-
	EA	90	10100	-65.4	-22.7
	GRAB	50	8700	-80.8	-33.7
26 Aug-25 Sep 2012	*In situ*	530	11400	-	-
	EA	770	9900	45.3	-13.2
	GRAB	350	13200	-36.0	15.8
Resampled	*In situ* hourly	3720	96700	-	-
	7h	3470	95700	-6.7	-1.0
	Daily (9am)	4240	93900	14.0	-3.0
	Daily (3pm)	5530	101000	49.0	4.4
	Weekly	1330	97400	-64.2	0.7
	Fortnightly	1350	102500	-63.8	6.0
	Montlhy (1st)	2040	92200	-45.2	-4.7
	Monthly (11th)	1170	94700	-68.6	-2.1
	Monthly (21st)	1630	93100	-56.2	-3.7

Implications for water quality monitoring



- **Low-frequency (weekly to daily) measurements:**
  - Temporally-constrained
  - Conceal the rapid response of nutrients to hydrologic events
  - Underestimate nutrient concentrations during storm flows and overestimate during baseflows
- **High-frequency (<daily) measurements:**
  - Spatially-constrained
  - Reveal complex nutrients behaviour in response to hydrological forcing (C-Q hysteresis) and during the baseflow conditions (diurnal patterns)
  - Underestimate particulate P concentrations

Implications for water quality monitoring

- **Groundwater-fed catchments:**
  - Agricultural catchments with no major point sources: intensive in-stream processing and nutrient attenuation along the subsurface pathways
  - However, peak nitrate loading for Penrith Sandstone in several areas of the Eden catchment including Cliburn will arrive in the next three decades
  - Different delivery mechanisms and differences in dominant hydrological pathways for TRP and NO_3-N but subsurface pathways important for both
  - Episodic TRP vs. chemostatic NO_3-N behaviour
  - Implications for load estimation: large errors for TRP (≥ 60 %) and small errors for NO_3-N (≤ 6 %)
  - Bieroza, MZ, Heathwaite, AL, Mullinger, NJ & Keenan, PO, 2014, *Understanding nutrient biogeochemistry in agricultural catchments: the challenge of appropriate monitoring frequencies*, Environmental Science: Processes & Impacts, doi: 10.1039/C4EM00100A

Acknowledgments

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Thank you!