Long-term spatio-temporal patterns and controls of faecal contamination risk in an agricultural catchment

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Introduction

Critical need to maintain the microbiological quality of water sources used to supply drinking water for legislative and public health purposes. In the UK, drinking water is required to have faecal indicator organism concentrations of 0 CFU / 100 ml after treatment.

Characterising sources of faecal pathogens and the hydrological pathways responsible for connecting these to ground and surface waters is necessary for mitigating against the significant issue of faecal contamination of private water supplies with limited treatment.

Objectives

For an agricultural catchment with a long-term water quality dataset:

1. Identify long-term spatial distribution of "hot-spots" of faecal contamination risk
2. Investigate how faecal contamination risk varies temporally with discharge and season
3. Investigate possible controls on spatio-temporal patterns of faecal contamination risk

Study Site and Methods

Tarland Burn, NE Scotland

- 51.4 km^2; 133-619 MASL.
- 25% arable, 35% improved grassland, 18% semi-natural grassland, 21% woodland, 0.7% urban (Fig. 1).
- Spodosol soils with histosols to regosols on higher ground. Acidic drift and granite.
- 10 nested sites (Fig. 2) monitored monthly to quarterly for faecal coliform concentrations (FC conc.) and geochemistry, for 10 years. 58 baseflow and 23 high flow events sampled; 44 summer and 37 winter events sampled
- Hourly discharge and temperature from Coull Bridge at site 1

Fig. 1: The Tarland catchment.

Data Analysis

- Wilcoxon Rank Sum tests of significance of differences in median FC conc.s spatially and temporally.
- Poisson regressions between median FC conc.s and network index-scaled land cover percentages.
- PCA / HCA with geochemistry data.

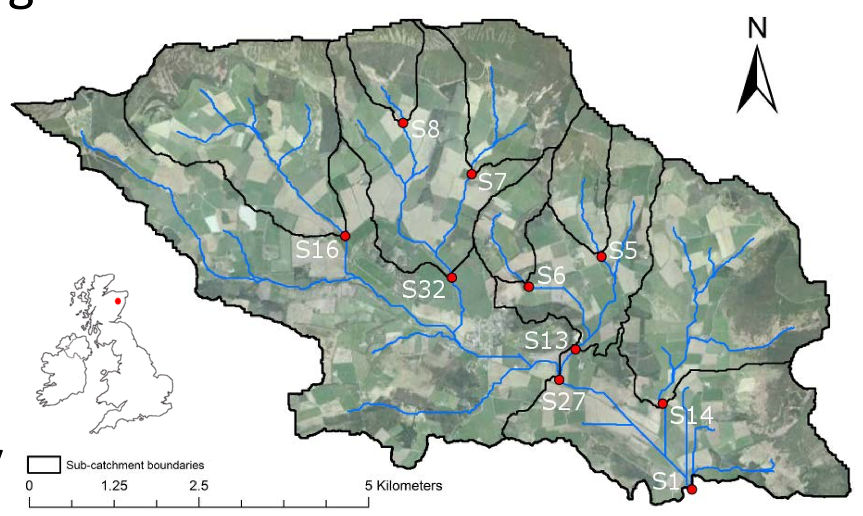


Fig. 2: Tarland catchment and the 10 monitored sites.

Results

Long-term "hot-spots" of faecal contamination risk

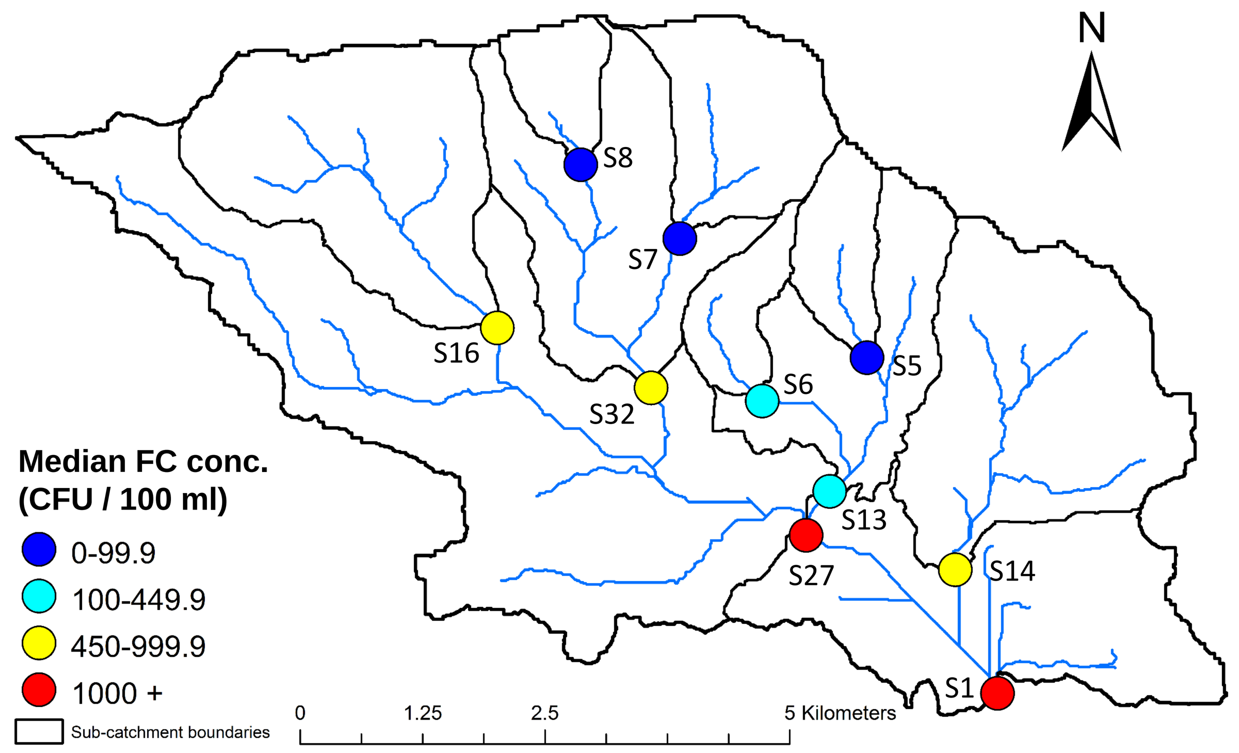
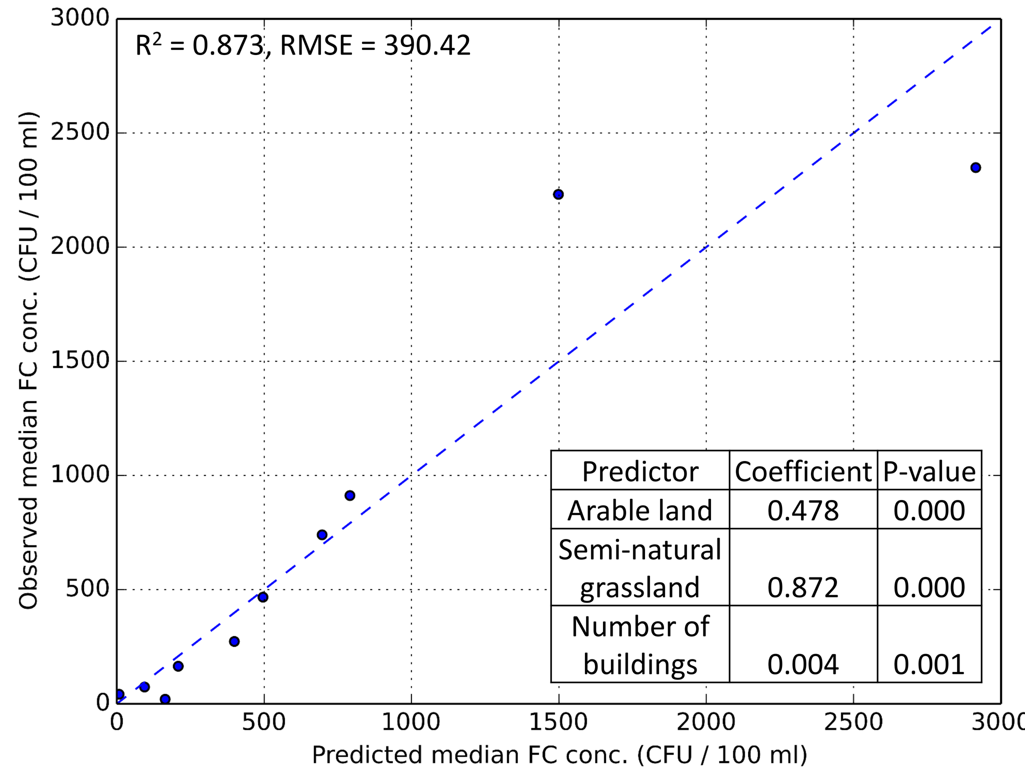


Fig. 3: Long-term median FC conc.s for the 10 monitored sites.



Predictor	Coefficient	P-value
Arable land	0.478	0.000
Semi-natural grassland	0.872	0.000
Number of buildings	0.004	0.001

Fig. 4: Predicted vs. observed median FC conc.s obtained with Poisson regression model. Inset are predictor coefficients and performance metrics.

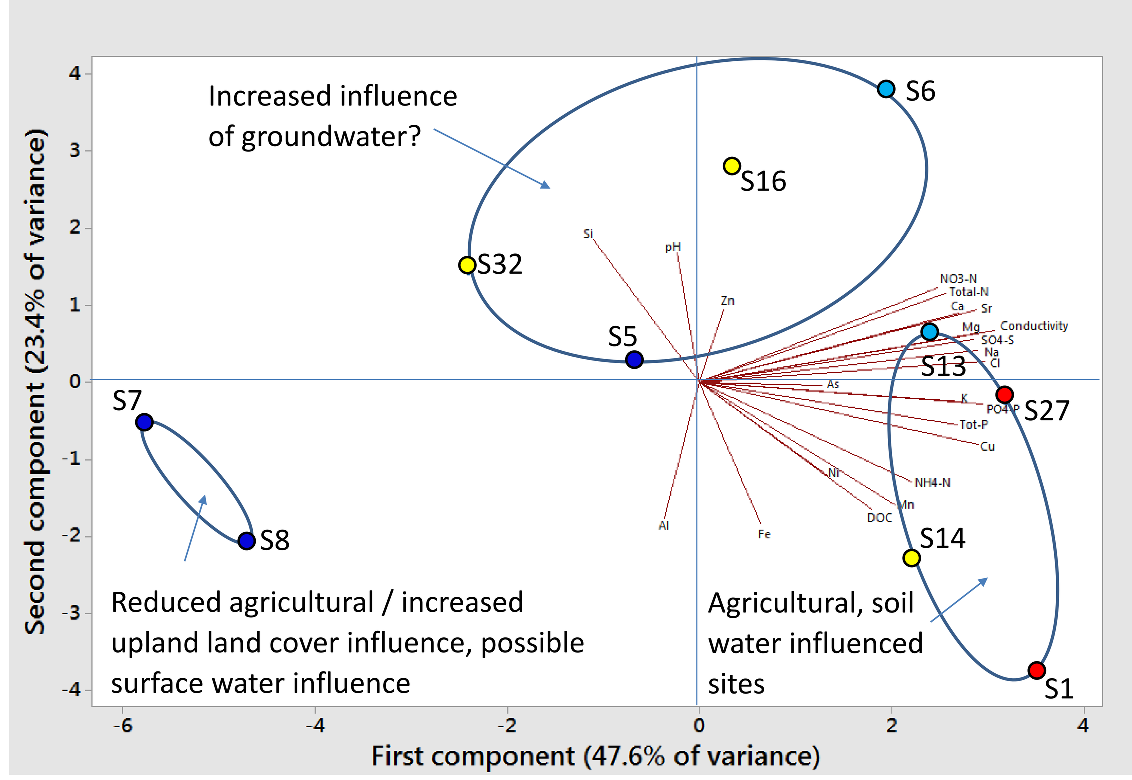


Fig. 5: Biplot showing clusters arising from PCA and HCA with long-term geochemistry dataset. Site symbol colours relate to long-term median FC conc.s as in Fig. 3.

Spatial patterns

- Highest FC conc.s in lower catchment (sites 1 & 27 – not significantly different; $p > 0.05$; Fig. 3).
- Upper parts of the catchment have lowest FC conc.s (sites 5, 7 & 8 - not significantly different; $p > 0.05$).
- Sites 14, 16 & 32 have moderately high FC conc.s which are not significantly different ($p > 0.05$).

Possible controls

- Poisson regression model with connected arable land, semi-natural grassland and number of buildings predicts long-term median FC conc.s well (Fig. 4).
- Suggests manure spreading on arable land, defecation by animals grazing on semi-natural grassland and farmyard / urban runoff may be important contaminant sources.
- HCA cluster and FC conc. relationship not clear; however, highest FC conc. sites plot in agricultural / soil water cluster whilst cleanest sites plot in upland cluster (Fig. 5).

Temporal variation in faecal contamination risk

Variation with discharge

- Median FC conc.s increased during high flows at all sites (Fig. 6).
- Increases only significant at sites 1, 5 ,6, 14 & 27 ($p < 0.05$), perhaps due to coarse sampling frequency.
- Poisson regression model for high flow conditions drops buildings as predictor – may suggest that as connectivity increases, influence of more diffuse agricultural sources increases at the expense of more permanent point-sources such as farmyards and urban areas (Fig. 7).

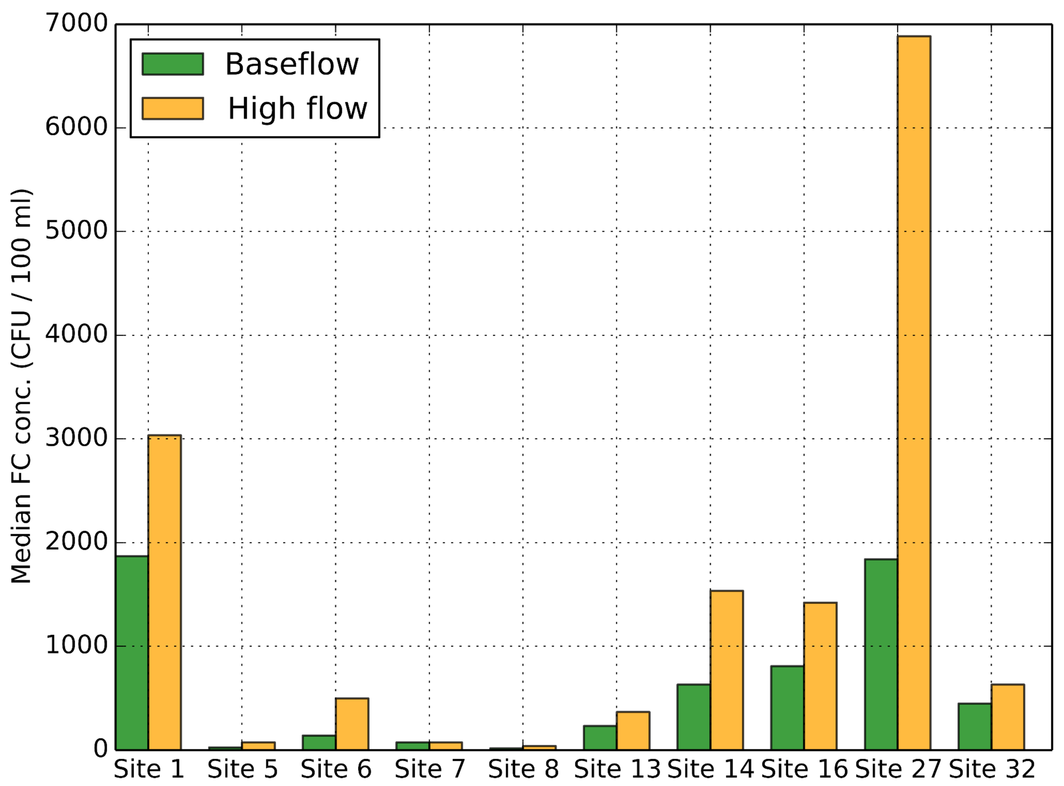


Fig. 6: Median FC conc.s under baseflow and high flow conditions.

Fig. 7: Examples of increased surface connectivity of agricultural land during a high flow event in January 2016.

Variation with season

- Median FC conc.s higher in summer (Apr - Sept; Fig. 8).
- Significant increases only at sites 7, 8, 16 & 32 ($p < 0.05$).
- Summer mean temp. was 10.6 ˚C. Warmer than winter by 5 ˚C, but low compared to optimal FC growth temp.

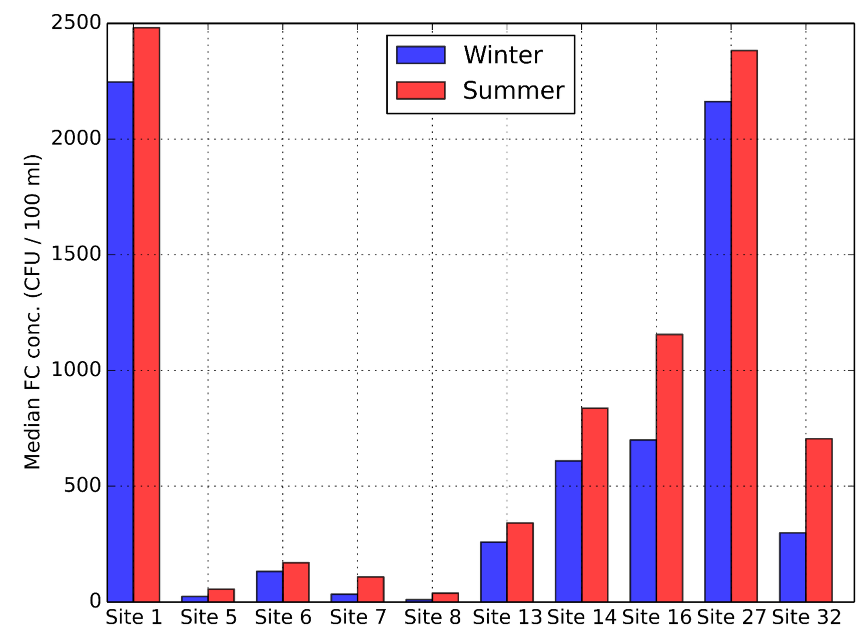


Fig. 8: Median FC conc.s during summer and winter.

Conclusions

Landscape controls on long-term "hot-spots" of faecal contamination risk suggest that manure spreading, extensive grazing and farmyard / urban runoff are important contaminant sources in the Tarland.

Increased connectivity of diffuse sources of faecal contaminants may explain greater FC conc.s observed during high flow conditions.

Seasonal influence on faecal contamination risk apparent, however significance may be restricted by low mean summer temperature.

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