QUANTUM

Quantifying the nutrient enrichment, pathogenic, and ecotoxicological impacts of livestock farming on UK rivers

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Davey Jones, Dave Chadwick (Bangor University)
Barbara Kasprzyk Hordern (University of Bath)
Charles Tyler (University of Exeter)
Andrew Binley (Lancaster University)

and our regulatory, industry and academic Project Partners:

The QUANTUM team: complementary skills and responsibilities

Penny Johnes

PI and WP4 lead: freshwater nutrient chemistry & ecology

Dave Chadwick

WP2 lead: soil nutrient cycling, livestock farming,

Barbara K-Hordern

Ecotoxins lead: pharmaceuticals in the environment

Richard Evershed

WP1 lead: isotope and molecular scale organic geochemistry

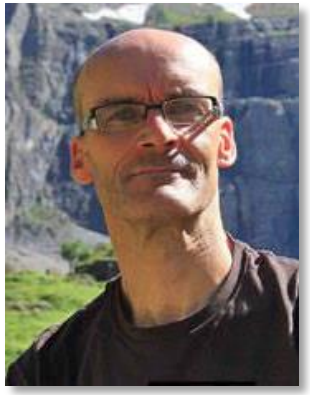
Andrew Binley

WP5 lead: hydrology geophysics and modelling

Davey Jones

Pathogens lead: environmental microbiology

Charles Tyler



WP3 lead: ecotoxicology in freshwaters

Ian Bull

Analytical lead: faecal biomarkers in soils and freshwaters

Our researchers:

- PDRA 1 Biogeochemistry
- Tech 1 Biogeochemistry
- PDRA 2 Analytical Chemistry
- Tech 2 Analytical Chemistry
- PDRA 3 Ecotoxin Chemistry
- PDRA 4 Ecotoxicology
- Tech 3 Ecotoxicology (PT)
- Tech 4 Pathogens
- PDRA 5 Modelling

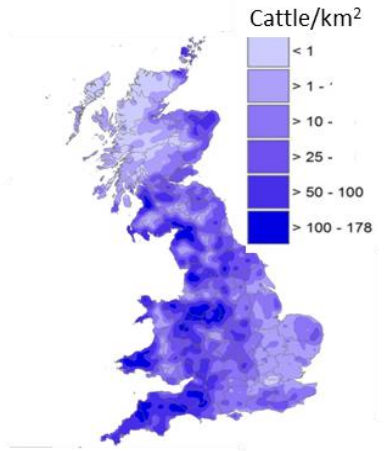
Our project partners:

- Defra
- Natural Resources Wales
- Natural England
- UKWIR
- Dwr Cymru Welsh Water
- Wessex Water
- Harper Adams University

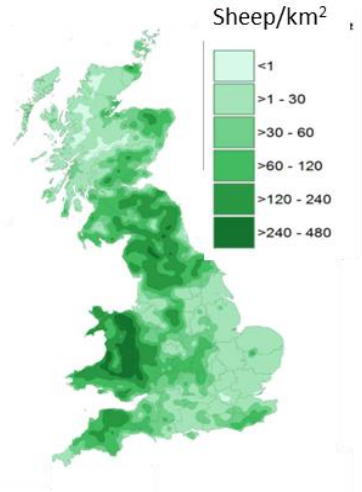
Livestock farming as a key driver of changing quality in UK rivers

- Cattle and sheep farming is concentrated in the wetter north and west of the UK on 10M hectares of grassland (57% of all UK agricultural land).
- There were 9.65M cattle, 32.7M sheep in the UK in 2020, excreting 4 x as much N and 3 x as much P as people in UK catchments.
- 80% of oestrogen in the UK environment derives from livestock, with cattle excreting an order of magnitude more oestrogen than humans.
- Livestock-derived pathogens, veterinary pharmaceuticals and other ecotoxins, their processing, critical concentrations and ensemble impacts in UK river ecosystems remain to be established, as do their interactions with livestock-derived organic nutrient loading.
- The role of environmental character and function in transforming these contaminant mixes and their impacts on UK rivers is unknown, creating uncertainty in the efficacy of both current mitigation and management strategies, and their likely efficacy under future climate change.

UK Cattle stocking density 2019 (www.apha.defra.gov.uk)

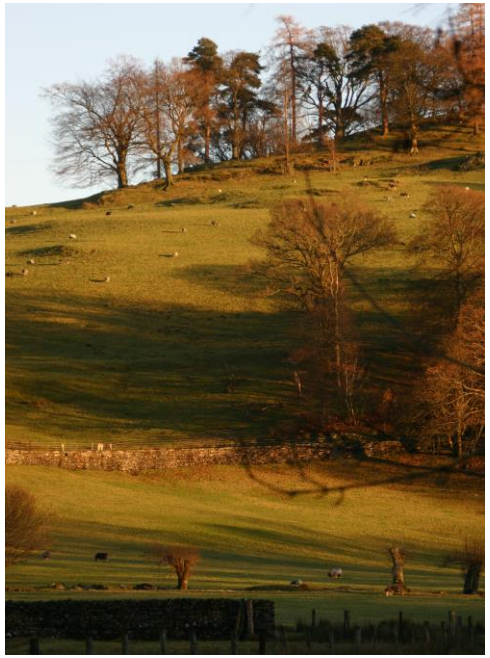


UK Sheep stocking density, 2019 (www.apha.defra.gov.uk)



The QUANTUM focus: livestock farming in UK catchments



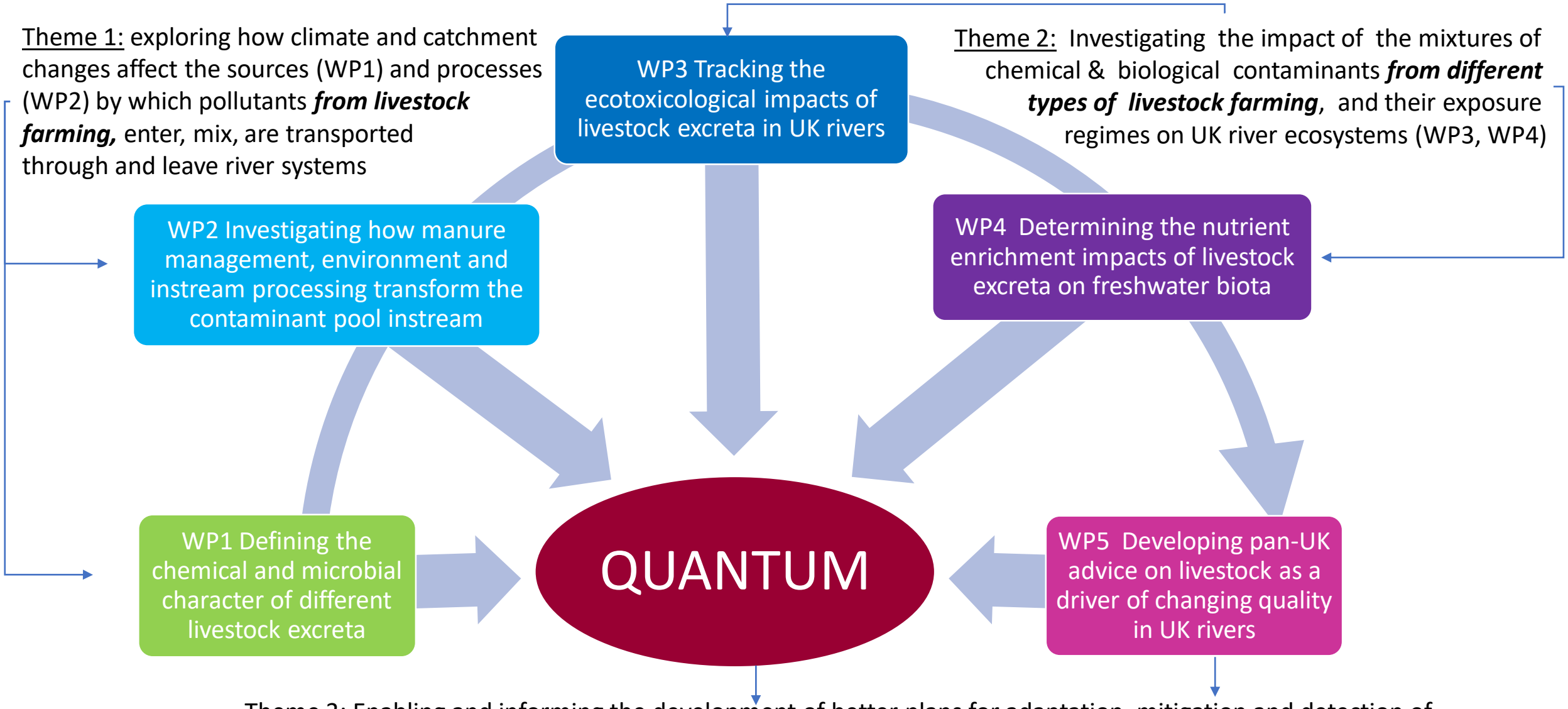







Sources - practices - pathways - impacts

The QUANTUM programme



Novel sensing, sampling and analytical approaches

Capitalises on novel approaches for DOM characterisation using targeted and non-targeted methods, together with bulk and compound specific stable isotope probing developed in our prior UKRI funded research.

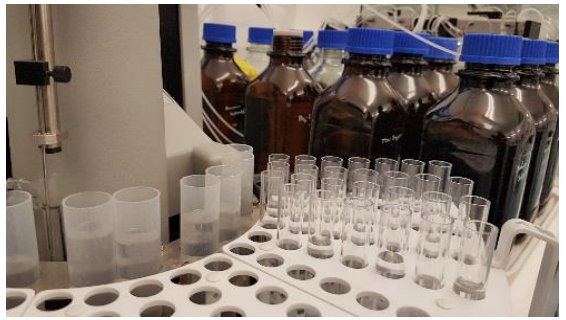
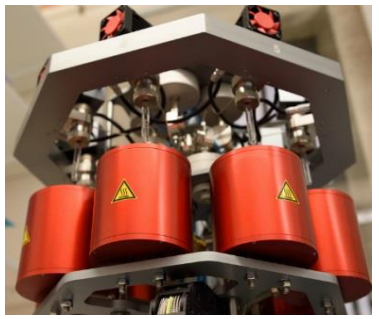
(a) Automated water samplers, telemetered sensor networks and novel chemical monitoring techniques (e.g. POCIS)






(b) Sample analyses using our suite of novel high resolution mass spectrometry, stable and radio isotope techniques



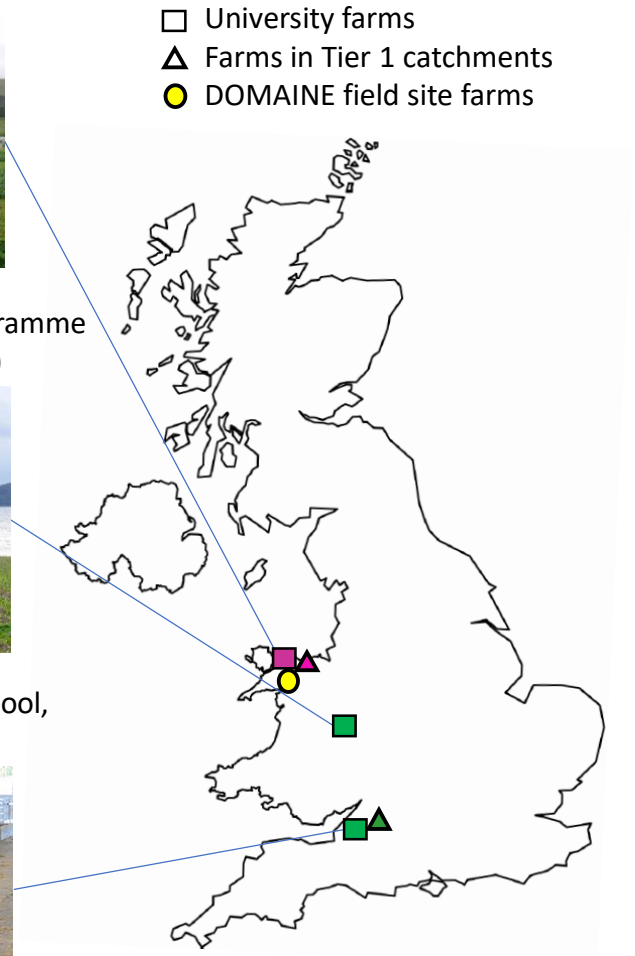





WP1 - Defining the chemical and microbial character of different livestock excreta

Henfaes Farm Research Centre,
Bangor University (sheep)

Innovate UK/Defra Slurry Management programme
Harper Adams Agricultural University (cattle)

John Oldacre Dairy Research Centre, Vet School,
University of Bristol



Research questions:

1.1 What is the chemical and pathogen composition of livestock excreta of differing type?

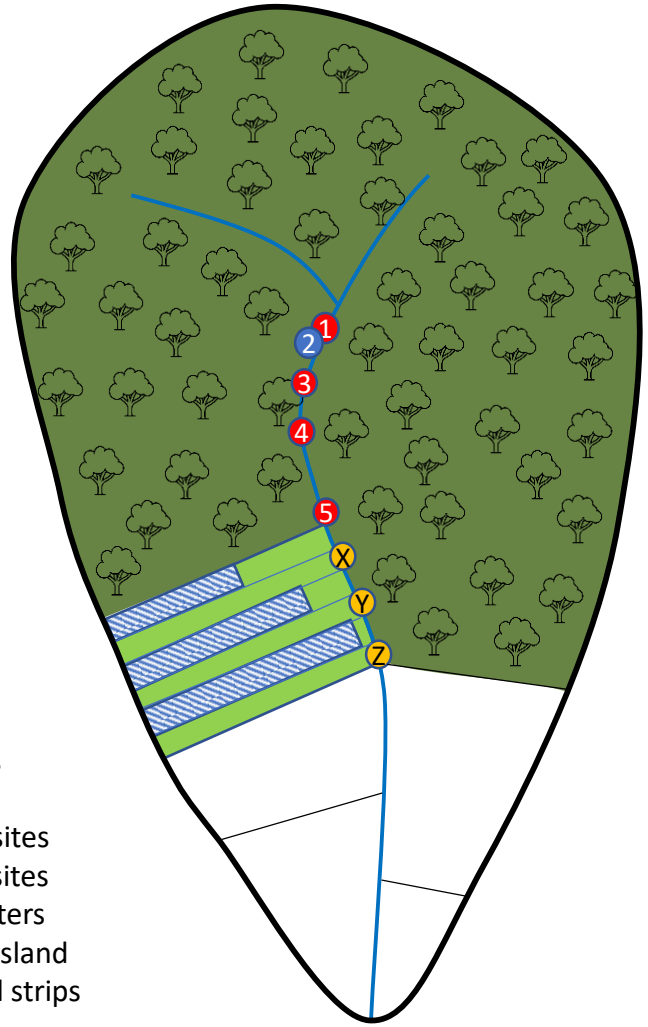
1.2 How does the composition of the livestock-derived OM (LDOM) pool vary according to production system/ management?

Approach:

1. Collect representative samples from sheep, dairy and beef cattle farms (Tier 1 catchments, university farms)
2. Link up with the Innovate UK and Defra funded slurry management programme ongoing at Harper Adams
3. Analyse samples to determine nutrient profile, organic matter composition including 6 key organic nutrient and 6 ecotoxin compounds, faecal biomarkers, microbes.
4. Subsamples sent to NRM (Cawood Ltd) for nutrient analysis to allow comparison under RB209.
5. Include at least one target identified in WP1 samples from each of the following in our WP2-4 experiments:
   a. nutrients (urea, amino acids, amino sugars, nucleotides);
   b. ecotoxins (antibiotics, antifungals, NSAID, antiparasiticides/ antihelminthics, natural oestrogens).

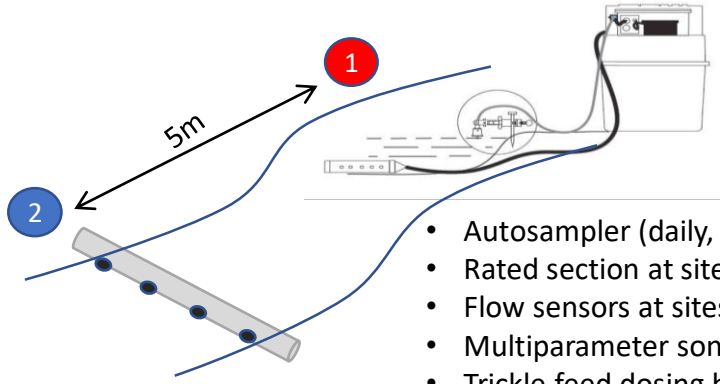
WP2 - Investigating how manure management, environment and instream processing transform the (L)DOM pool instream

(a) WP2 field experimental platform (Hiraethlyn, Chew)



- Catchment boundary
- Stream network
- Field boundary
- WP2.1-2.2 sampling sites
- 2 WP2.1-2.2 dosing point
- WP2.3 in-field sampling sites
- WP2.4 stream sampling sites
- Non-agricultural headwaters
- Ungrazed/untreated grassland
- Grazed/treated grassland strips

(b) WP2.1 – 2.2 installation detail, sites 1, 3-5, dosing at site 2



- Autosampler (daily, + hourly storms at 1 and 5)
- Rated section at site 5 (monthly and in storms)
- Flow sensors at sites 1, 5, **Z** (15 min)
- Multiparameter sondes (30 min) sites 1, 5, **Z**)
- Trickle feed dosing bar at 2 (slurry, urine)

Research questions:

2.1 How does the composition of LDOM delivered to streams transform due to instream processing?

2.2 How does the stream OM pool composition transform in response to hydrology and climate?

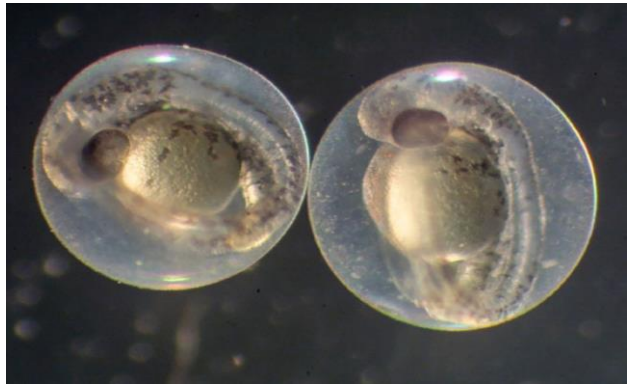
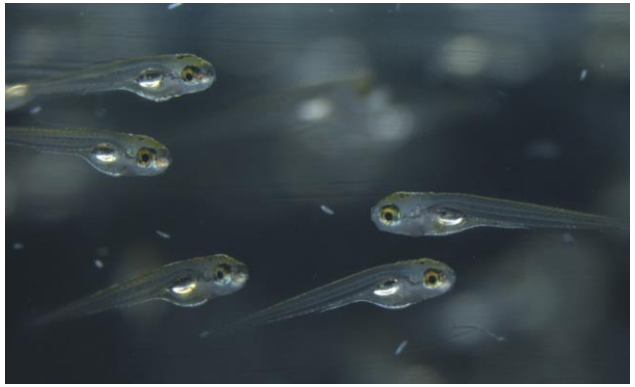
2.3 How does LDOM composition transform according to in-field management practices?

2.4 What are the exposure rates for LDOM targets under contrasting flow and management?

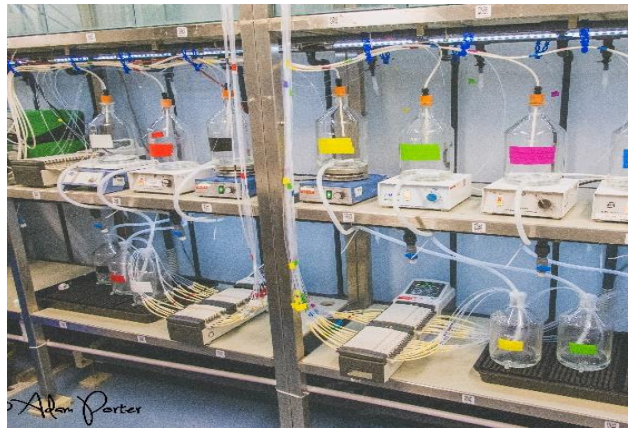
WP3: Tracking the ecotoxicological impacts of LDOM on freshwater biota under laboratory and ambient conditions

Research questions:

3.1 What are the toxicities of key compounds in livestock excreta (from WP1) to freshwater biota?
3.2 What are the bioaccumulation rates and effects of key compounds in invertebrates and fish?
3.3 How does ecotoxicological impact on stream biota vary according to environmental character and function?





WP4: Determining the nutrient enrichment impacts of LDOM on freshwater biota using stable isotope probing

Research questions:

4.1 How does LDOM nutrient uptake vary between different livestock excreta and chemistries?
4.2 How does bioavailability of LDOM to vary according to environmental character and function?
4.3 How is LDOM uptake modified by the matrices and interacting stressors in livestock excreta?





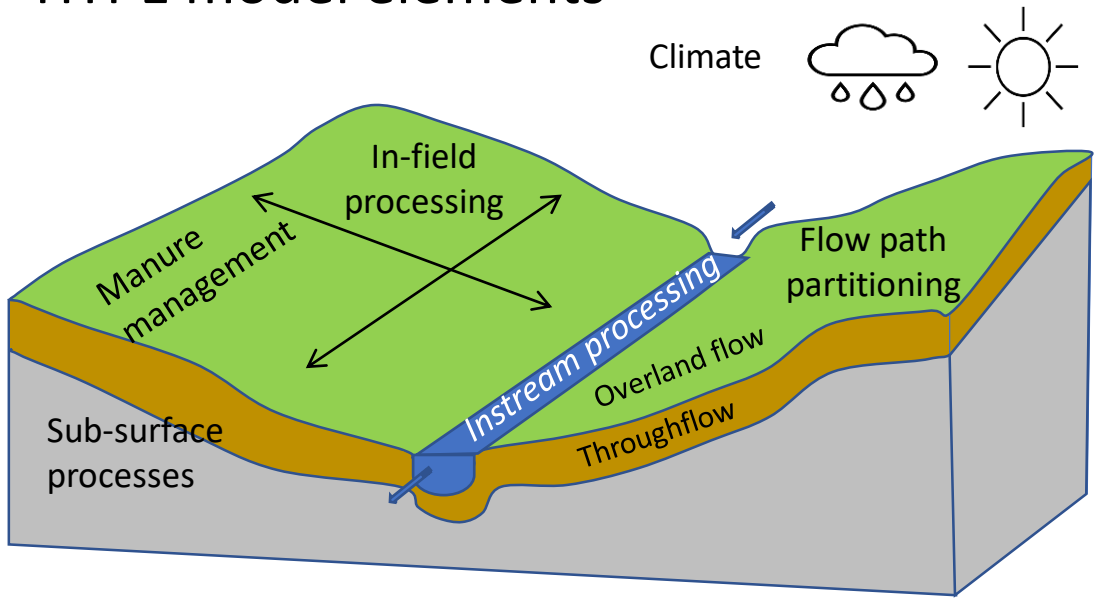

WP5 - Developing pan-UK understanding and advice on livestock as a driver of changing quality in UK rivers

Research questions:

5.1 Are there generic livestock impacts on UK rivers, linked to livestock type and environment?
5.2 How might impacts across UK conditions alter in response to a changing hydrological cycle?
5.3 Can we produce transferable evidence to improve policy and management for UK rivers?

- Sampling and analysis as in Tier 1, for 20 catchments of comparable environmental character
- HYPE model parameterisation linking specific chemistries from sheep versus cattle farming in differing environments, under ambient and climatically altered conditions to ecological and ecotoxicological impacts using Tier 1 outcomes
- Model validation using Tier 2, published and project partner data
- Scenario testing in consultation with our regulatory, industry and academic partners

HYPE model elements

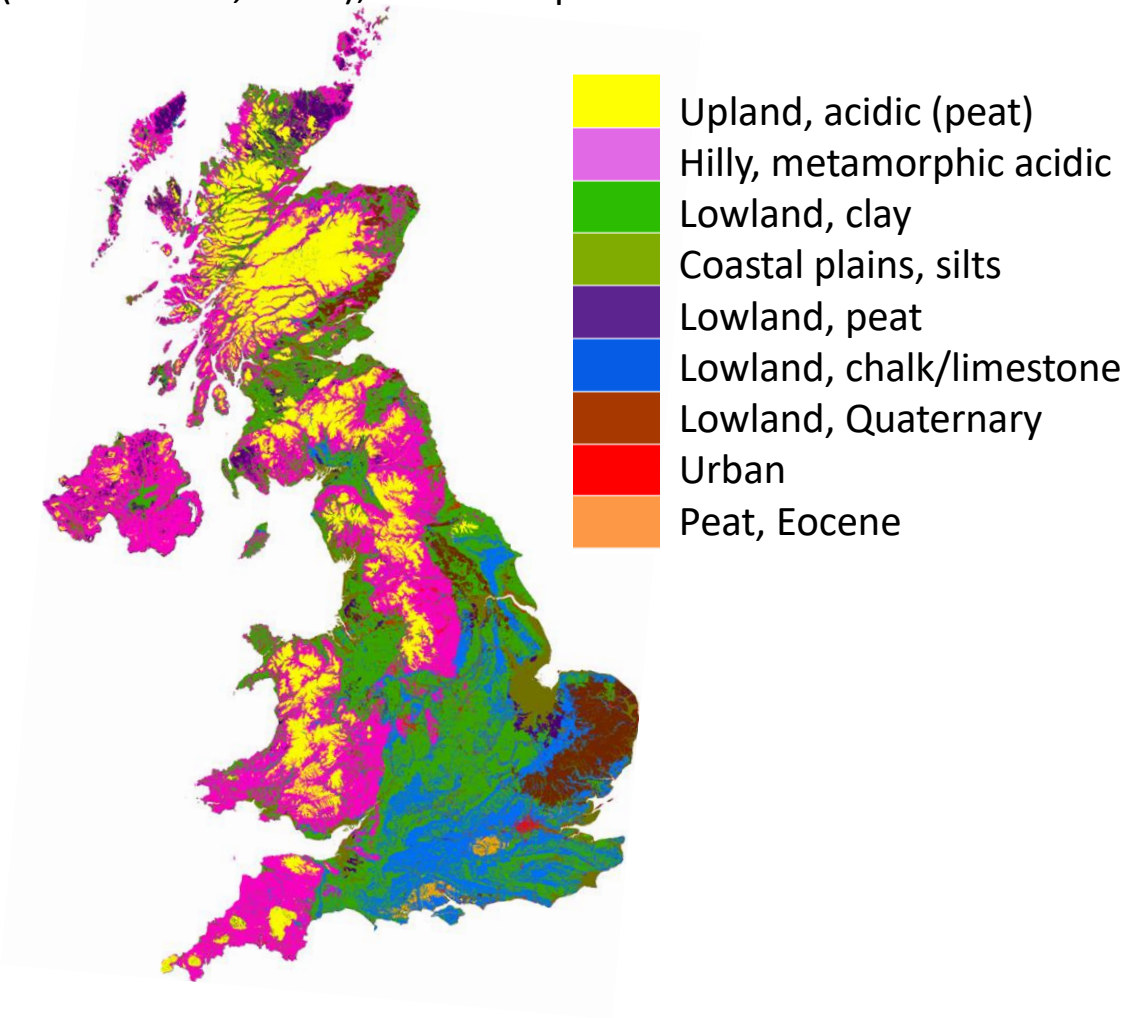


Environmental character

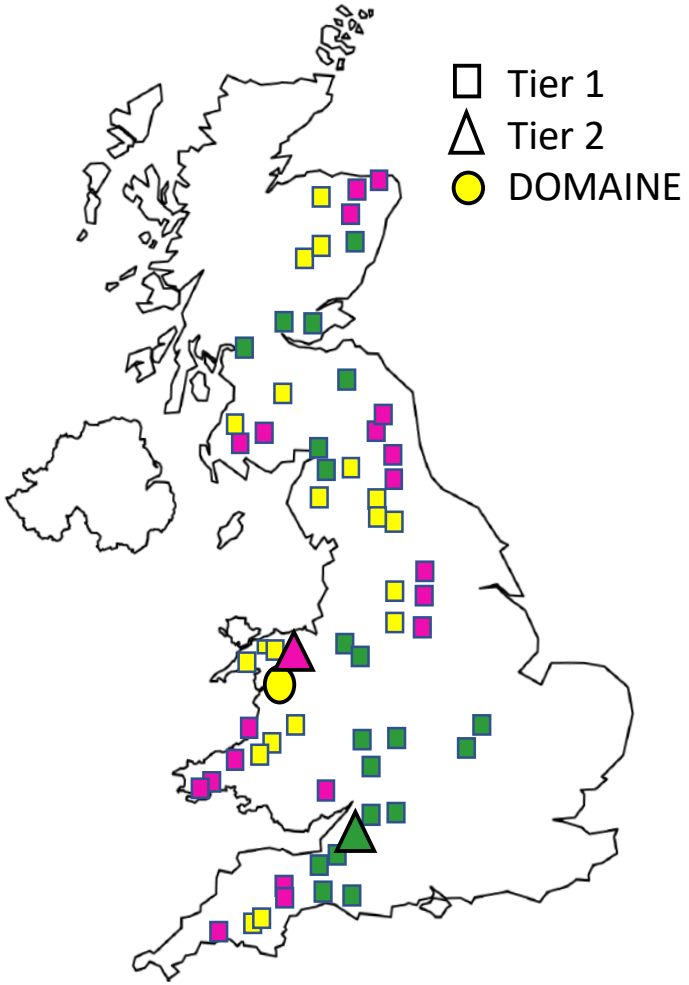
- Will generate pan-UK understanding and advice on the impacts of livestock farming on freshwater quality under ambient conditions, in response to climate change, and mitigation targeting manure management.

WP5 - Developing pan-UK understanding and advice on livestock as a driver of changing quality in UK rivers

(a) Biogeochemical Modelling Framework (Greene *et al.,* 2015); NERC EVOp



(b) Tier 1 & 2 sampling sites



Our research approach: *highlights*

WP1 Combining our novel methods for characterising multiple contaminant profiles in freshwaters, to diagnose the nutrient, pathogen and ecotoxin contaminant mixtures exported to UK rivers from different types of livestock farming

e.g. NERC DOMAINE, 2014-19, EPSRC ReNEW, 2017-20, NERC AMR, 2016-18, NERC EMHH, 2012-15, 2015-18, NERC Urgent Grant, 2020-21

WP2 Exploring how different livestock production methods in different environments produce multiple chemical and microbial exposure regimes instream, which combine and interact to impact on freshwater ecosystems

WP3 Taking laboratory-based ecotoxicology approaches out into the field for the first time, to really understand what the organism is seeing under ambient field conditions as these vary according to environmental character and function

WP4 Using our novel stream isotope dosing approach to determine compound-, environment-, and species-specific responses to livestock-derived organic nutrient chemistries under varying ambient and climatically-altered conditions

WP5 Embedding our Tier 1 experiments within a national Tier 2 programme, to generate pan-UK understanding of the impacts of differing livestock production systems as drivers of changing quality in UK rivers, now and in the future