ENVIRONMENTAL CHANGE RESEARCH CENTRE, GEOGRAPHY DEPT

UCL

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Aquatic Macrophyte Change in the UK Upland Waters Monitoring Network

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@eshilland

UKRI Natural Environment Research Council

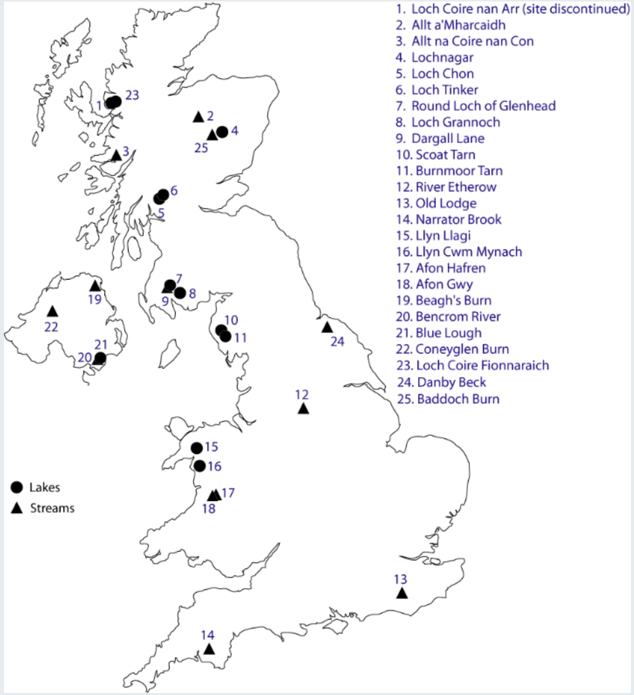
Queen Mary University of London

NATURAL HISTORY MUSEUM

NatureScot Scotland's Nature Agency Buidheann Nàdair na h-Alba

UK Upland Waters Monitoring Network

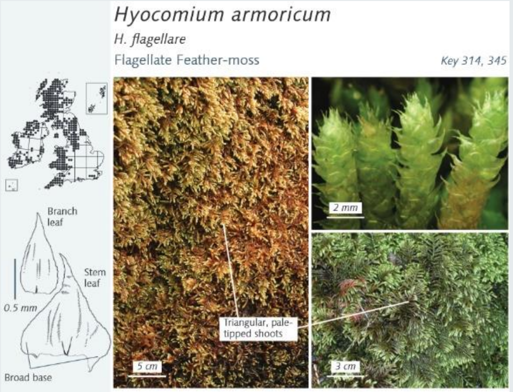
- Set up in 1988 to assess the chemical and biological response of acidified lakes and streams to emission reductions.
- Originally 22 sites across UK in N-S, E-W gradients, with afforested and non-afforested pairs and NW “control” sites.
- Water chemistry, fish, invertebrates, macrophytes, diatoms, temperature. Physical variables at some sites e.g. flow.
- Demonstrated the effects of reductions in Sulphur emissions – reduced xSO_4, also upwards Dissolved Organic Carbon (DOC) trends.
- Despite Nitrogen emission reductions demonstrated variable changes in NO_3
- Clear recovery evidence from chemistry but biological lags
- Aquatic plants not yet analysed – this project.

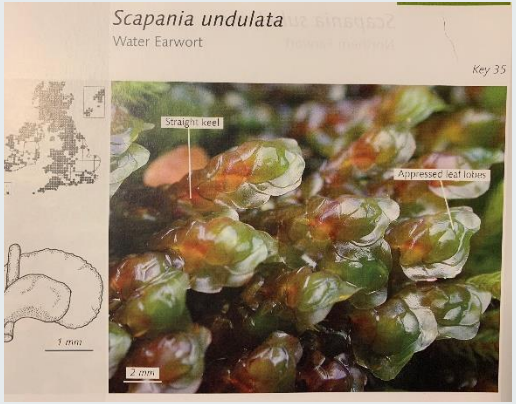


Aquatic Plants (macrophytes)

Higher plants

Stoneworts





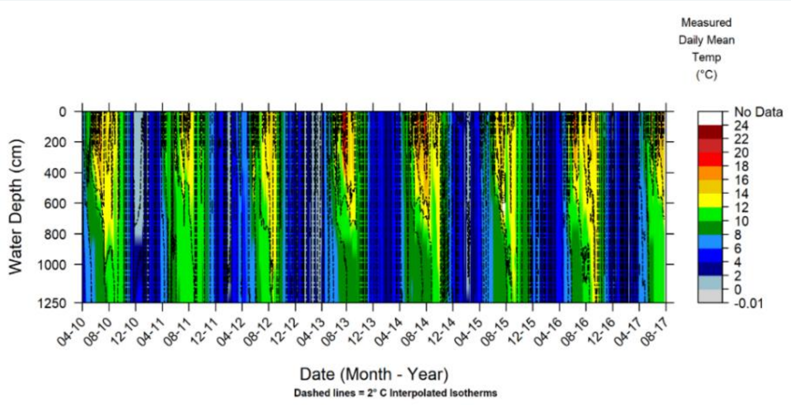
Mosses and Liverworts

Hypotheses

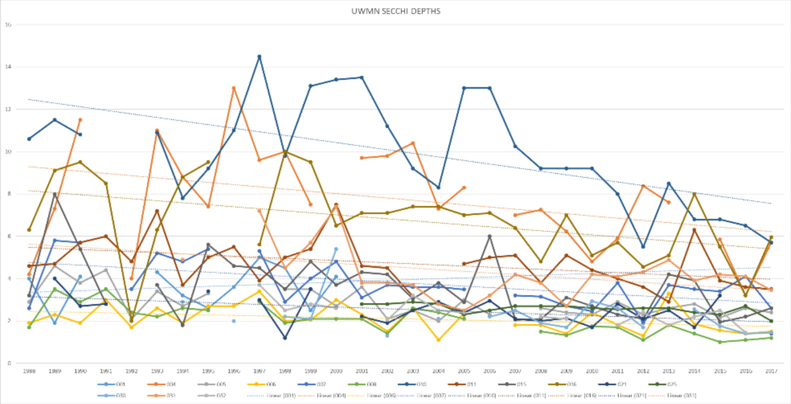
- H1. Upland stream macrophyte species compositions, abundances and ecosystem functions are affected by hydrology, water chemistry and temperature.
- H2. Upland lake macrophyte species compositions, abundances and ecosystem functions are affected by water chemistry, the light environment, wave stress and temperature.
- H3. Macrophyte environmental DNA preserves sufficiently well in lake water, sediment traps and the lake sediments of upland lakes to be identified using molecular techniques.
- H4. Contemporary water eDNA, sediment trap sedDNA and core surface sedDNA faithfully represent the macrophyte species currently growing in upland lakes.
- H5. Preserved macrophyte sedDNA in the lake sediments of upland lakes provides a reliable record, matching known long-term monitoring data, and is sufficient to reconstruct historic macrophyte assemblages.
- H6. Macrophyte dispersal ability limits rapid (re)colonisation of upland waterbodies.
- H7. Aquatic macrophytes are not returning to pre-industrial assemblages due to climate change and nutrient deposition.

Drivers of Change

- Water quality
    - Recovery from acidification
    - Elevated nitrogen levels
- Climate
    - Temperature
    - Hydrology
    - Flow
    - Storminess (aspect)
    - Light environment - DOC/Ice Cover
- Hydromorphology
- Others?



Llyn Llagi thermistor chain



UKUWMN secchi depths

Brief Methods - Plant Surveys

Streams

Fixed 50 m section of stream with transects every 5 m. Substrates, shade, filamentous algae, macrophyte taxa and cover recorded. Common Standards Monitoring (CSM) Methodology for stream macrophyte sampling also performed since 2019 – 100m sections. Temperature loggers.

Lakes

Inshore survey, fixed transect surveys, trawl surveys. Since 2009 also CSM Methodology for lake macrophyte sampling adding additional 100m shoreline transects and strandline species recording. Temperature loggers.

Brief Methods – DNA. Lake sites only.

DNA

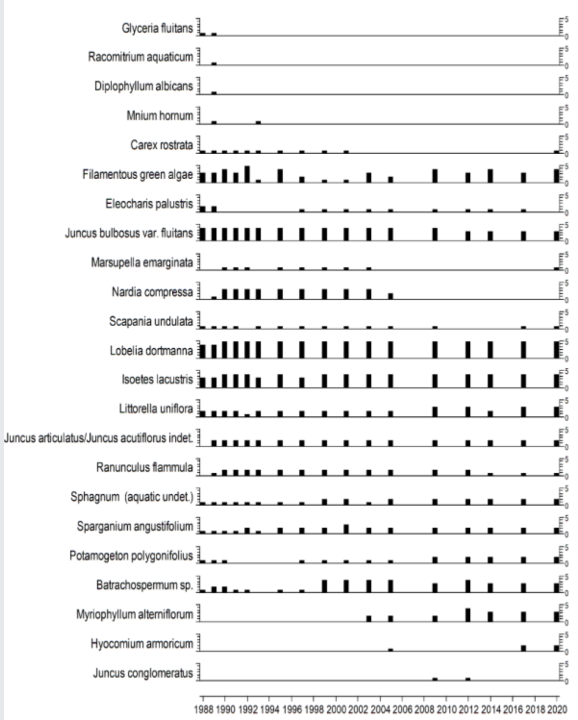
- Sampling: eDNA Sterivex water filtering. 3 x filters per site per year. Field blanks. 83 samples. sedDNA Annual sediment traps. 3 x traps per site per year. 66 samples. Shallow and deep-water sediment cores from two sites, Round Loch of Glenhead and Burnmoor Tarn (COVID backup site). Core extrusion into two replicates. 72 core sedDNA samples. Radiometric dating. All samples frozen until analysis.
- Extractions: QIAGEN PowerWater extractions for water eDNA, PowerSoil Pro for cores/traps. Blanks. Nanodrop, Qubit.
- trnL markers rather than rbcL, ITS2 or matK.
- BOLD/Genbank/PhyloNorway/PhyloAlps libraries.
- Voucher specimens collected and in SiO2 for reference library improvement if necessary.
- Metabarcoding PCR methods, Illumina sequencing methods and Bioinformatics pipeline under development.

Progress

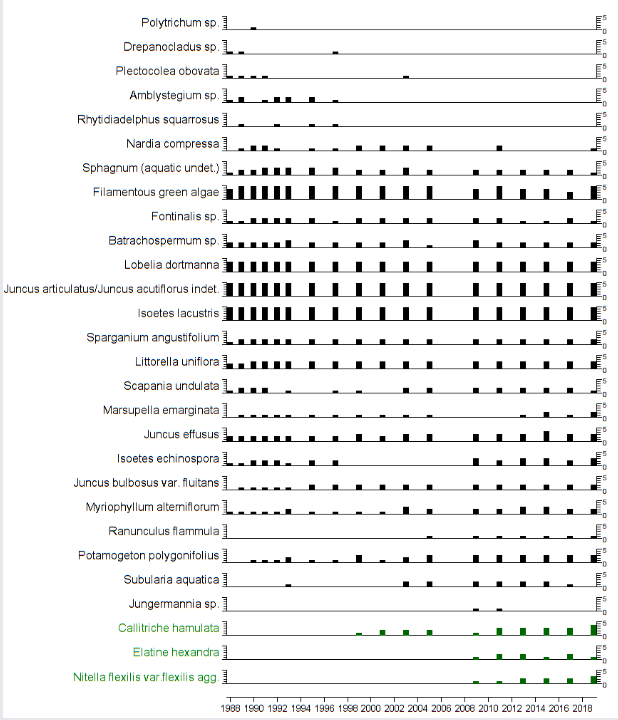
- Historic data entry/vouchers - ongoing
- Fieldwork. 2020 delayed by COVID and trips split into smaller units – finished in mid November rather than August. Challenging logistics! All sites visited however. Many thanks to volunteers and CASE partner Iain.
- Cores collected and extruded at home due to COVID.
- DNA extractions performed and Nanodrop purity/DNA concentrations measured for all filter, sediment trap and core samples @NHM
- Test PCRs and gels underway, refining recipe
- Core sample dry weights, loss on ignitions and wet densities measured @UCL. In the queue for drying and radiometric dating – funding secured from QRA.

Examples of plant time-series data

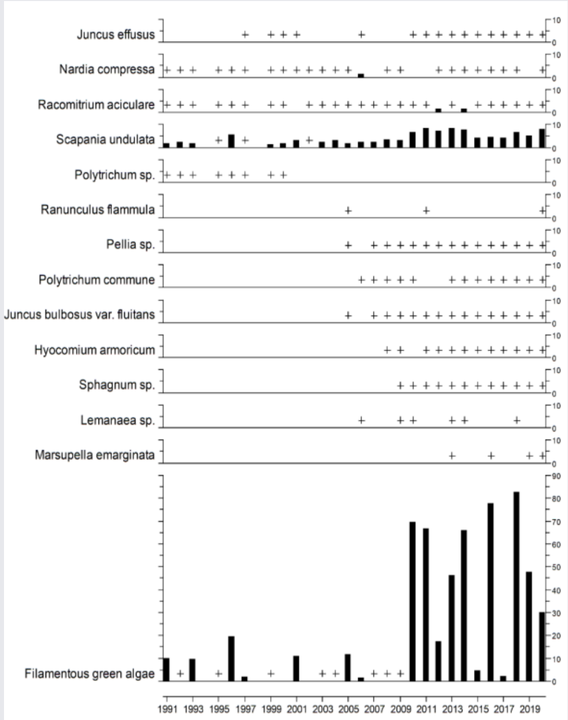
RLGH Scores (1-5)



Llyn Llagi Scores (1-5)



Afon Hafren % cover



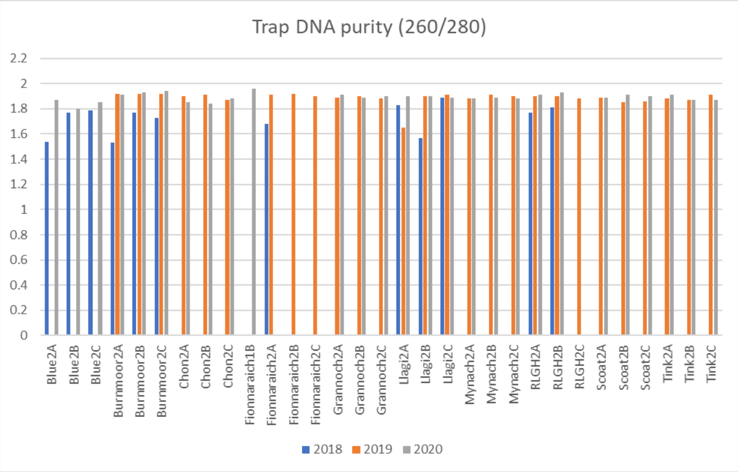
Preliminary Results UWMN

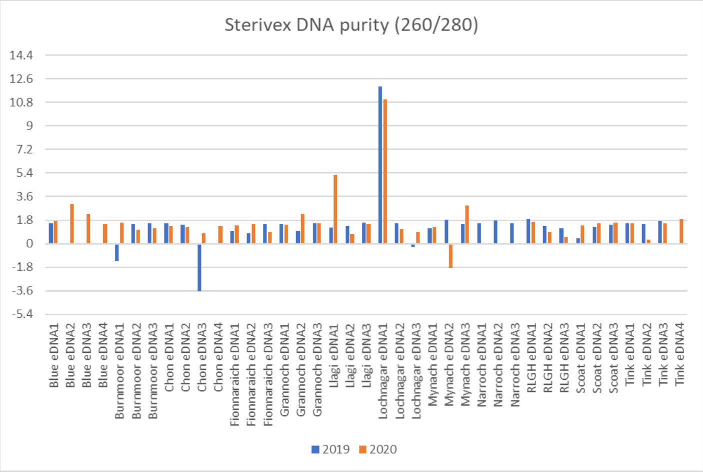
	species	Sample Year																									
LAKES		95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Lochnagar	*Subularia aquatica*	X	•	X	•	X	•	X	•	X	•	X	•	•	•	✓	•	•	✓	•	✓	•	•	•	•	✓	•
Loch Chon	*Elatine hexandra*	✓	•	✓	•	✓	•	X	•	X	•	X	•	•	•	•	•	•	✓	•	•	•	•	•	•	X	•
	Subularia aquatica	✓	•	✓	•	✓	•	✓	•	✓	•	✓	•	•	•	•	•	•	✓	•	•	•	•	•	•	X	•
	Chara virgata	X	•	X	•	✓	•	✓	•	✓	•	✓	•	•	•	•	•	•	✓	•	•	•	•	•	•	X	•
Loch Tinker	*Subularia aquatica*	✓	•	✓	•	X	•	X	•	✓	•	✓	•	•	•	✓	•	•	✓	•	•	•	•	•	•	✓	•
Round Loch of Glenhead	*Myriophyllum alterniflorum*	X	•	X	•	X	•	X	•	✓	•	✓	•	•	•	✓	•	•	✓	•	✓	•	•	✓	•	•	✓
Burnmoor Tarn	*Elatine hexandra*	✓	•	X	•	X	•	X	•	X	•	X	•	•	X	•	•	•	✓		✓	•	•	•	•	✓	•
	Chara virgata	X	•	X	•	X	•	X	•	✓	•	✓	•	•	✓	•	•	•	✓	•	✓	•	•	•	•	✓	•
	Nitella translucens	X	•	X	•	X	•	X	•	X	•	X	•	•	✓	•	•	•	✓	•	✓	•	•	•	•	✓	•
	Potamogeton berchtoldii	X	•	X	•	X	•	X	•	X	•	X	•	•	X	•	•	•	✓	•	✓	•	•	•	•	✓	•
	Potamogeton alpinus	X	•	X	•	X	•	X	•	X	•	X	•	•	X	•	•	•	X	•	X	•	•	•	•	✓	•
Llyn Llagi	*Callitriche hamulata*	X	•	X	•	✓	•	✓	•	✓	•	✓	•	•	•	✓	•	✓	•	✓	•	✓	•	✓	•	✓	•
	Nitella flexilis agg.	X	•	X	•	X	•	X	•	X	•	X	•	•	•	✓	•	✓	•	✓	•	✓	•	✓	•	✓	•
	Elatine hexandra	X	•	X	•	X	•	X	•	X	•	X	•	•	•	✓	•	✓	•	✓	•	✓	•	✓	•	✓	•
Llyn Cwm Mynach	*Eleogiton fluitans*	X	•	X	•	✓	•	✓	•	✓	•	✓	•	•	✓	•	✓	•	✓	•	✓	•	•	✓	•	•	✓
	Isoetes lacustris	X	•	X	•	✓	•	✓	•	✓	•	✓	•	•	X	•	X	•	✓	•	✓	•	•	✓	•	•	✓
STREAMS																											
Allt a'Mharcaidh	*Hyocomium armoricum*	X	X	X	X	X	X	X	X	X	✓	X	X	X	•	✓	X	X	✓	✓	X	✓	✓	✓	✓	✓	•
	Marsupella emarginata	X	X	X	X	X	X	X	X	X	X	X	X	X	•	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	•
Allt na Coire nan Con	*Fontinalis antipyretica*	X	X	X	X	X	•	X	X	X	X	X	X	✓	•	✓	•	✓	✓	✓	•	•	•	•	✓	✓	•
Dargall Lane	*Blindia acuta*	X	X	X	X	X	X	X	X	✓	✓	✓	✓	✓	✓	✓	•	•	•	•	•	•	•	•	•	•	•
	Hyocomium armoricum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	X	✓	✓	✓	✓
River Etherow	*Hygrohypnum ochraceum*	X	X	X	X	X	X	X	X	X	X	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Hyocomium armoricum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Old Lodge	*Hyocomium armoricum*	X	X	X	X	X	✓	X	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Afon Hafren	*Hyocomium armoricum*	X	X	X	X	X	X	X	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Fontinalis squamosa	X	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	X	X	X	✓	✓	X	X	✓	✓	✓	✓
	Marsupella emarginata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	✓	X	X	✓	✓	X	X	X
Afon Gwy	*Hyocomium armoricum*	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Marsupella emarginata	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	X	X	✓	X	X	✓	✓
Coneyglen Burn	*Hyocomium armoricum*	X	X	X	X	X	X	X	X	X	X	X	X	•	•	•	•	✓	•	•	•	✓	•	✓	✓	•	✓
Bencrom River	*Hyocomium armoricum*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	✓	✓

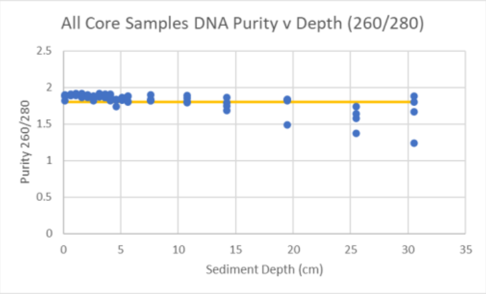
Key. ✓ species recorded during survey, X species not recorded during survey, • no survey

- New aquatic plant species at seven out of eleven lake sites and nine out of eleven stream sites.
- New species in streams tend to be less acid sensitive mosses (especially *Hyocomium armoricum*).
- New species in lakes tend to be those that can't extract carbon from sediments, relying on water-column carbon availability that improves with chemical recovery.
- Macrophytes lag behind diatoms and invertebrates in responding to improved water chemistry
- Little change at "control" sites.

Preliminary Results Nanodrop DNA purity

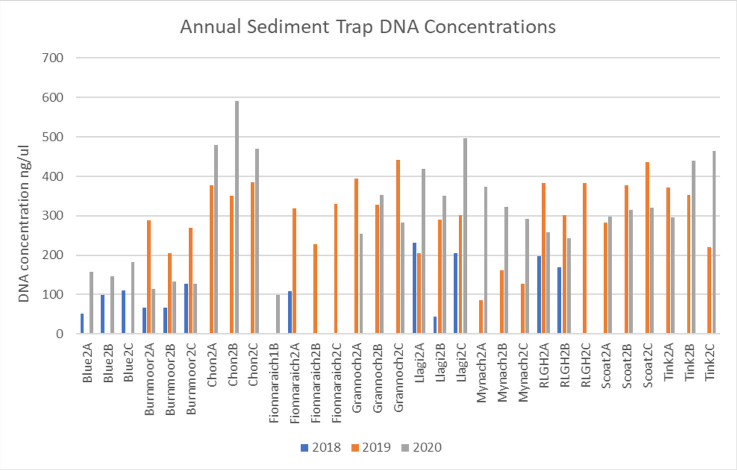


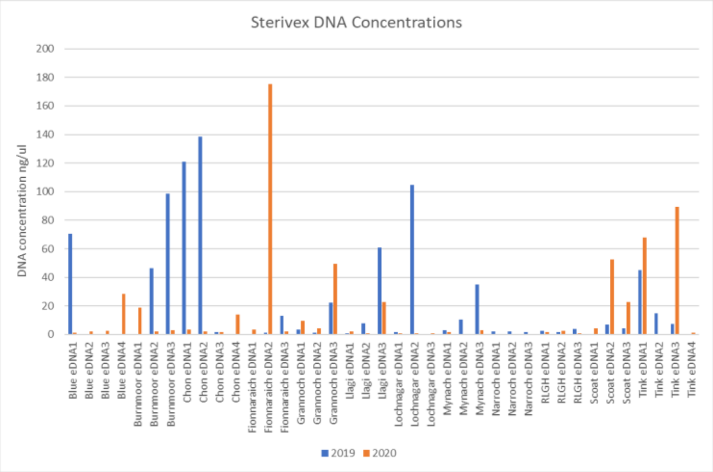


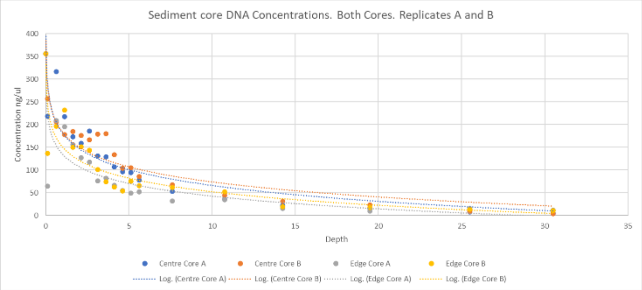


- Aiming for a ratio of 1.8 or above
- Sediment traps good (unfrozen 2018 less so)
- Core good at surface, less good at depth
- Sterivex filtered water less good, and variable

Preliminary Results Nanodrop DNA concs

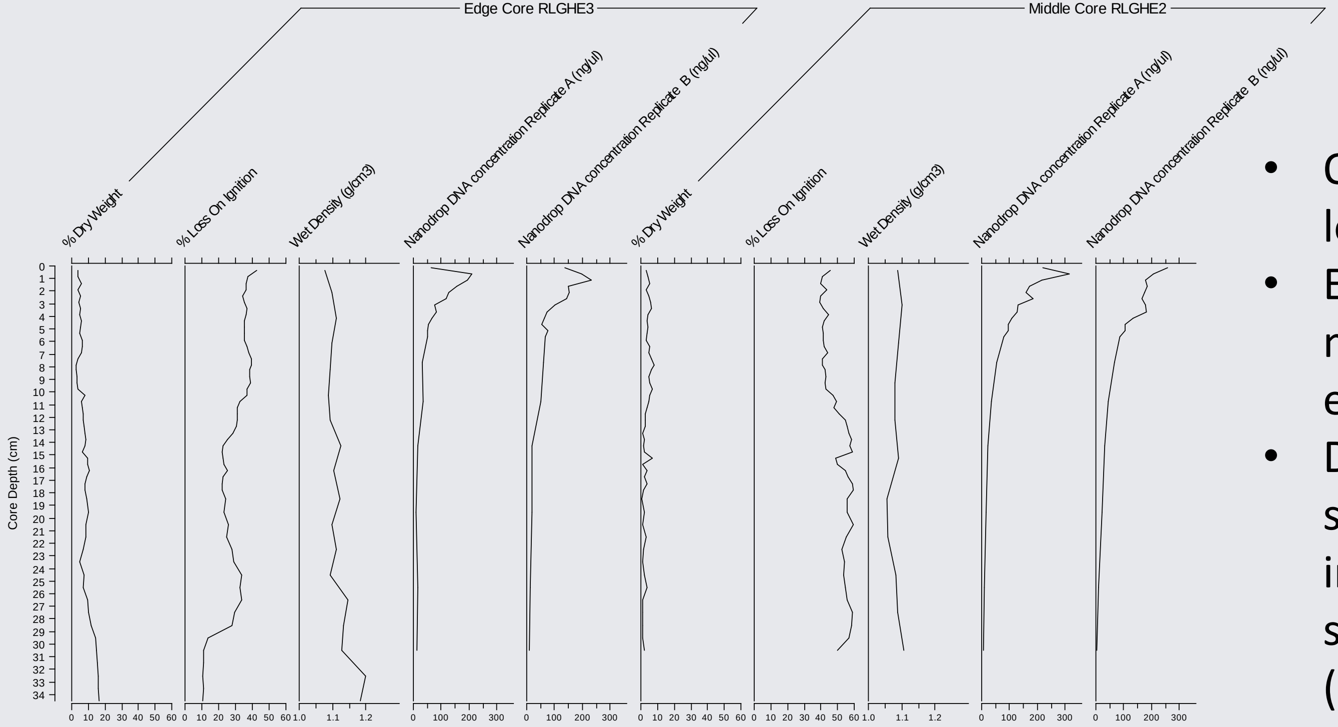






- Sediment traps high, generally ~consistent at a given site in a given year
- Core samples higher at surface, decline with depth
- Sterivex filtered water generally much lower, and variable

Preliminary Results Core Analyses



- Organic sediments – ~50% loss on ignition
- Edge core has greater mineral components, especially at bottom
- DNA concentrations similar between cores and in-core replicates, and suggest undisturbed cores (phew).

Questions?

Supervisors: Iwan Jones (QMUL), Anson Mackay (UCL), Anne Jungblut (NHM), Iain Sime (NatureScot, CASE). Support from the Quaternary Research Association and Rick Battarbee/ENSIS Trust Fund gratefully acknowledged.

Expected Outcomes & Impact

- Contribute to National Emission Ceilings Directive reporting (DEFRA)
- Contribute to SAC/SSSI site condition assessments (SNH/NRW/NE)
- Contribute to Water Framework Directive site condition monitoring (SEPA/NRW/EA) CSM/ LEAFPACS results.
- Produce a calibration dataset for statutory/conservation tool development e.g. LEAFPACS2/DARLEQ2 but for low nutrient/alkalinity sites
- Method development for lake restoration target-setting – eDNA cost savings v macrofossils/microfossils?