From Land to Water:

What is shaping our rivers?

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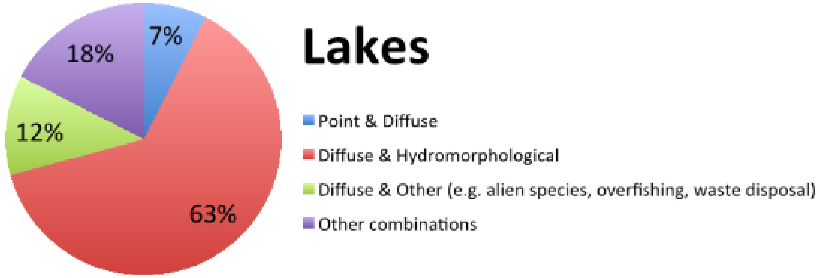
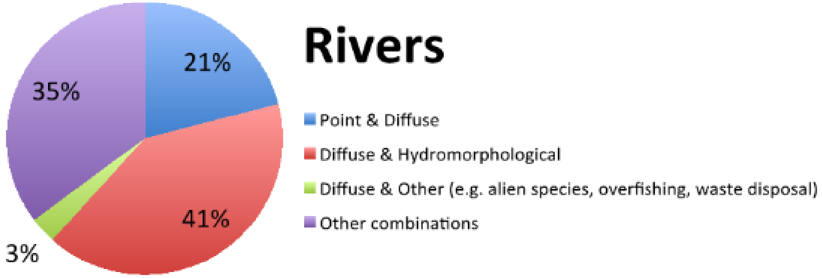
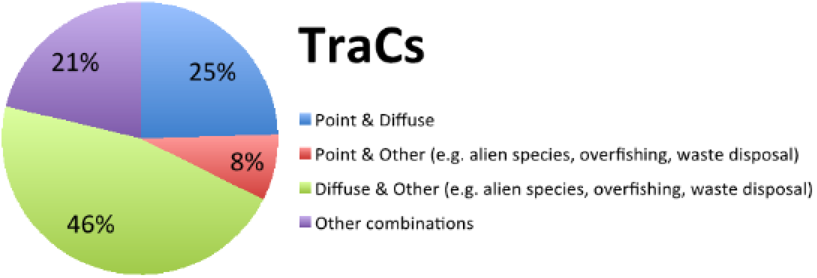
Multiple stressors drive ecosystem decline from source to sea

WFD pressures by waterbody type







Dominant stressors

Diffuse pollution and hydromorphological change

Diffuse pollution and hydromorphological change

Diffuse pollution and other pressures *(e.g. alien species, overfishing, waste disposal)*

Other unassessed pressures

- Pharmaceuticals (*sewage, livestock*)
- Personal care and cleaning products
- Recreational drugs
- Sediment pollution
- Pesticides and herbicides
- Antifungals, antibiotics, antihelminth agents
- Heavy metals (*including legacy stores*)
- Atmospheric deposition (*in acid-sensitive sites)*
- Acid mine drainage
- Climate change
- Organic microcontaminants (e.g. PFAS)
- Emerging chemicals including nanoparticles
- Parasites, microbial contaminants
- Altered flow regime (*abstraction/discharge*)
- Altered thermal regime (e.g. *industrial discharges*)

http://fis.freshwatertools.eu/index.php/infolib/stressors/multiple.html#multistress_europe

Focus of talk is on the River Exe and River Barle, upstream from Exebridge

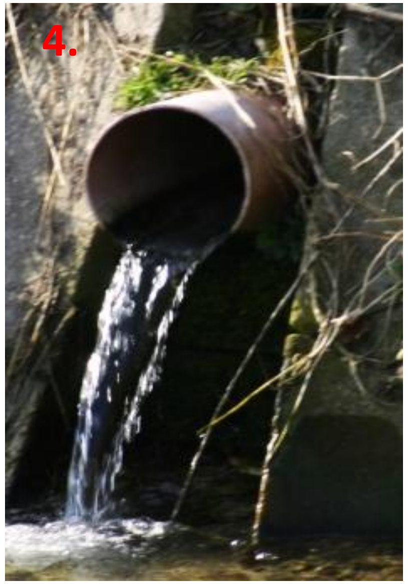
General principles regarding the need for *holistic understanding of the drivers of changing water quality* in UK freshwaters, and *integrated management strategies* apply across the wider Exmoor streams

Effluent discharges as a contaminant point source

1.


2.


3.


4.


5.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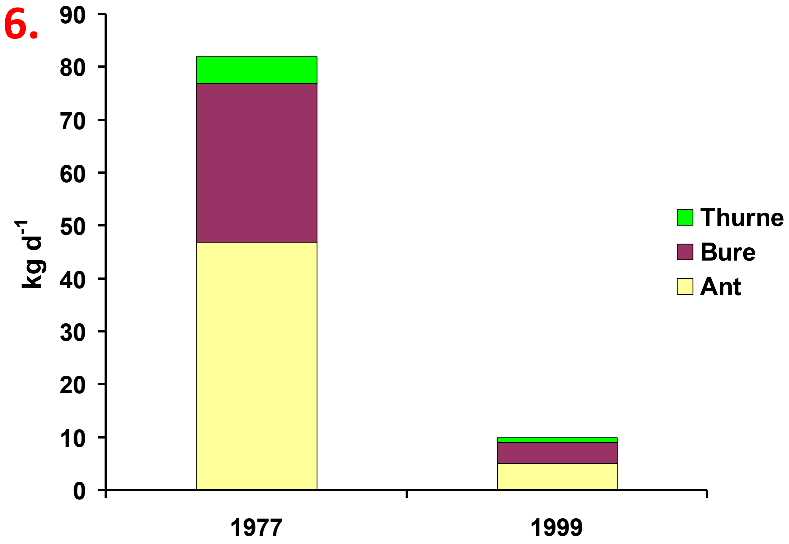


1. Point source discharges from WwTW
2. Sampling for laboratory analysis
3. Final effluent sampling point
4. Discharges from septic tank systems
5. Dynasand P stripping facility, Stalham, Norfolk
6. Impact of P stripping on the P load delivery to rivers feeding the Norfolk Broads

NB. Effluent discharges contain a wealth of other nutrient (N, C), ecotoxin (cleaning products, pharmaceuticals, microplastics, PLFAs etc.) and metals, not just P, which generate multiple stressor impacts in receiving waters, amplified by climate change.

Point sources of pollution in Exmoor National Park rivers

Westcountry Rivers Trust

Exmoor & Dartmoor National Parks' rivers polluted by pharmaceuticals

Aug 14, 2024 | 0 comments

A NEW study (released 13 August 2024) reveals National Parks in England are facing an unseen threat from pharmaceutical pollution.

Nearly half of Exmoor's rivers are below good ecological standards

https://www.wsfp.co.uk/news/nearly-half-of-exmoors-rivers-are-below-good-ecological-standards-new-report-reveals-833203

SEWAGE overflow into waterways in Exmoor National Park is 10 times higher than outside the park, and 44 per cent of its rivers fail to meet 'good ecological standards', a shock report revealed this week.

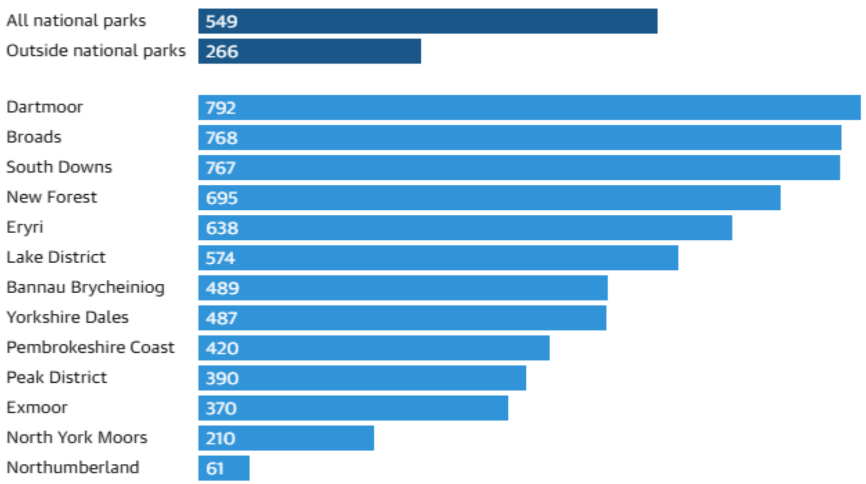
Claiming the park's rivers were now in 'crisis', research carried out by the Campaign for National Parks (CNP) in partnership with the Rivers Trust, revealed the average number of hours' spilling from a single sewer overflow per year in Exmoor National Park was 370, compared to 266 hours outside the park.

Revealed: river pollution twice as bad inside national parks as outside them

https://www.theguardian.com/environment/2025/sep/16/sewage-overflow-national-parks-england-wales-rivers-lakes

Sewage outflows in national parks were operating on average at twice the rate of those outside protected areas in 2024

Average total operating hours per outflow, England and Wales



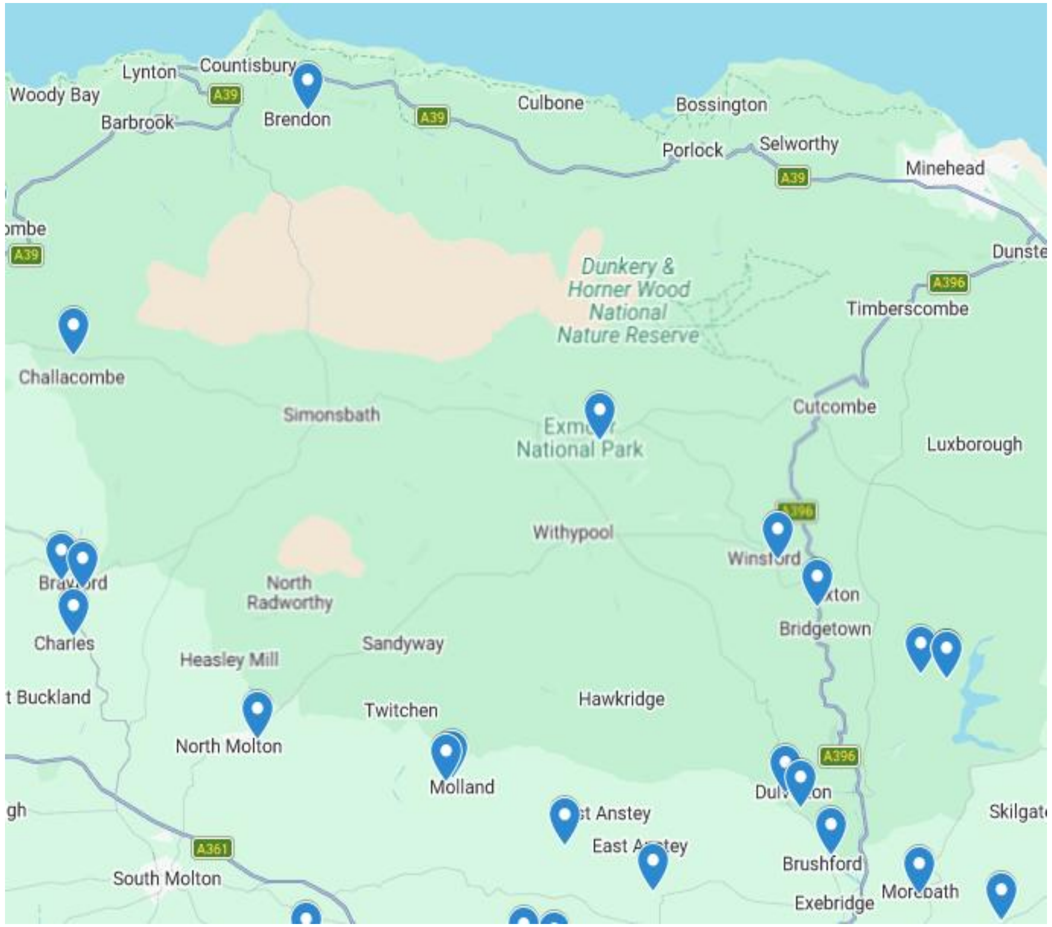
Guardian graphic. Source: Campaign For National Parks and Rivers Trust

How important are sewage discharges in the Exmoor streams and rivers?

River Exe at Exford STW

River Exe at Bridgetown STW

South West Water Sewage Treatment Works in Exmoor



River Exe at Winsford STW

River Barle at Dulverton STW

STW in the Exmoor streams and rivers upstream from Exebridge are small, serving <2000 people, providing biological treatment only

Sewage treatment works and combined overflows in Exmoor stream and river catchments vs septic tanks

The Rivers Trust Sewage Map:
https://theriverstrust.org/sewage-map

STW or larger WwTW

Septic tank (permitted)

Exe STW spills in 2025:
88 spills, 1410 hrs (6.5% of yr)

Barle STW spills in 2025
102 over 233 hrs (1% of yr)

Septic tanks/soakaways:
- *More in the Barle than the Exe*
- *Many unmarked, most unassessed*
- *All will discharge (seap) year round*
- *A key source in rural catchments.*

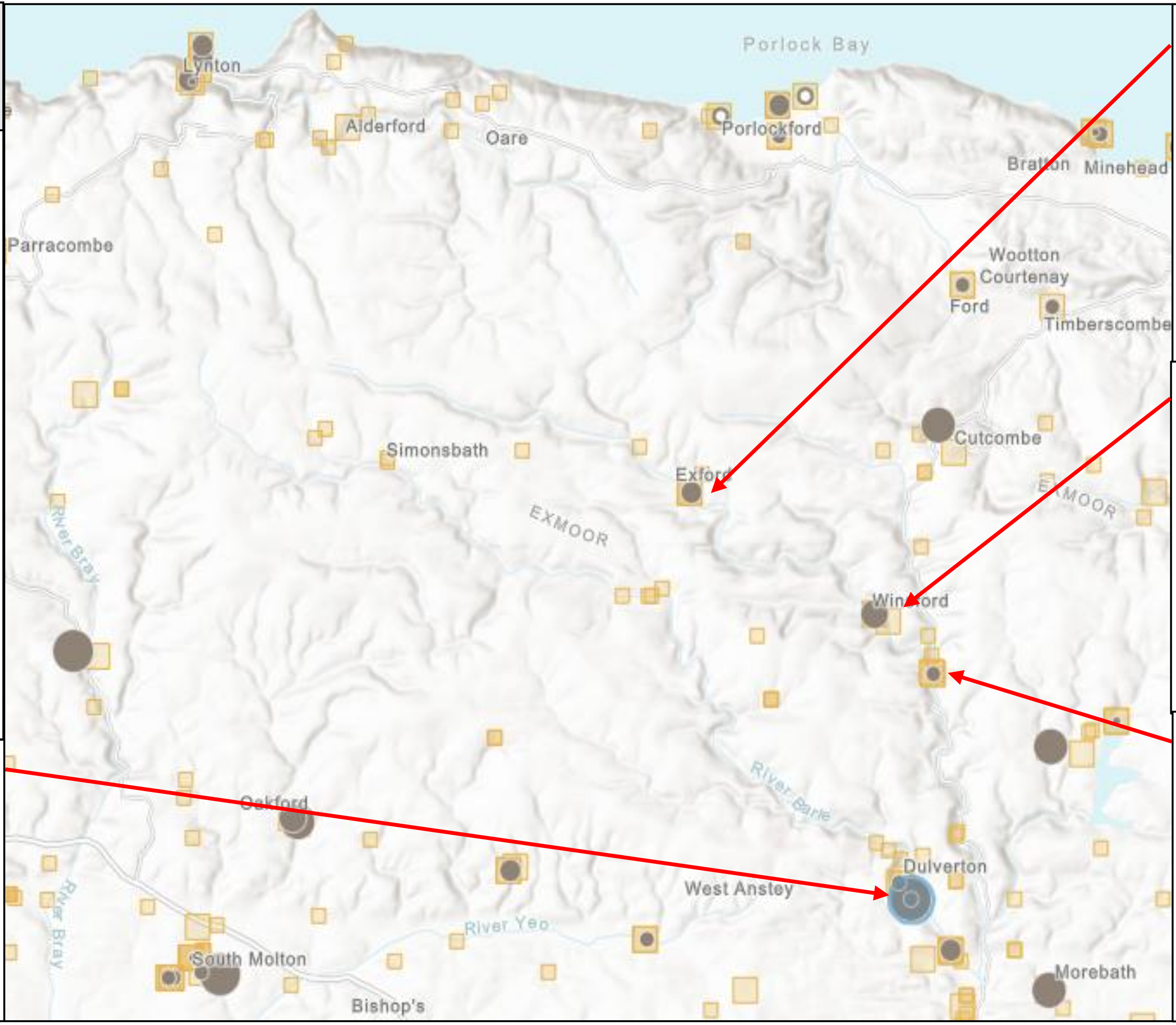
Dulverton Wwtw (South West Water)

Zoom to Pan

Unique ID: SBB00381

Permit number: 203027

In 2025, this sewer storm overflow spilled **102** times for a total of **232.86** hours, discharging into the River Barle.



Exford Stw (South West Water)

Zoom to Pan

Unique ID: SBB00432

Permit number: NRA-SW-3496

In 2025, this sewer storm overflow spilled **39** times for a total of **551.59** hours, discharging into the River Exe.

Winsford Pscso/eo (South West Water)

Zoom to Pan

Unique ID: SBB01369

Permit number: 203228

In 2025, this sewer storm overflow spilled **45** times for a total of **596.99** hours, discharging into the River Exe(s).

Bridgetown Wwtw Ps (South West Water)

Zoom to Pan

Unique ID: SBB00160

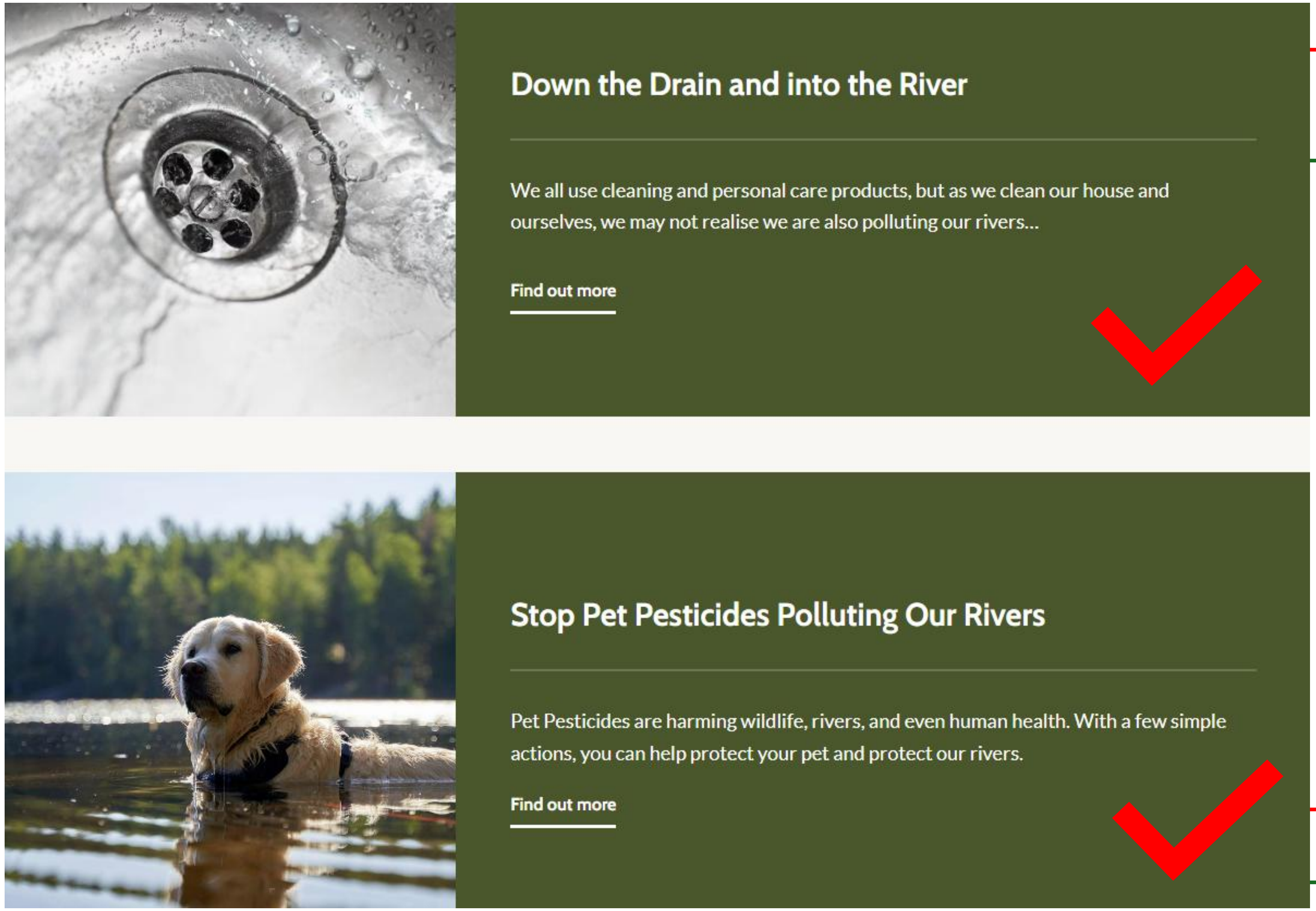
Permit number: NRA-SW-1069

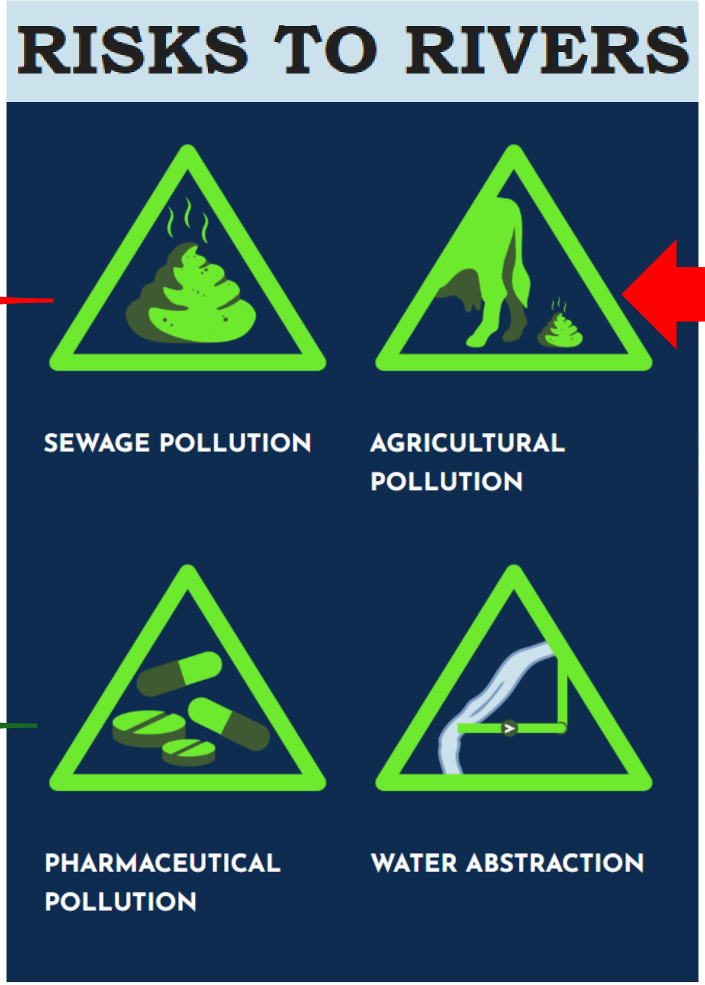
In 2025, this sewer storm overflow spilled **4** times for a total of **29.03** hours, discharging into the River Exe.

Targeting sources in Exmoor catchments: is anything missing?

The Exmoor Society campaign news, downloaded 21 June 2026

CAMPAIGN for NATIONAL PARKS



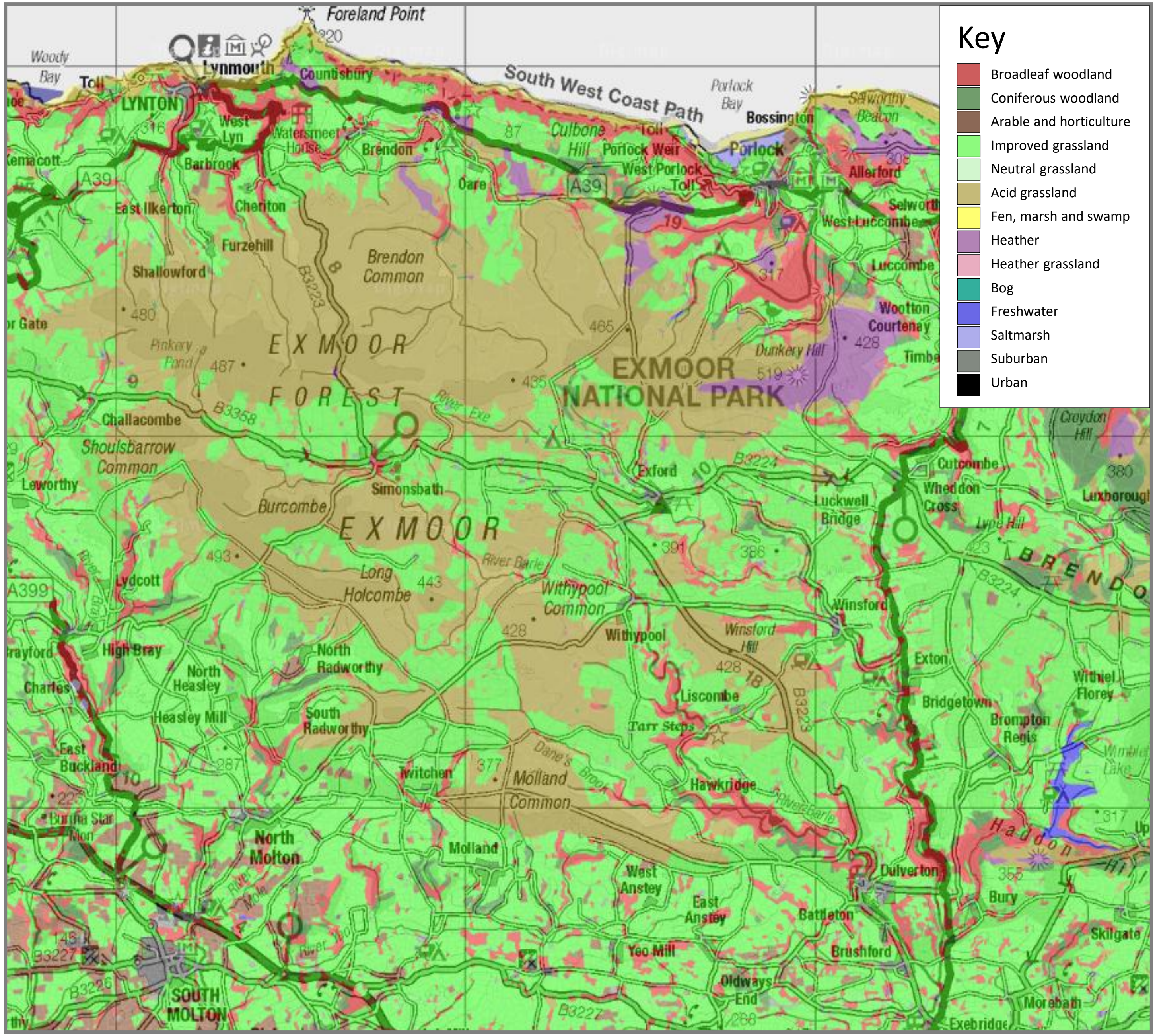


Diffuse nutrient sources in arable farming catchments

1. Application of inorganic, urea and organic fertilisers to arable land.
2. Erosion of bare arable soils in the winter months, with export of sediment and sediment-bound contaminants to streams.
3. Manure voided directly to fodder crops, containing a range of contaminants which shear off into nearby watercourses.
4. Flushing of accumulated Dissolved Organic Matter (DOM) from soil organic matter stores.
5. DOM, nutrient, pathogen and ecotoxin export from outdoor pig rearing units.
6. Contaminant delivery to rivers in dissolved and particulate form via field drains and ditch discharge.
7. and 8. Sewage sludge applied to land *(NFU photo 7, CHEM Trust photo 8).*

Diffuse nutrient sources in livestock farming catchments

1. Over-full slurry lagoon
2. Over-full FYM store
3. Dirty yard by parlour
4. Drain linking 3. to stream
5. Runoff from 1. to stream
6. Excessive slurry applications
7. Farm track channelisation
8. High stocking densities in fields
9. Out-wintering of livestock
10. Direct stock access to streams
11. Excess fertiliser use for double crop silage for 24/7 indoor dairy farms



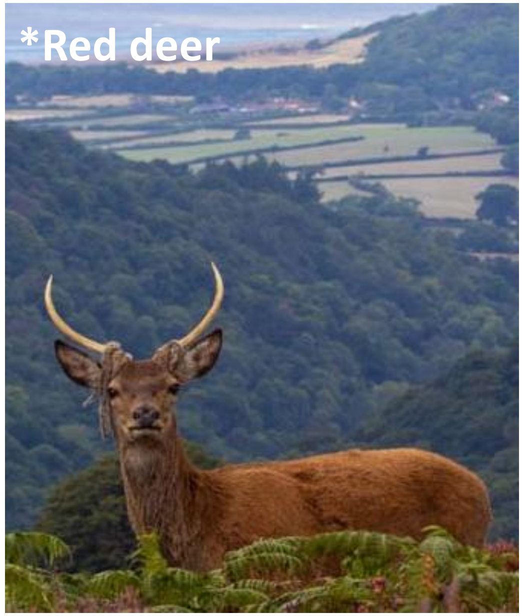
UKCEH Land Cover Map 2024: https://www.ceh.ac.uk/data/ukceh-land-cover-maps

The importance of landscape character

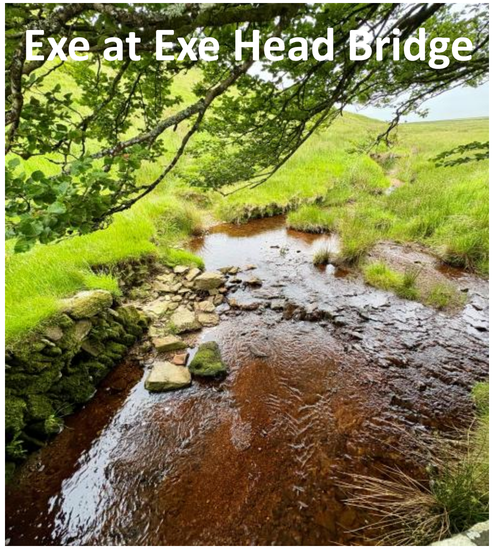
1. *Controls* the nature of land use and management in any catchment.
2. *Varies* between catchments and landscape types.
3. *Influences* the location and density of human settlements in catchments.
4. *Dictates* the type and intensity of farming in catchments.
5. *Affects* the connectivity of terrestrial and freshwater ecosystems.
6. *Determines* the efficiency of pollutant transport from land to water.
7. *Requires* bespoke solutions tailored to the conditions in each catchment.

Diffuse sources in the River Exe upstream from Exford

*Photos from *Exmoor Society, +ENPA, #Westermill Farm. Unmarked photos are by the speaker.*


*Red deer


*Exmoor ponies


Exe at Exe Head Bridge


*Aberdeen Angus cattle at Westermill


*Heather moorland with wooded coombes

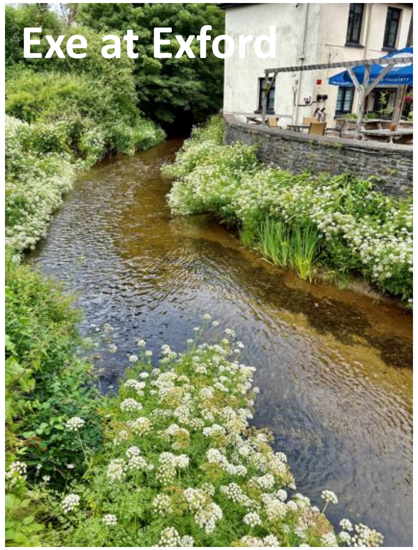

#Exe at Westermill Farm


#Sheep fording stream at Westermill

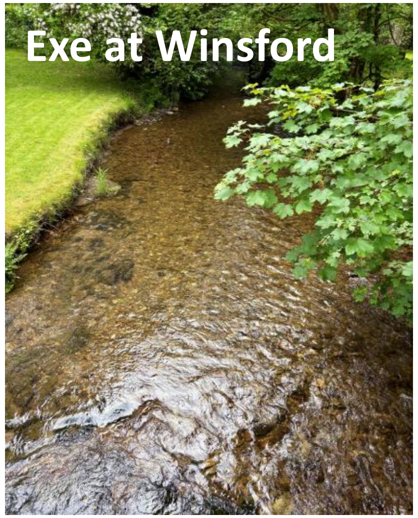
Open moorland, high proportion of peat soils, running onto enclosed grazing land upstream from Exford with wooded valleys

Cumulative diffuse sources from Exford to Bridgetown

Photos by the speaker.



Exe at Exford



Exe at Winsford

Intensive sheep grazing to riverbank at Bridgetown with 1m fencing from stream edge

Dairy cattle with direct stream access at Bridgetown

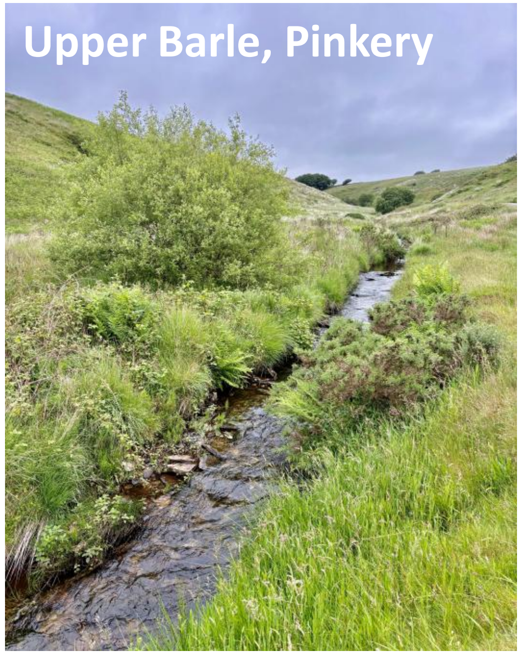
Shift to intensive grazing and some arable farming downstream from Exford

Intensive beef cattle production on sloping land upslope from Winsford

Enclosed grazing land downstream from Exford with wooded valleys, shifting to intensive livestock grazing on hills and valleys

Diffuse sources in the Upper Barle SSSI acid upland stream

*Photos from *Exmoor Society, +ENPA, #Westermill Farm. Unmarked photos are by the speaker.*


Upper Barle, Pinkery

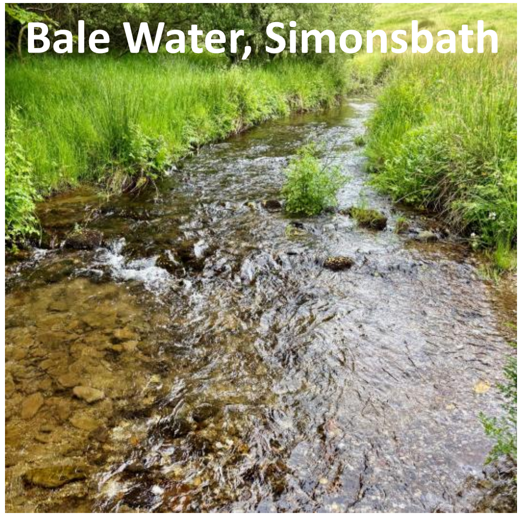

+Pinkery Centre landscape


+Pinkery Centre Exmoor ponies


Cultivated soils, upstream Withypool


Sheep farming on slopes, Room Hill


Bale Water valley


Bale Water, Simonsbath

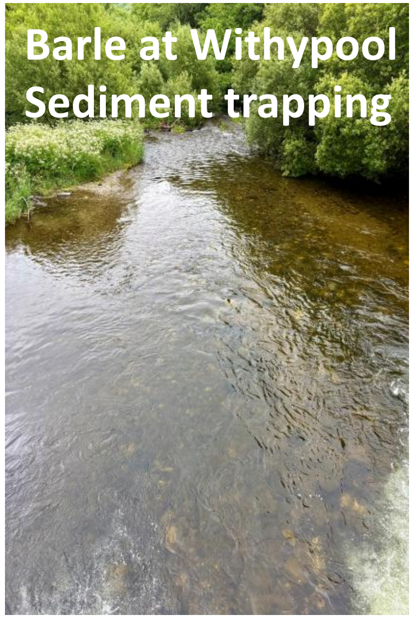

Bale Water, Simonsbath: fine sediment pollution

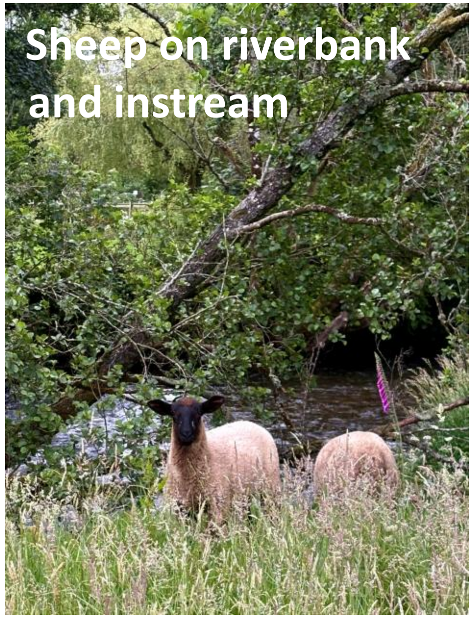

Fencing of sheep, 1m from stream

Open moorland with acid grassland, running onto enclosed grazing land upstream from Withypool, with wooded valleys

Cumulative diffuse sources: Withypool to Brushford & Exebridge

Photos by the speaker.





Shifts from lower intensity agriculture in enclosed farmed hills, to livestock production in flatter valley bottoms

QUANTUM

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

Penny Johnes, Ian Bull, Richard Evershed, Ana Castro-Castellon, Sydney Enns, Victoria Hussey (University of Bristol)
Davey Jones, Dave Chadwick, Dan Davies (Bangor University)
Barbara Kasprzyk Hordern, Tolulope Lawrence (University of Bath)
Charles Tyler, Simona Frascati, Anke Lange (University of Exeter)
Andrew Binley, John Ball, Hannah Champion and Barry Hankin of JBA Consulting via (Lancaster University)

and our regulatory, industry and academic Project Partners and Stakeholders

Contact: penny.johnes@bristol.ac.uk

Office for Environmental Protection

Department for Environment Food & Rural Affairs

Cyfoeth Naturiol Cymru Natural Resources Wales

Wessex Water YTL GROUP

Dŵr Cymru Welsh Water

Harper Adams University

Theme 1a: Revealing the potential nutrient, ecotoxin and pathogen risks to UK freshwaters from livestock excreta

Livestock excreta (dung, urine, FYM, slurry) were collected from sheep, dairy and beef cattle farms at 3 spatial and temporal frequencies:

Theme 1a: Seasonal (winter/summer) variation in composition

Dung, FYM, Urine, Slurry, **6 farms,** England, Wales)

- □ University/Research farms
- △ Farms in Tier 1 catchments
- WP2-4 experiments site, Rickford
- Sloping land, mixed drainage
- Lowlands, heavy clay soils

Henfaes Farm Research Centre, Bangor University (sheep)

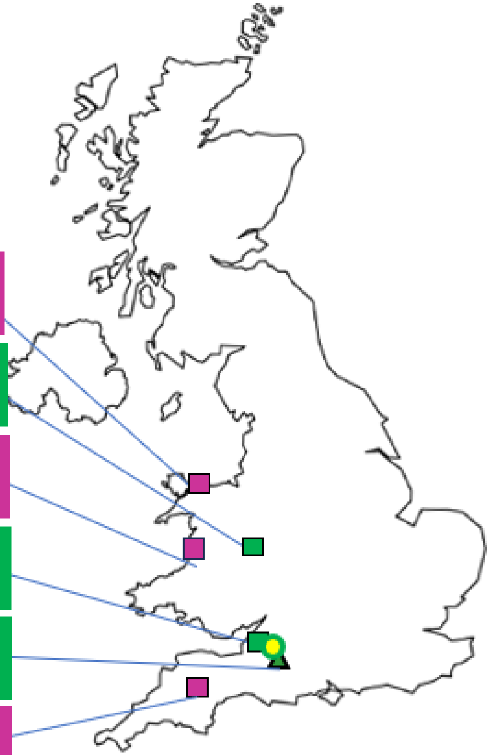
Harper Adams University (beef, cattle, dairy cattle, sheep)

IBERS Aberystwyth (beef cattle, dairy cattle, sheep)

Wyndhurst Farm, University of Bristol Vet School (dairy cattle)

Ebborlands Farm, Mendips (beef cattle, grass-fed, low intensity)

Rothamsted North Wyke Livestock Unit (cattle and sheep)



Theme 1b: Monthly variation in composition

(1 year) **Slurry** only, **1 farm, Congresbury Yeo**

Theme 1a National variation (summer only)

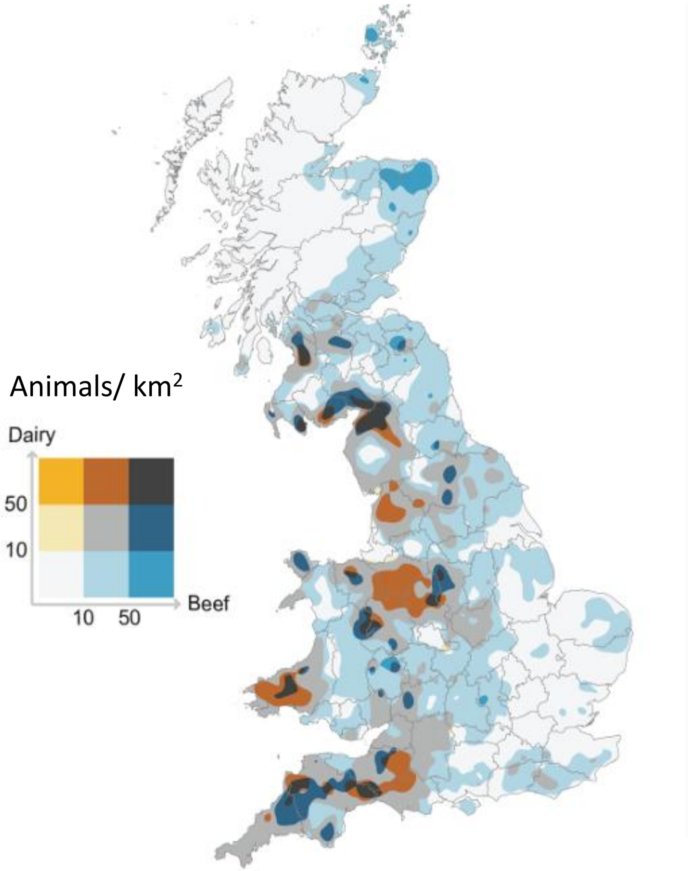
Dung only, **60 farms,** England, Wales, Scotland

- Samples were analysed to determine their nutrient, ecotoxin, pathogen and organic matter composition.
- *How does risk to UK rivers vary in space and time, between farms, livestock types and production systems, excreta types and contaminants?*

National sampling programme: selected sites *(single livestock type)*

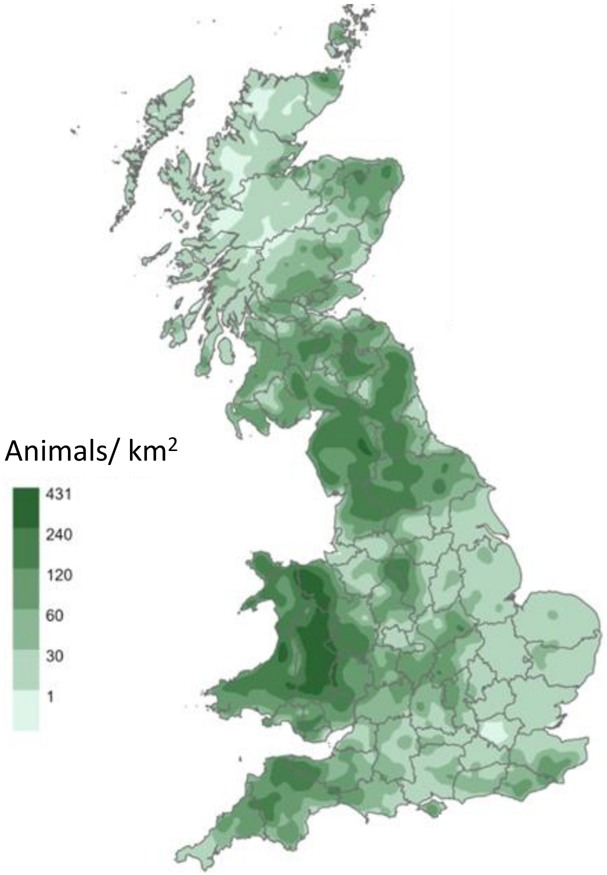
Animal & Plant Health Agency

GB Dairy/Beef Cattle Population Density, July 2024



Animal & Plant Health Agency

GB Sheep/Goat Population Density, Dec 2023 - Jan 2024

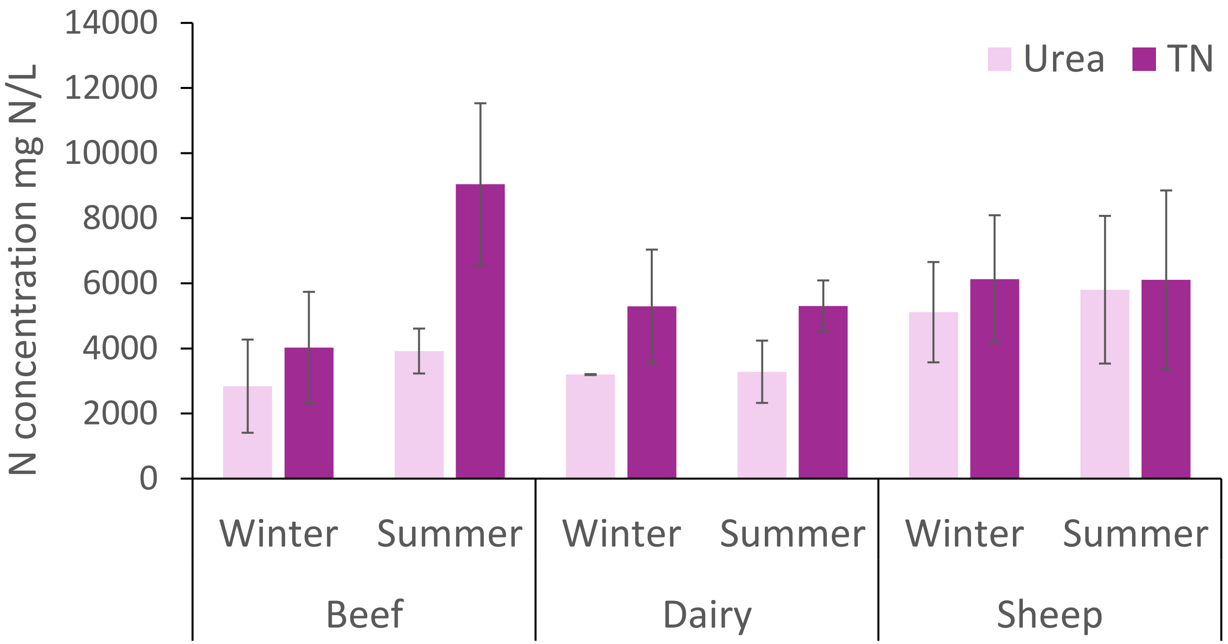


NERC QUANTUM sites SW England successfully sampled summer 2025

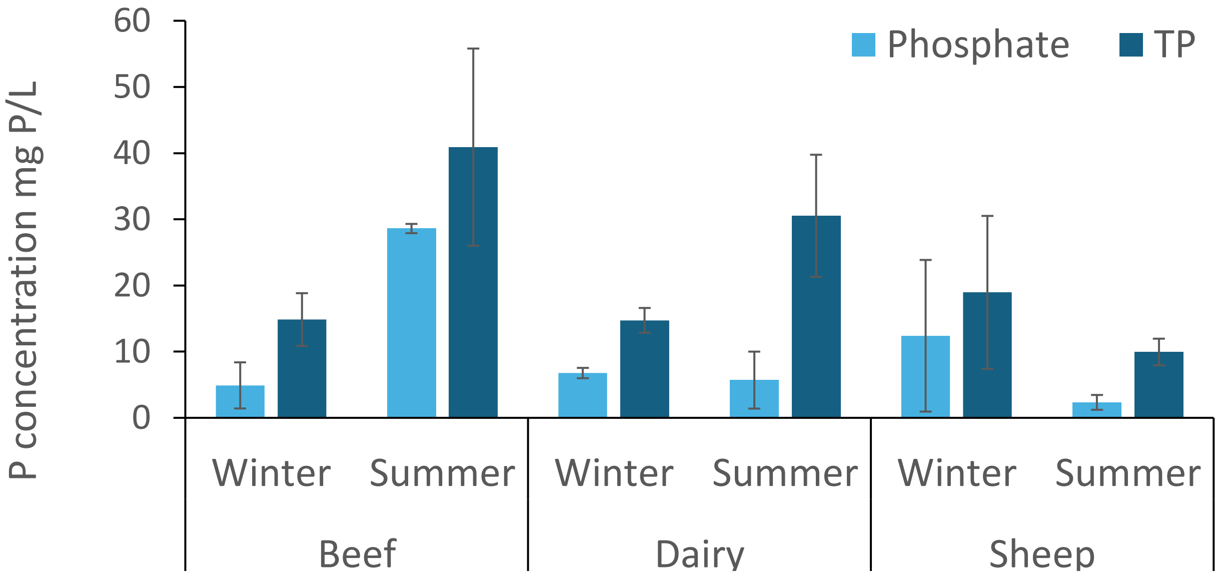
Tried to use several Exmoor sites incl. Westermill, Withypool, but couldn't use as had > 1 livestock type in the catchment

Nutrient composition in urine varies by season and livestock type

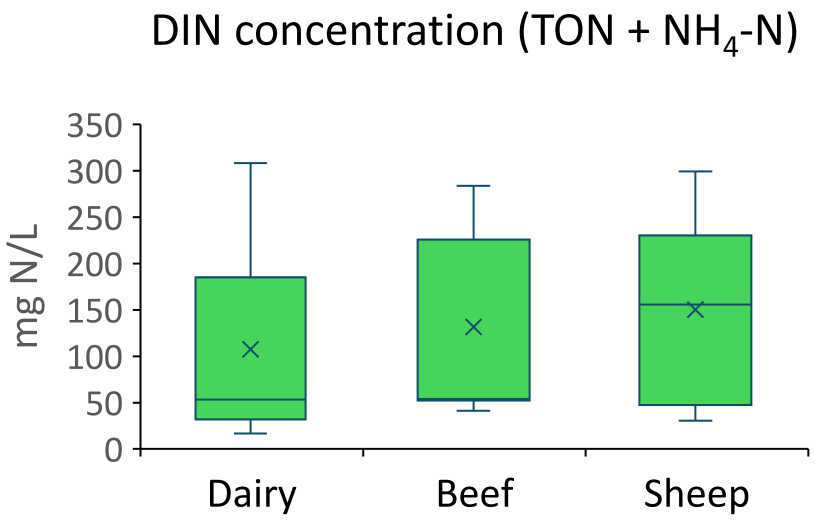
- In winter, urea and total N concentrations are highest in sheep urine.
- Total N and urea concentrations are almost equally high for sheep and dairy cattle urine, all year round.
- In summer, total nitrogen concentrations are highest in beef cattle urine.

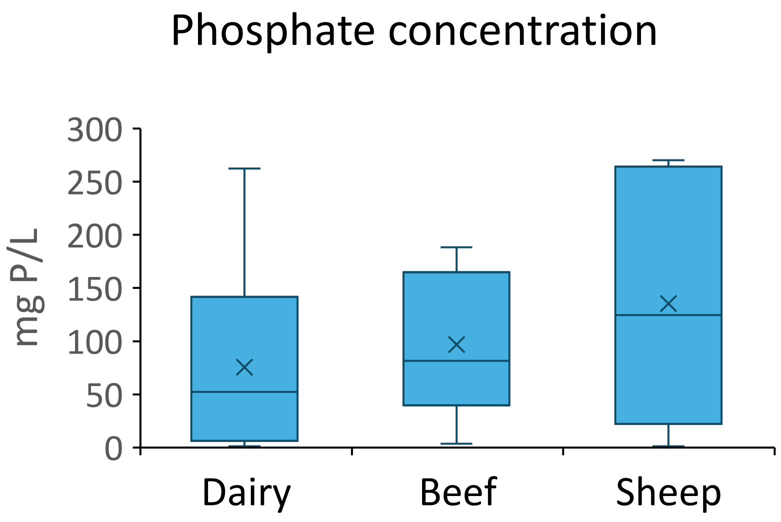


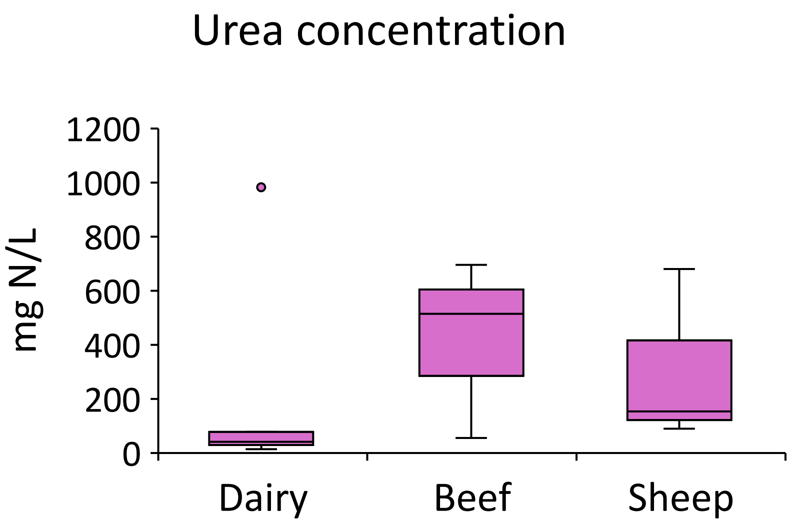
- Total P and phosphate concentrations are highest in beef cattle urine in the summer, compared to other livestock types.
- Total P concentrations are also higher in dairy cattle urine in the summer than in the winter.
- Total P and phosphate concentrations are highest in sheep urine in the winter.

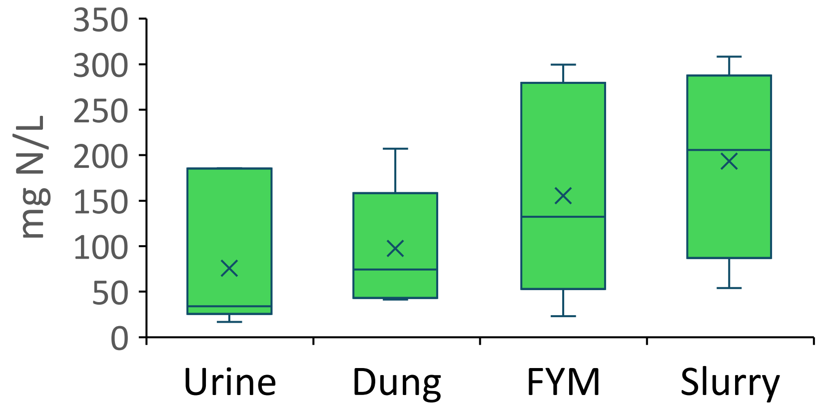


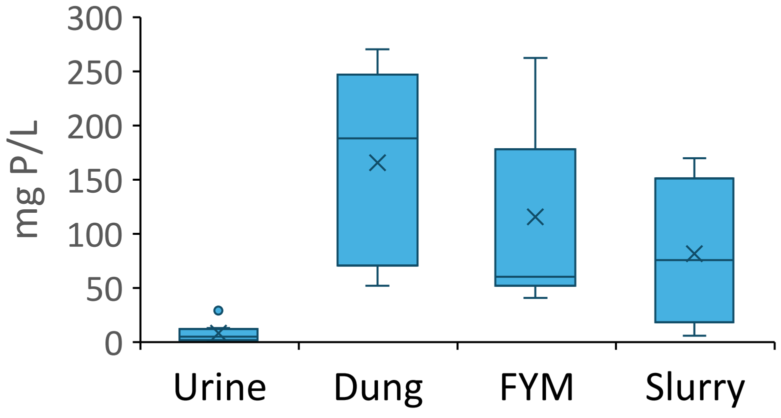
Dissolved nutrient concentrations in Winter excreta samples

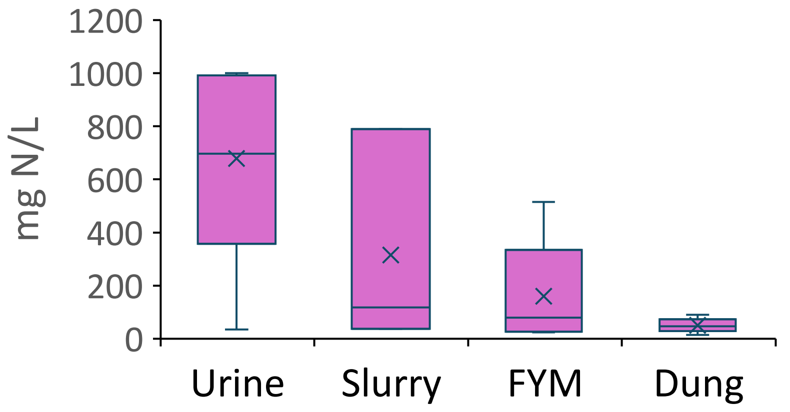






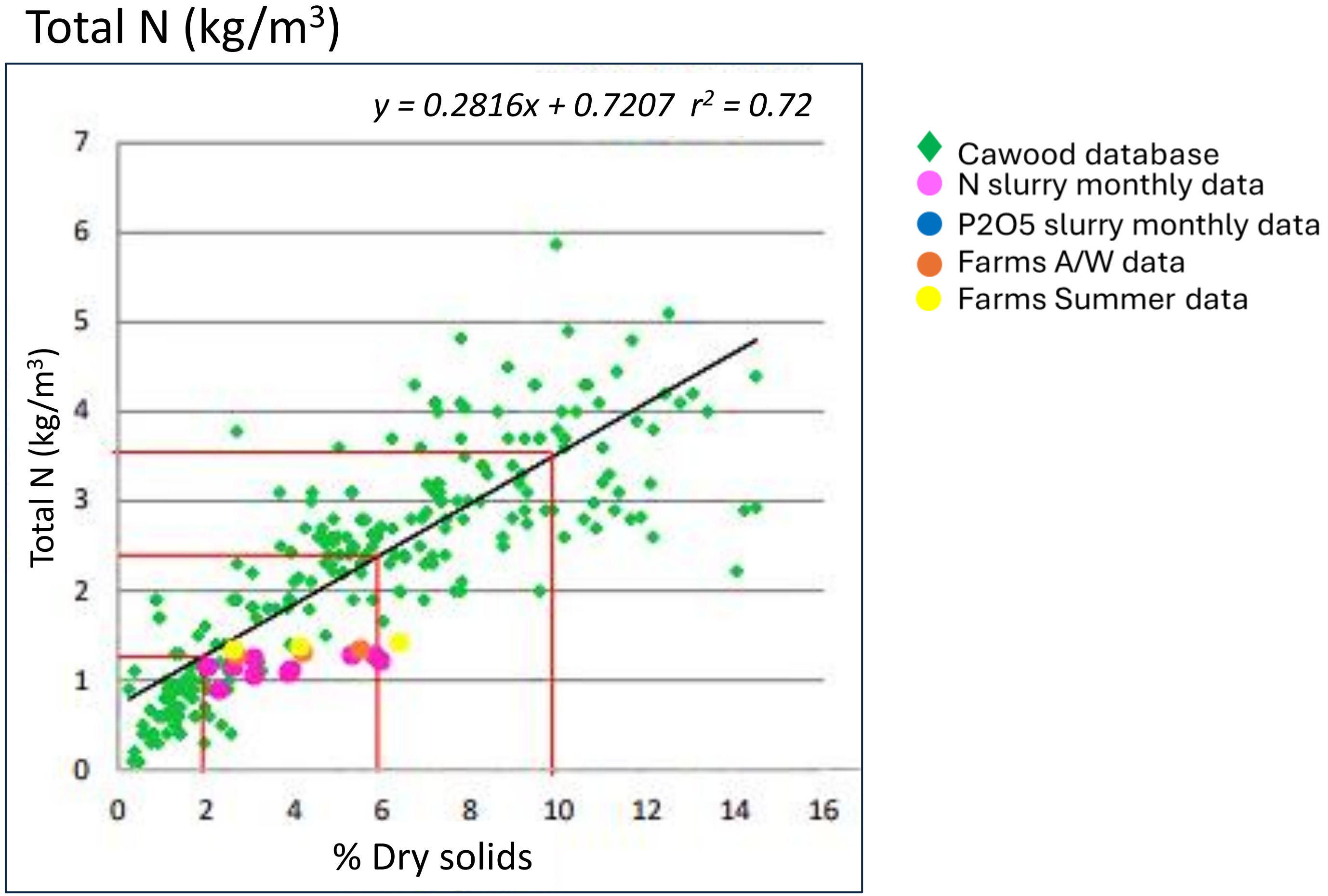


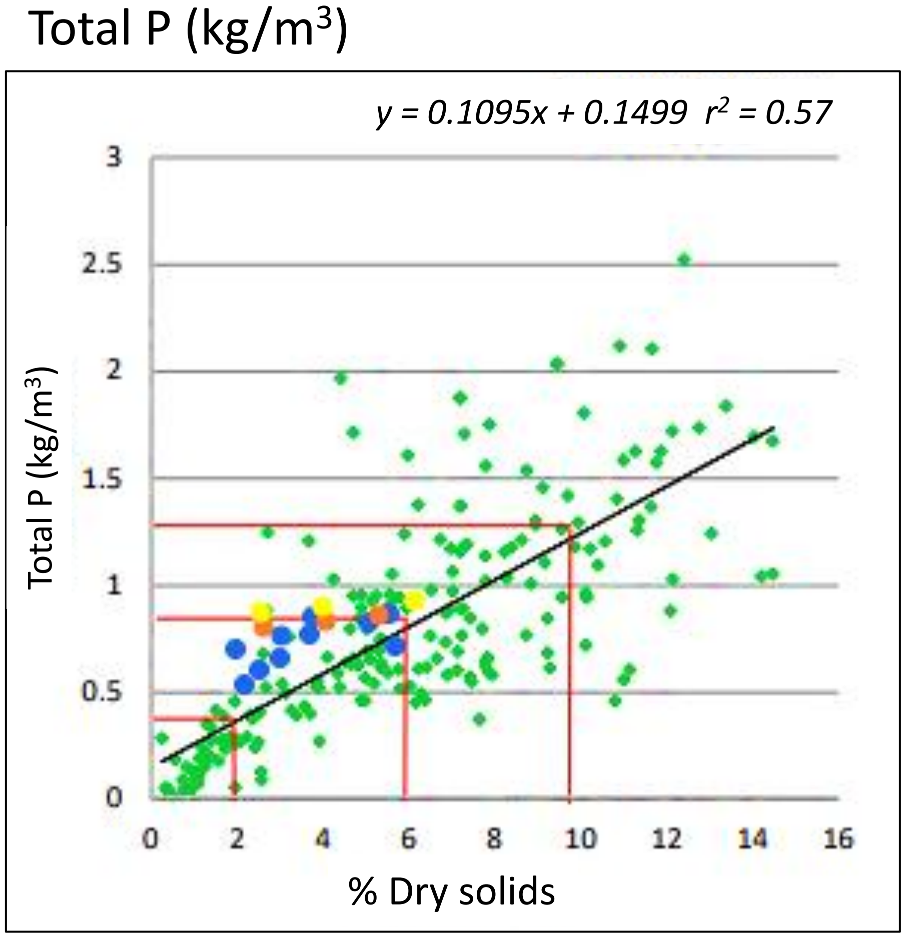




Livestock excreta present risks of nutrient pollution in UK rivers varying by livestock type, season and excreta type

Comparing monthly slurry nutrient and dry solid content to ranges observed nationally using NRM Cawood databases[1]





Total nitrogen and P_2O_5 kg/m³ concentration for QUANTUM cattle slurry samples fall within the expected national standard range reported by NRM Cawood. [1]https://cawood.co.uk/wp-content/uploads/2021/08/The-Value-of-Manure-and-Slurry-2018.pdf.

Characterising chemicals of concern in livestock and excreta

Screened for 198 target compounds. *Those detected are underlined in red*

Antibiotics

Nitrofurantoin, Ampicilloic acid, **Trimethoprim**, 4-hydroxy-trimethoprim, Sulfapyridine, N-acetyl sulfapyridine, Tetracycline, Ofloxacin (Levofloxacin), Desethylene ciprofloxacin, Oxytetracycline, Desmethyl-ofloxacin, Sulfamethoxazole, **Ciprofloxacin**, **Ampicillin**, Ofloxacin N-oxide, **N-acetylsulfamethoxazole**, Linezolid, **Hydroxy-norfloxacin**, Penicilloic G acid, **Azithromycin**, **N-desmethyl azithromycin**, Clindamycin, N-desmethyl clindamycin, Penicillin G, Penicillin V, Erythromycin, **N-desmethyl erythromycin**, **N-desmethyl clarithromycin**, **Clarithromycin**, Pyrazinoic Acid, Tazobactam, Benzalkonium Chloride (C12), Benzalkonium Chloride (C14), **Cefadroxil**, **Cefaclor**, **Cefazolin**, Cefotaxime, Minocycline, Clofazimine, Chlortetracycline, Piperacillin, Ceftazidime, Amikacin, Vancomycin, 5-Hydroxy-pyrazinoic acid, **Sulfadiazine**, **N-acetyl sulfadiazine**, Pyrazinamide, **Amoxicilloic acid**, Doxycycline, Flumequine, Sulfasalazine, **Ulifloxacin**, Prulifloxacin, Deacetyl-ketoconazole, Ketoconazole, Flucloxacillin, **Oxolinic Acid**, Marbofloxacin, Oxacillin, **Lincomycin**, Pirlimycin, Nafcillin, Pivmecillinam, Dicloxacillin, **Tiamulin**, Cefquinome, Valnemulin, Gamithromycin, Roxithromycin, Spiramycin, Tylosin, Clavulanic Acid, Mecillinam, Thiamphenicol, **Cefoxitin**, Norfloxacin, Enrofloxacin, Gatifloxacin, Besifloxacin, Isoniazid, Bedaquiline, Cloxacillin, Cefixime, Rifabutin 25-desacetyl, Metronidazole, Metronidazole hydroxy-, Roxithromycin ……

Pharmaceuticals and Biomarkers

Acetaminophen, Ranitidine, Daidzein, Thalidomide, **Chlorxylenol**, **Acesulfame**, **Ferulic acid**, **Ibuprofen**, **D-Pantothenic acid**, **O-desmethylnaproxen**, 2-Hydroxyibuprofen, Resveratrol, **Urolithin A**, Naproxen, Carboxyibuprofen, Ketoprofen, Dihydroketoprofen, **Genistein**, Phloretin, a-CEHC, Epicatechin, Diclofenac, 4-Hydroxy Diclofenac, Uracil, Creatinine, Valine, L-Threonine, L-Lysine, L-Methionine, Norephedrine, L-Phenylalanine, L-Histidine, Gabapentin, N-methyl Pregabalin, Formiminoglutamic acid, Melatonin, **8-hydroxy-2'-deoxyguanosine**, Amlodipine, N-desmethyl-sildenafil, Sildenafil, Nicotine, Cotinine, **4-Pyridoxic acid**, **Caffeine**, L-Carnitine, Pyroglutamic Acid, Tramadol, O-desmethyl Tamadol, N-desmethyl Tamadol.

Endocrine disruptors & Hormones

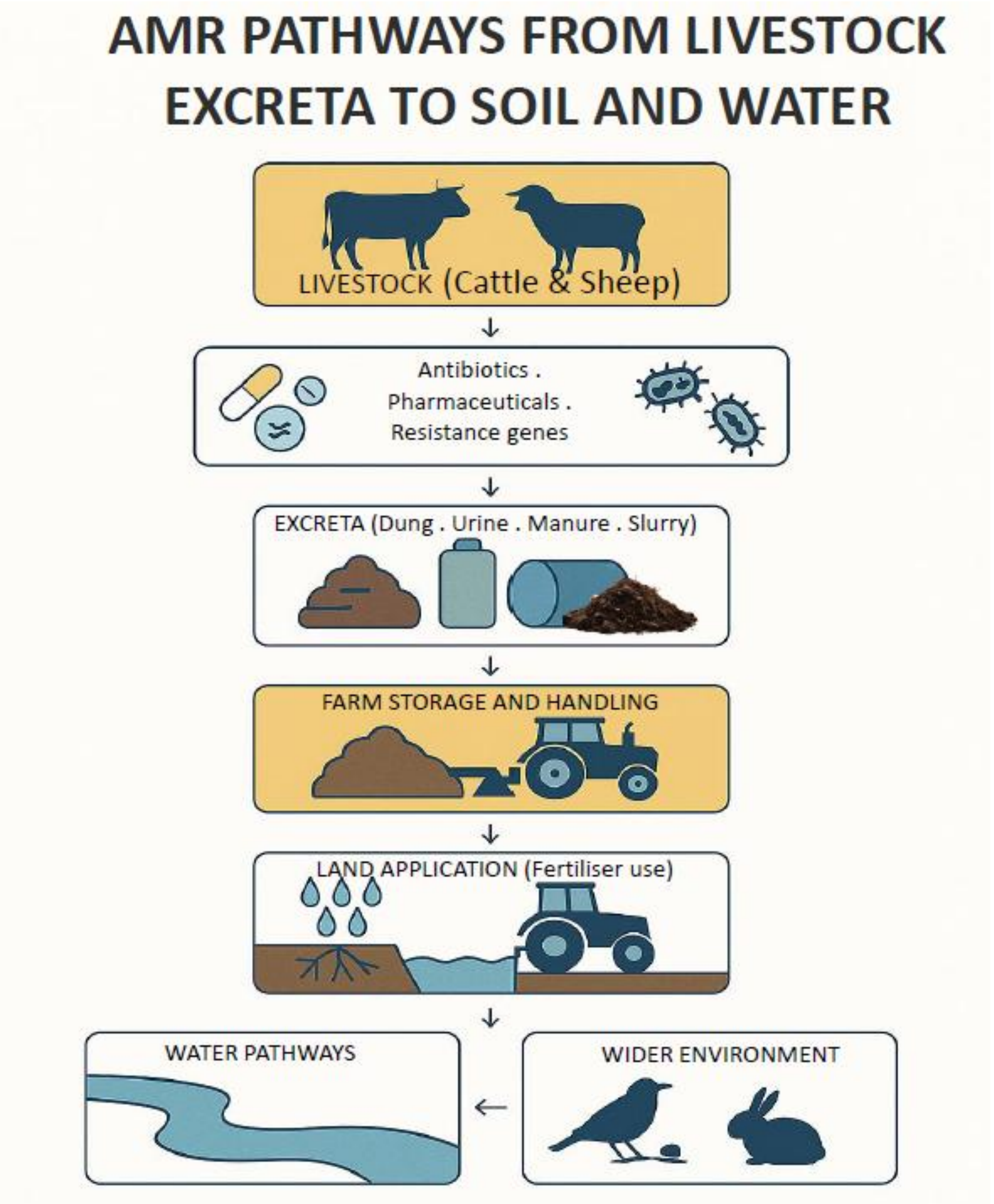
Methylparaben, **Ethylparaben**, **Propylparaben**, Butylparaben, **Bisphenol A**, **Equol**, **Estrone (E1)**, 17α-ethynylestradiol (EE2), Estradiol (E2), Triclosan, **Daidzein**, **Androstenedione**, Testosterone, **Progesterone**, **Urolithin A**, 17a-OH-Progesterone, **Enterodiol** and **Enterolactone**.

Fungicides & Antiparasitics

Terbinafine N-desmethyl-carboxy, Terbinafine N-desmethyl, Terbinafine, Imazalil, Fluconazole, **Tebuconazole**, **Prothioconazole-desthio**, Dichlofluanid, Griseofulvin, Thiabendazole, Prochloraz, Naftifine, Fenbendazole, **Ivermectin**, **Deltamethrin**, Abamectin.

Antimicrobial Resistance (AMR) *preliminary results*

- DNA has been extracted from all samples and sent to Resistomap for high-throughput qPCR for screening 96 genes
- These include genes for both AMR and mobile genetic elements (MGE – ‘superbugs’).
- Relative abundance of AMR genes conferring resistance to aminoglycosides, and tetracyclines were highest in all samples.
- Many other clinically relevant genes were also detected in the farm samples.
- Among MGEs, profiles varied between sample types, with integrons generally higher in **sheep** and **beef** compared to **dairy**.



Theme 2a: Investigating the impact of the mixtures of chemical & biological contaminants from different livestock farming types, and their exposure regimes on UK river ecosystems

Work on ecotoxicology underway, led by the University of Exeter (Charles Tyler and team).

Ecotox experiment 1: In-situ duplicate caged exposure experiment at Rickford u/s and d/s from slurry amendment plots. Uses 3-spined stickleback (*Gasterosteus aculeatus;* 30 fish/cage), and *Gammarus pulex* (40 per cage). 28 day exposure.

Initial results:

- Stickleback maintained relatively good condition throughout
- *Gammarus pulex* had a poor survival rate (37%) so wild *Gammarus* from the stream were also collected for analysis

Ongoing analyses:

- Histopathology - gonadal samples embedded and ready for sectioning and maturity assessment.
- Genetic sex - analyses in progress.
- Chemical analyses -
  - (a) Passive Samplers to assess presence of selected target CoCs in the stream.
  - (b) Method development to measure selected target chemicals liver tissue.

Potential further analyses:

- Bioaccumulation of exposure chemicals in the liver.
- Liver transcriptome analyses by RNA-seq to link chemical exposures with functional responses.

Theme 2b: Investigating the impact of the mixtures of chemical & biological contaminants from different livestock farming types, and their exposure regimes on UK river ecosystems

Stable isotope dosing experiments to investigate Livestock-derived (LDOM) uptake as a nutrient resource by stream biota

Organisms: Biofilms (mixed communities), bryophytes *(Fontinalis antipyretica)* and pond snails *(Lymnaea stagnalis).*

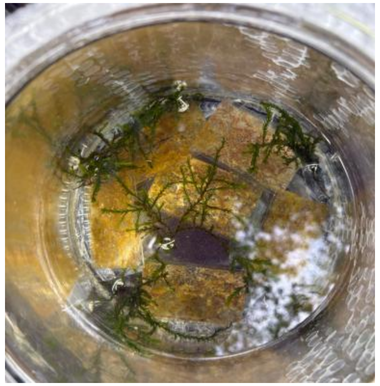
LDOM targets: $^{13}C^{15}N$ labelled Urea (amide of carbonic acid, excretion product), Glucosamine (amino sugar), Creatinine (imidazolidinone, excreted by kidneys), Glutamate, Glycine and algal-derived amino acid mix (all amino acids).

Inorganic N targets: ^{15}N labelled Ammonium sulphate and Potassium nitrate.

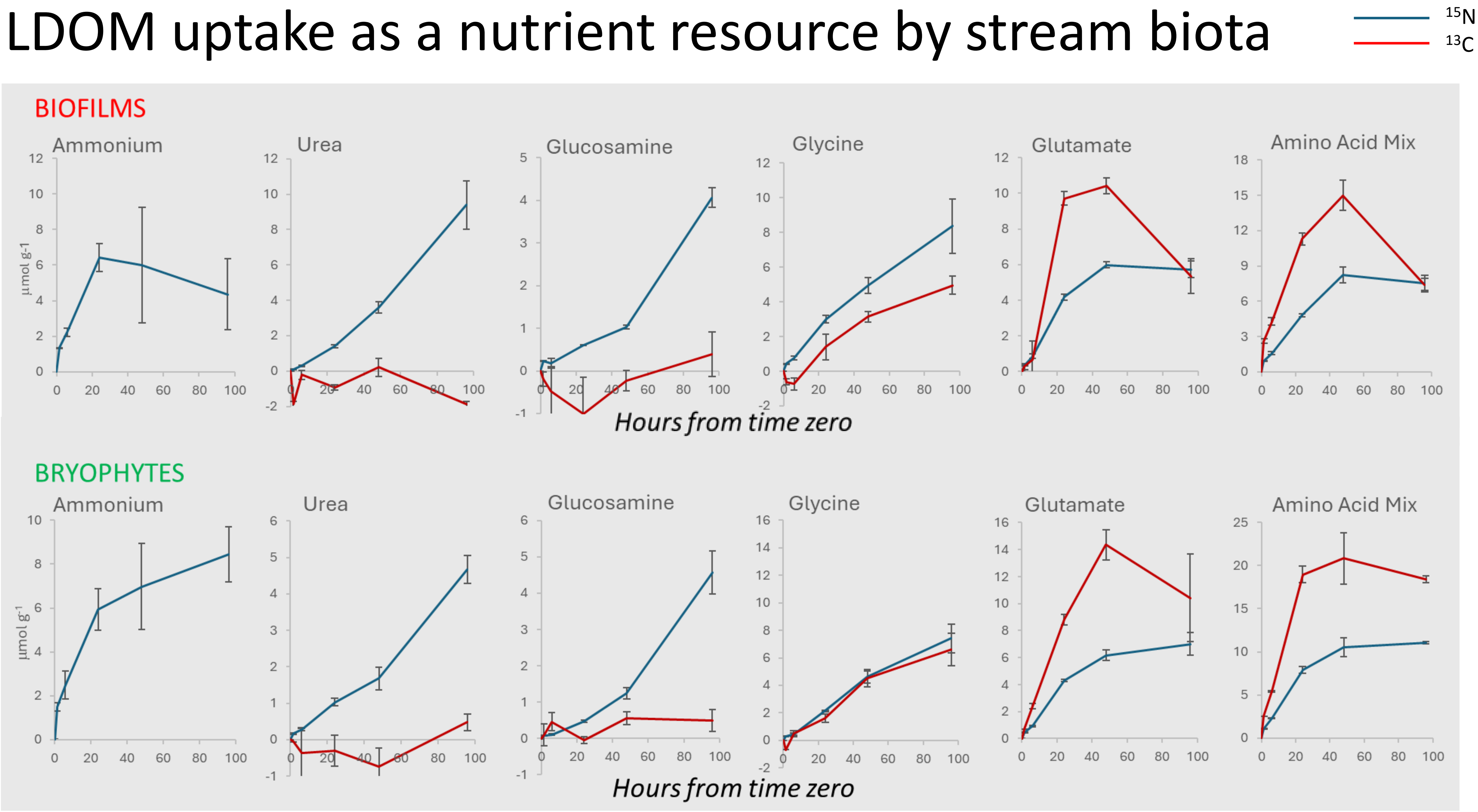
Experiment type: 1% enrichment over ambient concentrations, 4-d incubation at ambient temperature. Sampling of biofilms and bryophytes at 0, 1.5, 12, 24, 48, 96h. Pond snails introduced at 96h, collected once, 192h. Climate warming experiment. (water @ +2.3 ^{o}C) run in parallel.

	Frame 1		Frame 2	
	Lane 1	Lane 2	Lane 3	Lane 4
a.	Gly-1	CO-1	Cre-1	CC-1
b.	AAx-1	Nit-1	Amm-1	Gly-2
c.	Gko-2	Glu-2	AAx-2	CS-1
d.	CC-2	CS-2	Gko-3	Ure-3
e	Cre-3	CC-3	Nit-2	Amm-3
	Frame 3		Frame 4	
a.	Ure-1	CO-3	Gko-1	Glu-1
b.	31b	Amm-2	Ure-2	CO-2
c.			Cre-2	Gly-3
d.			Glu-3	Nit-3
e.			AAx-3	CS-3

	Controls	Tape colour
CO	Control Open	White
CC	Contol Closed	Grey + Red
CS	Control Sealed	Grey + Blue
	Treatment	
Gly	Glycine	Blue
AAx	Amino acid mix	Grey
Gko	Glucosamine	Stripped
Cre	Creatinine	Green
Ure	Urea	Red
Nit	Potassium nitrate	Yellow
Glu	Glutamate	Brown
Amm	Ammonia sulphate	Black



LDOM uptake as a nutrient resource by stream biota



Ongoing experiments under ERC REFRESH (incl. currently at Simonsbath) are exploring trends for snails and bacterioplankton

Key findings from our national sampling programme *(so far)*

- No sites had a 10m buffer zone for slurry applications. Only 1/60 had a 5m buffer zone (Scottish sheep site in receipt of environmental stewardship funding - an SRUC farm). Mitigation through buffer zone use is universally poor in UK headwater catchments.
- Beef cattle farming was visibly the 'dirtiest', with the highest Particulate N and P, and highest Total P out of all livestock categories.
- Direct stock access to streams was common practice for both beef cattle (100%) and sheep (90% of sites, 9% at 1m usually on one side of the stream only, and 1 site at 5m for part of the stream). Mitigation through fencing is poor in UK headwater catchments.
- 75% of dairy sites had outdoor grazing with high stocking densities at some. Most had direct access to streams or were 1m fenced out of watercourses (usually on one side only). Direct access to streams zeros the options for mitigation of contaminant fluxes to streams.
- Outdoor dairy sites often had low flows, reducing dilution capacity and increasing contaminant concentrations from dairy washings/direct discharges to streams and environmental exposures for stream biota.
- Indoor dairy systems had some of the highest nutrient concentrations (78 mg N/L ammonium at one site).
- We await the ecotoxin, organic geochemistry and pathogen results with interest, to see if they follow the nutrient transfer trends.
- Streams draining 24/7 indoor dairy production sites were often dry to 3 tributaries d/s from source.
- Loss of dilution capacity for contaminants may be an additional 'hidden' environmental damage cost of dairy farming.
- Dairy farming had the highest N concentrations, typically from indoor 24/7 and high intensity outdoor grazing farms.
- Sheep production is typically less intensive, but in sensitive moorland and mountain streams, it can present significant organic enrichment of streams. Peaks in urea concentrations are a particular concern in hotter, drier summer periods.
- *E. coli* detected at all sites, in both excreta and stream samples.
- *Policy advice and mitigation strategies* tested in modelling will likely focus on indoor/outdoor production including pharmaceutical use (rates/timings), buffer zones, stocking densities and stock access to water on farms.

QUANTUM key findings *so far*

Find out more: https://www.youtube.com/watch?v=rkT7Vp__Lqo

Livestock excreta are rich sources of organic matter, nutrients, antibiotics and phytoestrogens. Their *composition and the risks the present to freshwaters vary* by livestock type (beef, dairy, sheep), excreta type, production system and season.

E. coli was present in all livestock excreta and from all farms, presenting a risk not only to freshwaters but also to *drinking water sources and bathing water quality*.

Macrolide antibiotic and phytoestrogen findings suggest the potential for *AMR proliferation and endocrine disruption* in freshwaters in all livestock farming catchments.

Ecotoxin profiles reflected similar treatments/practices across all 6 farms initially sampled, but some compounds (e.g. tiamulin, lincomycin) appeared to be farm-specific. *We await the national survey and ecotoxicology results with interest.*

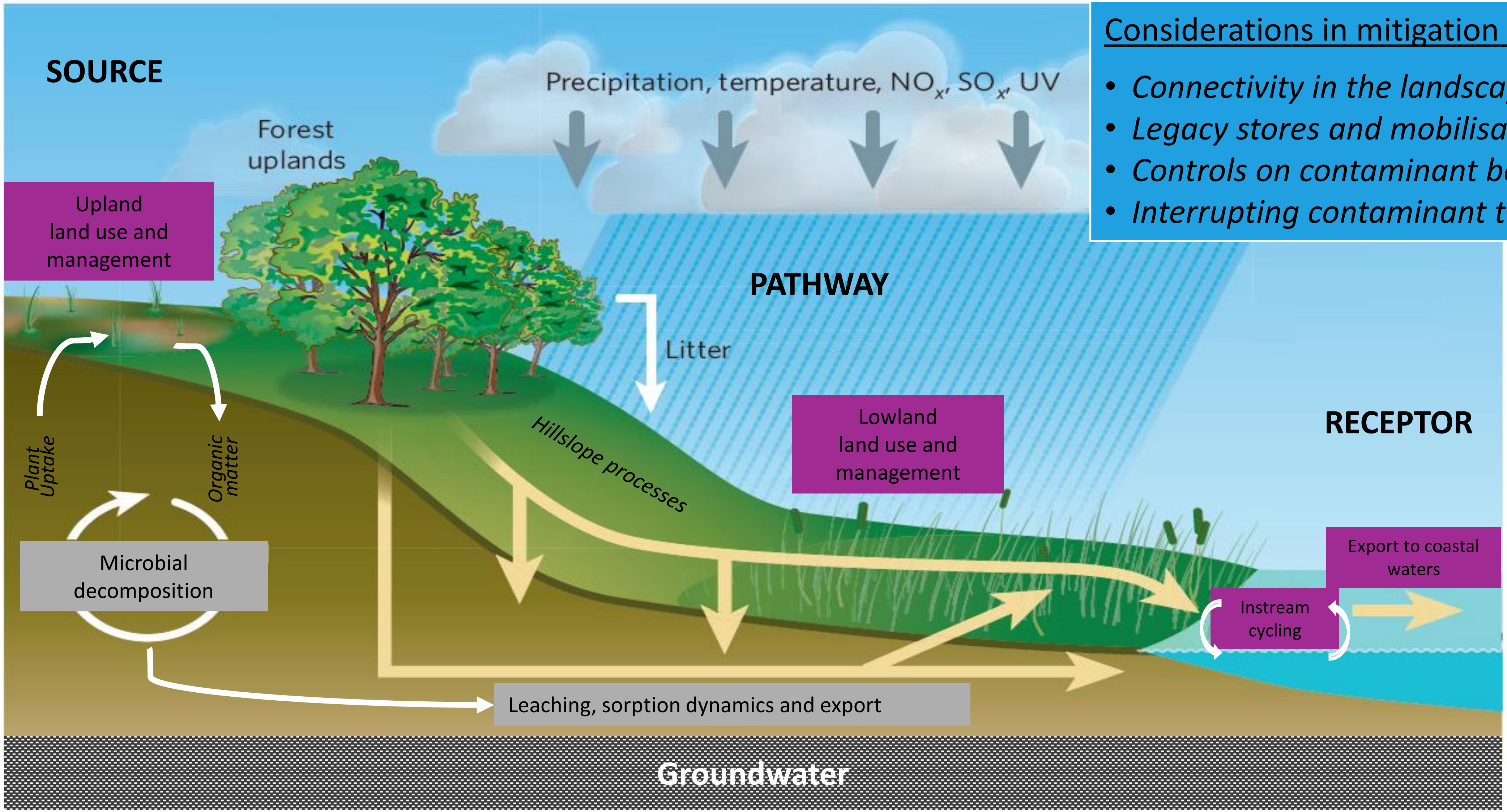
Our instream experiments confirm that livestock excreta are a key source of organic nutrient enrichment in livestock farming regions. Uptake rates are comparable to or higher than for inorganic nutrients for primary producers, and the material is rapidly transferred to heterotrophs, causing *whole ecosystem impacts if washed/directly voided into streams*.

Our buffer zone experiments confirmed negligible ability to trap event-based dissolved contaminants flushing from land, even when extended from 10m to 40m from the stream. Efficacy may be higher for sediments. At catchment scale our modelling shows nutrient retention of < 3% when limited to feasible locations. *They are not a universal solution*.

Mitigation efforts need to *reduce* chemical use on farms at source, reduce stocking densities and flow pathway transfer efficiencies, prevent direct stock access to waters, and improve excreta use and handling as part of whole-farm planning.

How do we rise to the multi-stressor challenge for UK freshwaters?

The Source – Pathway – Receptor framework for mitigation action



<u>Considerations in mitigation planning:</u>

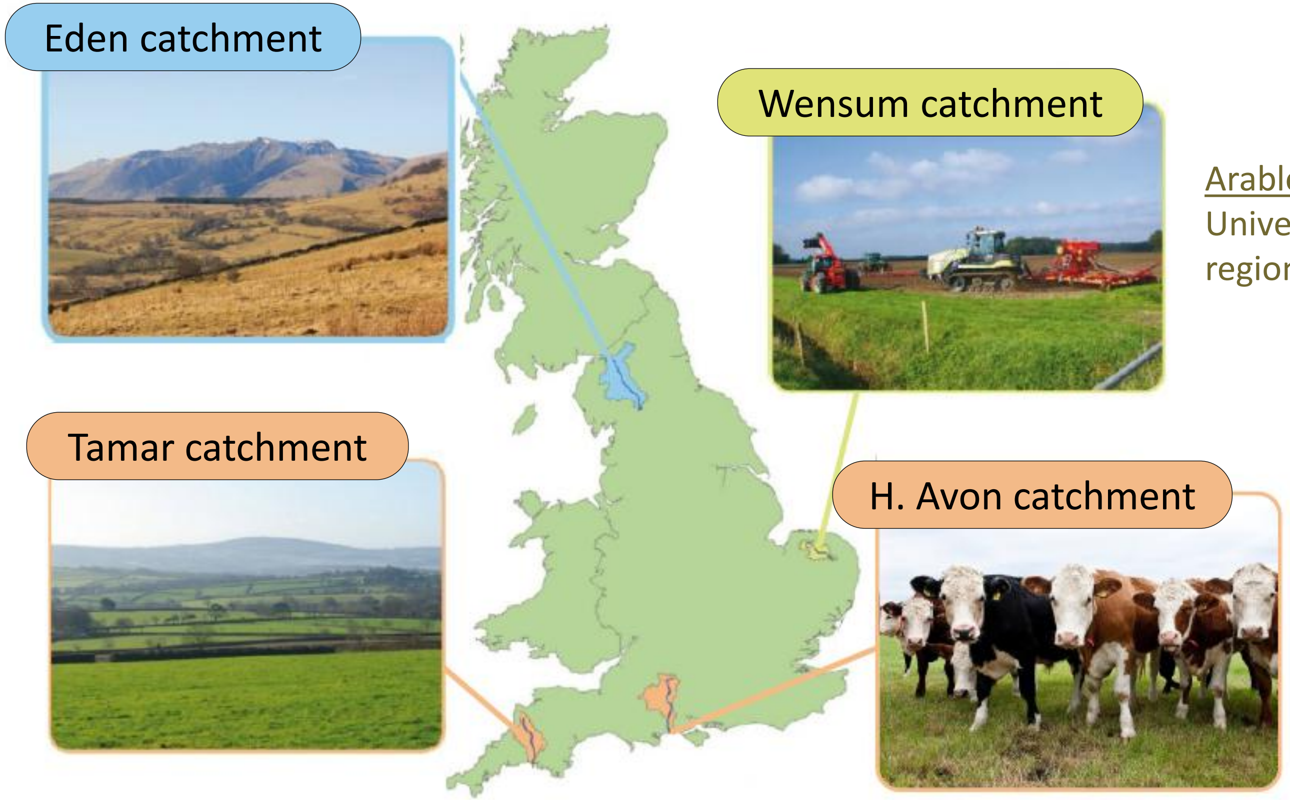
- *Connectivity in the landscape*
- *Legacy stores and mobilisation*
- *Controls on contaminant behaviours*
- *Interrupting contaminant transfers*

Demonstration Test Catchments programme: testing ecosystem impacts of diffuse source mitigation measures at catchment scale

Department for Environment Food & Rural Affairs

Delivered by 4 consortia of research institutes, universities and stakeholders, in 4 representative catchments **£10m, 2010-2019**

Livestock farming. Led by Lancaster University, with Durham and Newcastle universities, and the *Eden Rivers Trust*



Arable farming. Led by University of East Anglia with regional stakeholders.

Tamar (Mixed/Livestock farming) and Hampshire Avon (Mixed farming) joint leads Rothamsted Research, Universities of Bristol and Exeter, QMUL and ADAS, linking up with *SWW Upstream Thinking* and *Westcountry Rivers Trust* in the Tamar, and *Wessex Water* and *Wessex Rivers Trust* in the Hampshire Avon.

Demonstration Test Catchments Evidence Compendium available here: https://tinyurl.com/yc8rweh4

Summary – Interventions 1

Interventions overview

Choosing where and which measures to install is an iterative process of synthesising knowledge and evidence, alongside negotiation with the farmer/landowner. The treatment train approach maximises protection by addressing the key stages in the pollution delivery continuum.

p44

Winter cover crops

Cover crops on arable land can significantly reduce nitrate leaching losses by up to 97%, with the potential for the crop to act as a 'green manure'. Farmer attitudes to cover crops have changed over recent years and uptake is becoming more common. The main disadvantages include additional costs, difficulties in destruction before sowing cash crop and pest problems under certain conditions.

p45

Conservation tillage

Conservation tillage does not appear to significantly improve the short-term environmental sustainability of farming practices in lowland intensive arable systems. However, improvements in farm business performance from operational efficiency savings and improved yields demonstrate land managers can make important financial gains by converting to a conservation tillage system.

p46

Biobeds

Biobeds are highly effective at mitigating point source pesticide pollution related to handling operations, reducing individual pesticide concentrations by up to 98%. Construction and maintenance costs are relatively inexpensive, making them suitable for catchment-wide deployment.

p47

Sediment traps

Sediment traps are a highly effective tool for intercepting surface runoff and capturing eroded sediment before it can enter a watercourse. They are cheap to construct and maintain, and occupy a relatively small footprint in a field. However, loss of land is a main concern for farmers. Note that traps become less effective when full.

p48

Runoff detention features

Runoff detention features are an effective method of delaying water movement and trapping pollutants, reducing the rate at which they would enter watercourses. As with sediment traps, the area of land is small but remains a major farmer concern, along with additional workload associated with maintenance and emptying sediment.

p49

Summary - Interventions 2

Riparian fencing and wetlands

Riparian fencing and wetlands can be an effective way of intercepting surface pollutant pathways and reducing FIO transport to watercourses. Management is key, especially for wetlands, where the removal of accumulated nutrients in the green biomass delays the system from reaching capacity. Wetlands do not provide a long term, indefinite buffering option in catchments. Provided riparian areas are carefully managed, they present the opportunity to contribute to farmland bird conservation. It should be recognised that all livestock access within a catchment must be restricted to achieve the necessary pollutant reductions, and farmers' attitudes toward the loss of productive land should be noted.

p50-51

Clean and dirty water separation

Clean and dirty water separation through better infrastructure yields benefits in the form of improved farm efficiency such as a decreased need for extra slurry storage. Measures include yard coverage via roofing, improvements to guttering, slurry drains, and ditch water pools. Farmers have a positive attitude toward the uptake of this group of measures, with the main barrier being installation costs.

p52

Soil aeration

A low-cost measure which has the potential to mitigate flood risk as well as diffuse pollution. Subsoiling will only require one pass every four years which minimises labour costs. However, there is only a small window of opportunity to carry out work as weather conditions must be optimal to do so.

p53

Track management

Farm track resurfacing encourages cattle to remain on the track, avoiding alternative routes which can lead to lameness, bruising and decreased milk production. Tracks improve farm access and can be done using a variety of materials sourced on or off farm, e.g. aggregate and concrete. The slope of the track and additional attenuation features must be considered during design due to the risk of increased connectivity to watercourses.

p54

Summary - Social Science I

Social science overview

DTC research paid particular attention to the importance of different types and sources of information, as well as the scope for facilitating social learning amongst groups of farmers, because wider evidence suggests increased understanding, awareness and a shift in social norms are important for increasing uptake of mitigation measures.

p56

Farmer behaviours

Farm practice surveys help improve the reliability of decision support tools as well as guide intervention strategies needed to address low uptake of specific mitigation measures. Behaviours change over time, therefore repeatable surveys are required to capture such alternations.

p57

Farmer attitudes

There is currently no established norm within the farming community which encourages the proactive adoption of steps to deliver pollution mitigation. A significant shift in farmer identities and beliefs is likely to be required before water pollution mitigation behaviour becomes embedded.

p58

Farmer motivations

Differing complexities of decision processes for the adoption of mitigation measures imply the need to consider each measure separately and take account of the diversity in farming contexts which exist when designing policy interventions. Considering the entire decision process and supporting interventions at multiple stages can help to accelerate adoption.

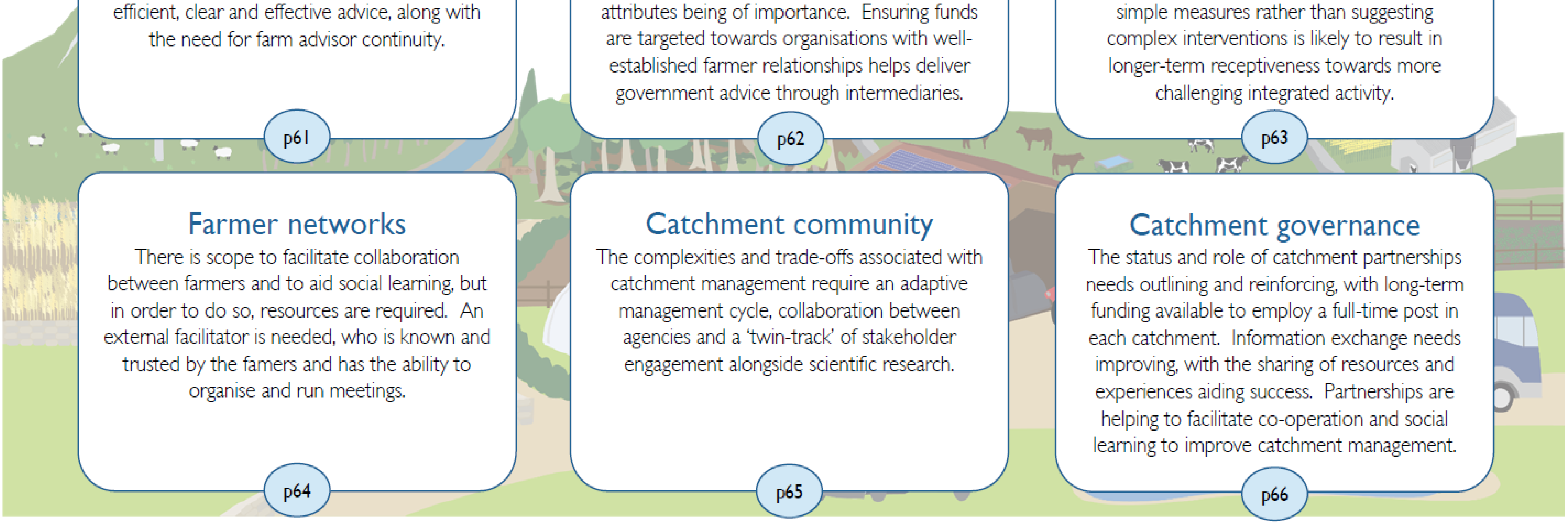
p59

Farmer barriers

Barriers vary greatly between farms and mitigation measures. Policy interventions for measures which have internal barriers need to focus on changing social norms and attitudes and will often take a longer time to successfully change behaviours. Measures with external constraints require efforts which alter such restrictions.

p60

Summary - Social Science 2



Farm advice delivery

Advice must be consistent and delivered from a trusted source. Improvements to communication and co-ordination amongst advisors are required to provide farmers with efficient, clear and effective advice, along with the need for farm advisor continuity.

p61

Attitudes to advice

To disseminate advice effectively it is essential to appreciate who farmers listen to in each area and why, as farmer attitudes towards advisors varies across catchments, with different attributes being of importance. Ensuring funds are targeted towards organisations with well-established farmer relationships helps deliver government advice through intermediaries.

p62

Farmer engagement

Providing demonstration sites, training, research platforms, facilitated discussion groups and catchment data engages farmers at a local level. Encouraging farmers to initially change relatively simple measures rather than suggesting complex interventions is likely to result in longer-term receptiveness towards more challenging integrated activity.

p63

Farmer networks

There is scope to facilitate collaboration between farmers and to aid social learning, but in order to do so, resources are required. An external facilitator is needed, who is known and trusted by the famers and has the ability to organise and run meetings.

p64

Catchment community

The complexities and trade-offs associated with catchment management require an adaptive management cycle, collaboration between agencies and a 'twin-track' of stakeholder engagement alongside scientific research.

p65

Catchment governance

The status and role of catchment partnerships needs outlining and reinforcing, with long-term funding available to employ a full-time post in each catchment. Information exchange needs improving, with the sharing of resources and experiences aiding success. Partnerships are helping to facilitate co-operation and social learning to improve catchment management.

p66

Do we know how to reduce pollution from agriculture?

Yes: *a Five Point Plan*

While pollution by agriculture is widespread and complex, there are some general principles which could deliver multiple benefits for a range of environmental problems.

To deliver these we need to work with farmers to develop holistic mitigation approaches which will:

1. Increase water retention in the landscape
2. Hold soils within fields
3. Sequester carbon in soils
4. Drive up (all) chemical use efficiency at farm scale
5. Invest in environmental regulation and monitoring, advice and financial support to farmers that is holistic and fit for purpose

Do we know how to reduce point source pollution?

Yes: *a Five Point Plan*

Pollution from point sources contains 10s of 10000s of contaminants that are not removed during treatment and are routinely discharged to waters.

A fresh policy/regulatory approach is needed, to:

1. Identify the full range of stressors in wastewaters impacting on ecosystem and human health
2. Calculate their maximum acceptable concentrations in receiving waters, resilient to future climate change
3. Connect septic tank systems to WwTW with advanced treatment technologies to strip key contaminants prior to discharge to any waterbody
4. Require industry to monitor/report all discharges, and improve storage of treated wastes prior to discharge
5. Invest in environmental regulation and enforcement that is holistic and fit for purpose

Addressing the legislative gap:

New (since 2024) Water Targets under the Environment Act 2021

Abandoned Metal Mines	• Reduce river length polluted by harmful metals from abandoned mines by half by 2038 (2042), compared to a baseline of 1,500 km
Water Demand	• Reduce the per capita public water supply use in England by 20% in 2037/38 (2042) vs a 2019/2020 reporting year baseline
Nutrient pollution from agriculture	• Reduce N, P and sediment pollution from agriculture by at least 40% by 2038 (2042), compared to a 2018 baseline
Nutrient pollution from wastewater	• Reduce P loadings from treated wastewater by 80% by 2038 (2042) against a 2020 baseline.

<u>Office for Environmental Protection (2023)</u>

Progress in Improving the Natural Environment in England, 2021/2022

"Progress is not demonstrably on track for any of the 23 environmental targets"

Where next for UK freshwaters?

Addressing the efficacy gap in policy & practice

- Embedding an understanding of the current science in policy and practice
- Investing in monitoring that is fit for purpose
- Providing advice and investment to support effective and just transition
- Developing and implementing effective regulation and enforcement
- Joining up policy and practice across agencies and devolved government

Thank you and any questions?

ERC REFRESH experiment running 19-26 June on the Bale Water, u/s from Simonsbath with kind permission from ENPA. Visitors welcome!